EAZA Best Practice Guidelines

Atlantic puffin (*Fratercula arctica*)

Photo: Frank Rønsholt, Copenhagen Zoo

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Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the "Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria". These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

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Introduction

This EAZA Best Practice Guideline is based on published research literature on Atlantic puffins (*Fratercula arctica*) in the wild and in captivity. Lots of personal communications have also been collected and incorporated into the text to provide hands-on knowledge from people directly involved in the keeping and breeding of this species.

Puffins are a long-lived species. But the current population living in EAZA Member institutions is aging and, without a more frequent flow of new young birds, will not remain viable in the long term. Currently, it is not possible to secure the long-time survival of the population with breeding as the main tool for growth. Securing new founders from the wild to keep up the population has turned out to be nearly impossible. The main purpose of these Best Practice Guidelines is to present the current knowledge available on Atlantic puffin keeping and breeding within EAZA Member institutions, and to provide a comprehensive insight into this bird's biology through field data and research from the wild population.

The wild population is in a heavy decline across its whole range and requires our full attention, in compiling our skills and knowledge of keeping and breeding this species in human care we are producing these Best Practice Guideline to ensure birds in our care are kept at the highest standards possible.

First, we would like to thank Rotterdam Zoo and Copenhagen Zoo for helping with this project and providing the opportunity and workplace to develop this document. Thank you, Harald Schmidt, Linda van Sonsbeek, Willem Schaftenaar, Dionne Slagter and Flemming Nielsen for taking the time to help with any questions that we`ve had and providing information. Besides this we would also like to thank Simon Bruslund from Copenhagen Zoo, formerly Heidelberg Zoo for providing additional information and allowing a visit to Heidelberg. A big thank to Henrik Futtrup from Copenhagen Zoo for providing the chapter on Management Training, and general personal comments.

We would also like to thank Flemming Nielsen, Jo Gregson, Nigel Simpson, and Henrik Futtrup for evaluating drafts of this document and providing useful feedback.

A number of zoos and aquariums globally have contributed to this project by filling out questionnaire (Questionnaire B. Vernooij, 2015) and sending photographs and additional information. These zoos and aquariums are:

- National Aquarium, Baltimore USA
- Biodôme Montreal, Canada
- Copenhagen Zoo, Denmark
- Den Blå Planet, Denmark
- Loro Parque, Spain
- Nasu Animal Kingdom, Japan
- Oceanário de Lisboa, Portugal
- Omaha's Henry Doorly Zoo and Aquarium, USA
- SeaWorld Orlando, USA
- Tierpark Bern, Switzerland
- Blijdorp Zoo, Rotterdam, The Netherlands

Summary

In Section 1, Biology and Field data, the current knowledge of the species' biology and field data is presented, including conservation status and descriptions of habitat, feeding behaviour and reproduction. The information presented in this section is based on the published literature on the species as well as field observations. For some of the subsections, information is based on observations from the captive population, as field data in these areas is lacking.

Section 2, Management in Zoos and Aquariums presents the best practice for managing the species in captive populations. The recommendations given are primarily based on experience as well as knowledge from facilities breeding and keeping this species. The most important aspect of keeping and breeding this species seems to be designing a near-natural environment and at the same time preventing vector-carried diseases. Furthermore, the environmental conditions such as temperature, lighting and humidity seem to be of importance for successful development and reproduction. Colony size also might have an influence on breeding success. This section presents recommendations for enclosure design, feeding, breeding, handling and management training, among others. In the end, a list of suggested future research topics is given.

In section 3, all references for the literature cited in this document are presented.

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Section 1: Biology & Field Data

1.1 Taxonomy

1.1.1 Order

The Atlantic puffin is placed in the order of Charadriiformes. This order is home to shorebirds, gulls, alcids, plovers and oystercatchers (itis.gov [1], 2013).

1.1.2 Family

The order Charadriiformes is comprised of 20 families (itis.gov [2], 2013):

- *Alcidae*
- *Burhinidae*
- *Charadriidae*
- *Chionidae*
- *Dromadidae*
- *Glareolidae*
- *Haematopodidae*
- *Ibidorhynchidae*
- *Jacanidae*
- *Laridae*
- *Pedionomidae*
- *Pluvianellidae*
- *Pluvianidae*
- *Recurvirostridae*
- *Rostratulidae*
- *Scolopacidae*
- *Stercorariidae*
- *Thinocoridae*
- *Turnicidae*

The Atlantic puffin belongs to the Alcidae, along with other puffin species, murres, auks, guillemots and murrelets (itis.gov [2], 2013).

1.1.3 Genus

The family is divided into 11 genera. These genera are (itis.gov [3], 2013):

- *Aethia*
- *Alca*
- *Alle*
- *Brachyramphus*
- *Cepphus*
- *Cerorhinca*
- *Fratercula*
- *Pinguinus*
- *Ptychoramphus*
- *Synthliboramphus*
- *Uria*

The Atlantic puffin is placed in the genus *Fratercula* (itis.gov [3], 2013).

1.1.4 Species

The genus *Fratercula* has three species: *F. cornicularа* (horned puffin), *F. cirrhata* (tufted puffin) and *F. arctica* (Atlantic puffin). The Atlantic puffin was first described by Linnaeus in the year 1758 (itis.gov [1], 2013).

1.1.5 Subspecies

The Atlantic puffin has three recognised subspecies: *F. a. arctica*, *F. a. grabae* and *F. a. naumanni*. These subspecies are differentiated based on bill length, bill depth, and wing length (Sangster et al., 2005; itis.gov [1], 2013).

1.1.6 Common names

The most common name for this species is Atlantic puffin or common puffin.

Table 1.1: Translation of Atlantic puffin into several languages (Hutchins, 2002; Nettleship, 1996).

Languages	***Fratercula arctica***
English	Atlantic puffin, (common) puffin
German	Papageitaucher
French	Macareux Moine
Spanish	Frailecillo Atlántico
Danish/Faroe	Lunde
Dutch	Atlantische papegaaiduiker

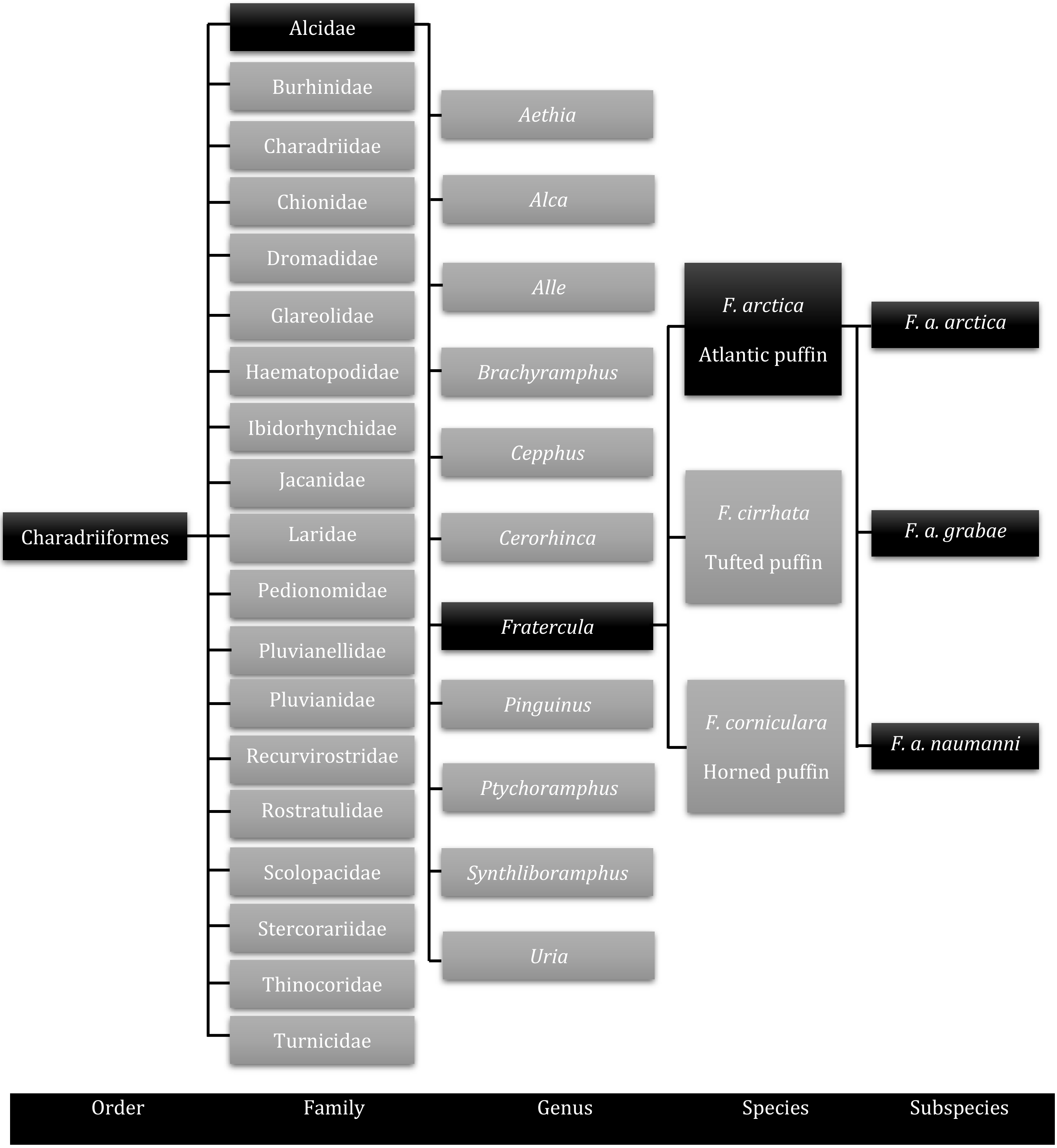


Image 1.1: Classification of the Atlantic puffin, with relevant entries coloured in black (itis.gov, 2013).

1.2 Morphology

1.2.1 Body dimensions

This species can reach 28-37 cm in height with a wingspan of 47-63 cm. Puffins from northern regions tend to be larger in size than those living further south. Puffins living around the UK have an average weight of 400g, while puffins living in Arctic regions weigh on average around 600g (Hutchins, 2002; Nettleship, 1996; Dunn, 2014).

1.2.2 Coloration

Image 1.2: The distinct head of the Atlantic puffin (Trepte, 2011)

The beak is coloured bright red and features a blueish grey base and a pale yellow cere. The mandibles show distinct transverse ridges. At the gape, an orange-yellow rictal rosette can be seen. The tongue has an orange colour. The face is white to greyish-white with a grey chin. The dark eyes are encircled by a crimson ring, with a dark grey triangular plate above, dark grey trapezoidal plate below and a dark post-ocular stripe. A black strip extends from the forehead to the nape. This black colour continues to the throat and the dorsal side of the wings. The ventral side of the wings feature a lighter grey colour. The breast and belly are coloured white. The legs and feet have a bright orange colour with black claws (Dunn, 2014; Nettleship 1996; Hutchins, 2002).

The coloration changes in winter. Bright coloured plates are shed from the beak, revealing the very dark grey foundation. Eye plates also fall off, revealing a similar dark colour. The cheeks fade to a dark grey colour and the rosettes shrivel and fade. The legs and feet fade to a plainer yellow colour. The colouring of juveniles is predominantly black and gradually starts resembling that of adults during winter. Beaks have a darker colour and are stubby and smaller, with 3-4 grooves forming over a period of 3 years. Once fully mature, it is impossible to estimate the age of a puffin, since they show no signs of aging. (Dunn, 2014; Nettleship 1996). Their bills have photoluminescent properties which mean they glow under UV light, it is unclear why but could be a sign of health, used in display, or a visual signal for birds to find others or remote breeding ground while out at sea (Dunning, 2019).

A rare leucistic variation of the Atlantic puffin also occurs, featuring an all-white body with some black feather tips, but with regular colouring on the eye and beak ornaments (Dunn, 2014).

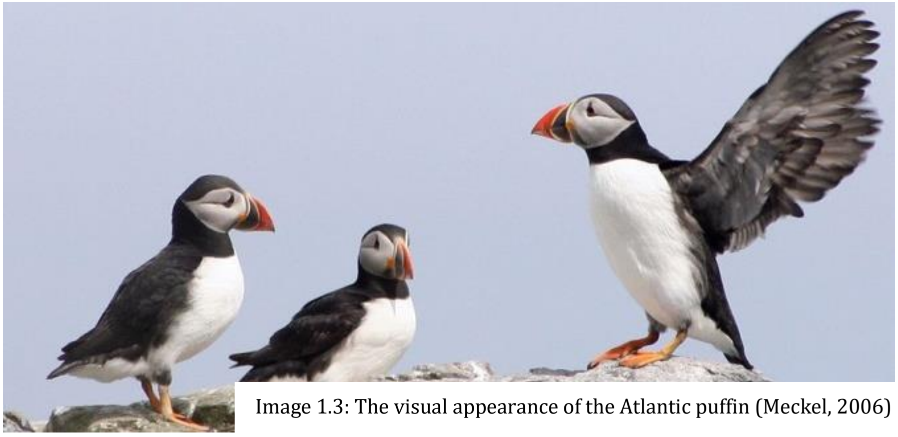


Image 1.3: The visual appearance of the Atlantic puffin (Meckel, 2006)

1.2.3 Description

The reduced surface area and shortened wings of this species significantly improve underwater propulsion but impede aerial flight capabilities. Flight requires a lot of energy due to high wing loading. This also makes the animal less manoeuvrable once airborne. A puffin can beat its wings with high frequency, up to 400 times per minute. The maximum speed of this species is around 80km/h. When moulting in autumn, this species temporarily loses its ability to fly for a period of 45-50 days. A complete visualisation of the moulting process can be found in image 1.4 (Blet-Charaudeau et al., 2010; Dunn, 2014).

Image 1.4: Visual representation of the moult sequence (Dial et al, 2015).

The legs of this species are short, and the feet are palmate, with the first toe is absent or vestigial. The second toe is particularly strong to excavate underground burrows in combination with the muscular neck and beak. Puffins have spines on the roof of the mouth, which allow them to hold on to caught prey while pursuing the next target. Puffins are capable of running, as the post-acetabular part of the pelvis is broad (Dunn, 2014).
Plumage is identical in both males and females. Males are slightly larger on average and have a slightly larger beak as well, but telling sexes apart based on size alone proves to be difficult due to a large size overlap (Dunn, 2014).

The subspecies of the Atlantic puffin *(F.a. arctica, F.a. grabae* and *F.a. naumanni*) are differentiated based on bill length, bill depth and wing size, but there is much individual variation and overlap. The size difference between the subspecies is paralleled at more local levels (northern puffins are generally larger than southern puffins). (Sangster et al., 2005; Dunn, 2014).

1.3 Physiology

Hatchling puffins have body temperatures which are below those of adults. Newly hatched puffins have a thermal neutral temperature of 38.6°C, however at a day old their temperature lowers to a zone between 32°C to 35°C. Within this range, the respiratory rate is approximately 20-23 breaths/min. The metabolic rate can be maintained at submaximal levels down to an ambient temperature of approximately 20°C. Over a period of 9 days, the thermal neutral body temperature slowly increases to 38°C. This increase continues to grow to 40.1°C, which is the thermal neutral body temperature for adults. These rates are based on research conducted on the island of Sklinna off the central west coast of Norway. Eggs were collected and put in an artificial incubator (37°C and 60-70% relative humidity). Chicks were allowed to dry after hatching and were not fed before initiation of the actual experiment (Bech et al., 1987).

No data was available regarding the heart rate of the Atlantic puffin.

Like other seabirds, puffins have internal salt glands. Salt that is consumed during hunting, is absorbed into the bloodstream and excreted partly through these glands and partly through the kidneys. One of these glands is located above each eye. These secrete a salty fluid, which trickles down the beak and is eventually shaken off (Dunn, 2014).

1.4 Longevity

The average longevity for Atlantic Puffins is 25 years, with the oldest puffin ever recorded being 41 years old (Wickett, 1999; Dunn, 2014).

1.5 Field Data

1.5.1 Zoogeography

The Atlantic puffin is confined to an ocean area which spans from New England, USA and Greenland in the east to the shores of Spain and Portugal to Novaya Zemlya, Russia in the West. Table 1.2 includes all countries in which the Atlantic puffin is present (Birdlife International, 2012; Dunn, 2014; Hutchins, 2002). Additionally, Table 1.3 details in which areas the subspecies of the Atlantic puffin are present (Nettleship, 1996).

Table 1.2: All countries in which the Atlantic puffin is considered a native species (Birdlife International, 2012).

Breeding	Non-breeding
Canada; Faroe Island; France; Greenland; Iceland; Norway; Russia; Ireland; Saint Pierre and Miquelon; Svalbard and Jan Mayen; United Kingdom; United States.	Algeria; Belgium; Denmark; Germany; Gibraltar; Italy; Morocco; Netherlands; Portugal; Spain; Sweden; Tunisia

Image 1.5: Distribution of the Atlantic puffin (Birdlife International and NatureServe, 2014).

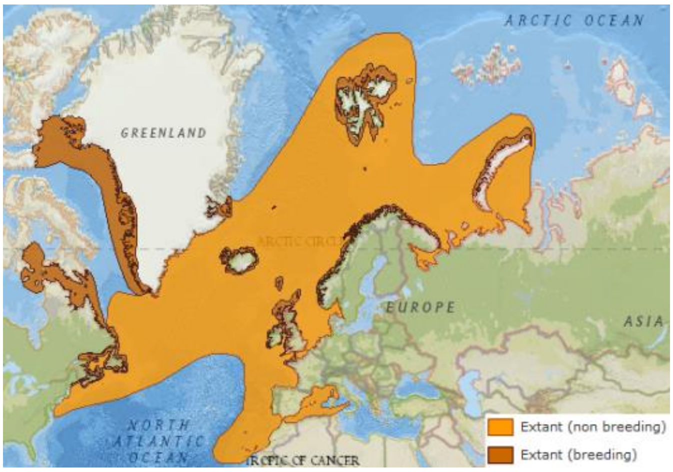


Table 1.3: Distribution of subspecies (Nettleship, 1996)

Subspecies	Occurrence
F. a. arctica	SE Baffin Island, Hudson Bay, S to Maine, E through SW & S Greenland Iceland to Bear Island, C & N Norway, Kola Peninsula and S Novaya Zemlya
F. a. grabae	Faroe, S Norway and SW Sweden S through British Isles to Channel Islands and NW France.
F. a. naumanni	NE Canada, NW & E Greenland to Svalbard and Jan Mayen and N Novaya Zemlya.

1.5.2 Habitat & Ecology

This species lives exclusively in marine habitats, occurring along offshore islands and rocky coasts. Breeding sites are located on turf- or peat covered maritime slopes or adjacent flattish grounds, boulder fields, sea cliffs and scree slopes. Roughly 60% of Atlantic puffins breed in the boreal water zone, while 40% breeds in the low Arctic waters. Less than 1% breeds in the marine zone of the higher Arctic. During winter, this species can be found in habitats within open water regions of the breeding range, to slopes and the edge of the continental shelf. These animals infrequently venture into the open ocean and rarely into cool subtropical waters. The ranges of water conditions within the natural habitat of Atlantic puffins can be found in table 1.4 (Nettleship, 1996; Hutchins, 2002).

Table 1.4: Water values within the natural habitat (Ocean Biographic Information System, n.d.)

Variable	Value
Temperature range (°C)	-0,455–19.253
Nitrate (umol/L)	0,796–12.040
Salinity (PPS)	30.418–37.775
Oxygen (ml/L)	5.032–8.560
Phosphate (umol/L)	0.068–0.809
Silicate (umol/L)	0.565–7.673

1.5.3 Population

At the time of publishing, the highest concentration of puffins can be found in Iceland, which supports around 3 million pairs. Norway supports around 1.5 million pairs. The Faroe Islands (an island group off the northern coast of the United Kingdom, which is part of the kingdom of Denmark) has nearly 500,000 pairs (Dunn, 2014). The European population is estimated to be 4.7-5.8 million pairs, which equates to 9.5-11.6 million mature individuals (BirdLife International, 2015). The global population size is estimated at 12–14 million mature individuals (Harris and Wanless, 2011; Berglund and Hentati-Sundberg, 2014).

According to a population genetic study by Kersten et al. (2021), there are 4 genetically unique clusters of Atlantic puffins within the central range of the puffin distribution, where *F. arctica* is split into two clusters. These finding challenges current classification of three subspecies: *F. a. arctica*, *F. a. grabae* and *F. a. naumanni*. The four clusters identified by the article resulted in the following groups: Canada, Isle of May (Scotland), Spitsbergen (high Arctic) and a larger group encompassing Iceland, Faroe Islands and Norway. Furthermore, the article states that Faroese puffins are genetically closer to *F. a. arctica* than to *F. a. grabae,* which suggest that the geographical divide between the smaller sized puffins (*F. a. grabae*) and the mid-sized puffins (*F. a. arctica*) is much further south than previously thought. Due to an unexpected southward expansion of *F. a. naumanni*'s range, hybrids of *F. a. naumanni* and *F. a. arctica* has been genetically identified on an island in between the high Arctic and Norway (Bjørnøya) (Kersten et al., 2021 & 2022). This genetic information should be considered during conservation planning, however there is still much of the population structure of Atlantic puffins that is unknown due to the lack of sampling towards the outskirts of the species range sampling in areas such as northern Canada, the US, Greenland, Ireland, western UK, France, and Russia.

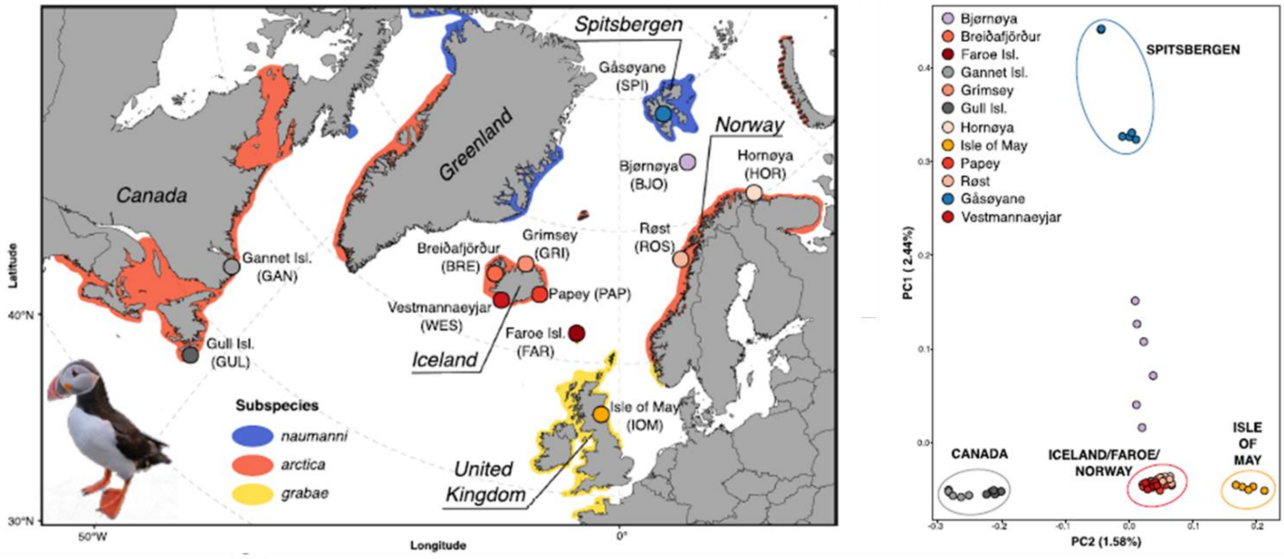


Figure 1: Map of sampling effort and PCA figure from Kersten et al. (2021)

1.5.4 Threats

Previous research regarding factors that influence the survival of adult puffins has found that in a period of 21 years (1973-1993), the adult survival has shown a slight decline, lowering from 97.5% to 92% on average. Within this period, the annual survival rate has only once gone below 89% (1990). This percentage was similar in both male and female adult puffins. Birds above 25 years had a lower resighting probability than birds below the age of 25. Fish availability showed a strong correlation with survival rate, especially when a decline in fish stocks occurred. However, an increase in fish availability was not directly followed by an increase in puffin population size. There was also correlation with wind and sea temperature variables. Colony size and the number of occupied burrows also had a negative impact on the adult survival rate (Harris et al., 1997).

Other threats to puffin populations are expansion of human populations and fisheries, marine pollution, chronic oil fouling, disturbance of nesting grounds, winter hunting (which is now banned in multiple areas) and flooding, which has increased in frequency and severity due to climate change (Blet-Charaudeau et al., 2010).

The main cause of the recent decline in puffin numbers is food shortage/low energy values in prey. Sandeels (*Ammodytes tobianus)* which are the most important food source for this species, are disappearing. Large-scale oceanographic changes in the North Atlantic allow warm subtropical water to enter northern water, which disrupts the food chain. The warm streams have a negative impact on cold-water plankton, the primary food source for sandeels (*Ammodytes tobianus*). This ultimately deprives seabirds such as the Atlantic puffin of food. This leads them to hunt for prey that is less nutritious, which causes adults to be in poorer condition when returning to the colonies, resulting in fewer and smaller eggs. Fewer chicks survive to fledging and the survivors are often underweight. On top of this, puffins have to bear with increasingly stormy sea conditions (RSPB; Wanless et al., 2005).

The herring (*Clupea harengus)* should be less affected by the oceanographic changes that have occurred in recent years, but this species is limited by other factors, like overfishing. Research regarding herring found that annual survival within (adult) puffins is positively correlated with the availability of this fish species. However, throughout the years, both puffins and humans have been less successful in landing herring, which is another indication that populations of this species are declining (Breton et al., 2014).

There has been research regarding the impact of gulls on puffin colonies. Research spanning 23 years, conducted on the Isle of May in south-east Scotland, found that in areas where gull control procedures were implemented, puffin recruitment increased. There was a positive correlation between the reduction of gulls and recruitment rate of puffins (Finney et al., 2003).

Previous research regarding this topic tested whether delaying gull breeding would have a similar effect as removing gulls from an area entirely. In areas where gulls are absent, puffins can more easily provide chicks with food and had a lower risk of kleptoparasitism. However, the gull-free habitat showed no significant difference in chick growth or survival, which lead to the conclusion that gulls had no immediate negative impact on puffin reproductive performance (Finney et al., 2001).

Chick survival is influenced by multiple factors. Couples with a burrow located closer to the edge of a cliff are more likely to successfully raise chicks. There is also a positive relation between successful breeding and the presence of common guillemots (*Uria aalge)*, especially in smaller colonies. The presence of another species in the same area can stimulate a smaller colony to breed similarly to how a large colony would, granted that those animals would not compete for burrows (Blet-Charaudeau et al., 2010).

Another threat to puffins, specifically in the UK, is the presence of an invasive plant species, tree mallow (*Lavatera arborea*). This species causes loss of coastal habitats which are used as breeding sites by puffins. For one of the largest colonies in the United Kingdom, located in Craigleith, this has led to a decrease from 28,000 burrows to 12,100 burrows. In areas where this plant has invaded, puffins are unable to breed due to the plant blocking the entrance of burrows, making it harder and eventually impossible for puffins to enter, which leads to abandonment (Leitch, 2005; Fischer et al., 2007).

1.5.5 Conservation status

At the time of writing (2021), the Atlantic puffin has the IUCN Red List Category of Vulnerable (VU) for the global population, but Endangered (EN) for the local population of Europe. This has been assessed as of August 07, 2018. At the time of assessing, the wild population was decreasing. This species has experienced rapid declines across most of its European range. Population trends outside Europe are unknown. Extrapolated over three generation lengths and allowing for uncertainty, the population is thought to be declining at a rate sufficient to be listed as Vulnerable. Should population trends become less uncertain both within and outside its European range, it may merit uplisting or downlisting. (BirdLife International, 2021).

At the national level however, this species is considered to be threatened in multiple countries. In the United Kingdom, the puffin is included on the UK Birds of Conservation Concern Amber List due to the small number of breeding sites and large population declines. The species is also considered a threatened species in Maine, USA (RSBP.org.uk, 2014; Wickett, 1999).

Various efforts have been made to conserve the puffin. An interesting one is the use of decoys to trick animals into believing that a large colony is present. In some locations, the decoys were not only used on land, but also offshore (Dunn, 2014).

1.5.6. Conservation actions

The species is listed under the African Eurasian Waterbird Agreement. It is included in the Action Plan for Seabirds in Western-Nordic Areas (TemaNord, 2010). There are 76 marine Important Bird Areas identified across the European region. Within the EU there are 40 Special Protection Areas which list this species as occurring within its boundaries.

1.6 Diet & Feeding Behaviour

1.6.1 Food preference

The diet of Atlantic puffin mainly consists of fish. This is sometimes supplemented by small crustaceans, polychaetes and squid, mostly during late summer. The prey species vary per area but are mainly small pelagic fish with high caloric value. The estimated daily food intake is around 15-20% of an adult's body weight (Barrett, 2002; Nettleship, 1996).

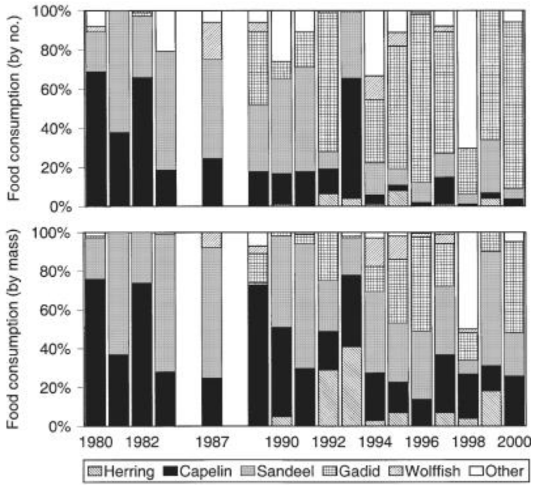


Figure 1.6: Annual variation in puffin diet composition (Barrett, 2002)

Research regarding chick diet and growth of wild Atlantic puffins and common guillemot in the Barents Sea area observed the bird populations to indicate fish stocks that were present. This information also shows the natural diet of these species. This research collected data regarding 2,283 food loads over a period of 17 seasons between 1980 and 2000. In this area, the chick diet consisted of 6 different prey categories: capelin, sandeel, herring, gadids, wolffish and "other". The research did not specify the total diet mass per day, or the number of loads presented to chicks on a daily basis, only that the chicks were "normally fed" (Barrett, 2002). In general, capelin and sandeel were the main components of the diet throughout the years. During the second half of the research, wolffish were also caught in high numbers, but made up a small part of the total mass diet, with some exceptions e.g., the years 1996 and 2000 (±40%).

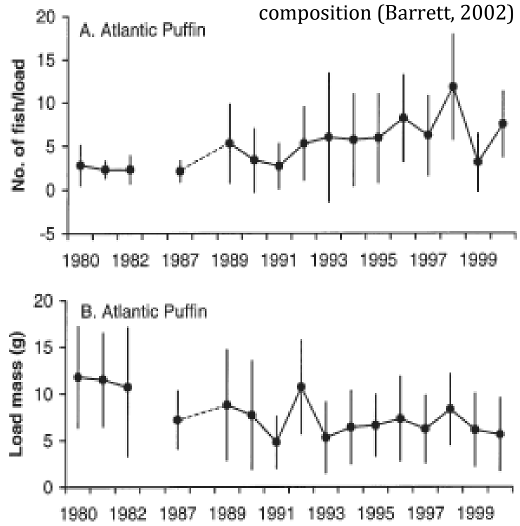


Figure 1.7: Annual variation in fish/load amount and mass (Barrett, 2002)

These results can be seen in Figure 1.6. Throughout the years, the prey gradually shifted from large fishes to smaller fishes with lower calorific content, which is an indication of a decreasing fish stock. Even though the total nutritious value of the diet lowered, the growth rate stayed the same. This is an indication that parents will sacrifice their own wellbeing for the sake of their offspring, until this reaches a certain threshold (Barrett, 2002).

More recent research has revealed more about diet and winter diet of first-year (self-feeding) puffins consumed. Crustaceans are fed more frequently than previously thought. In this research, 40% of chick stomachs were found containing only crustaceans, 20% containing only fish and 40% containing a mix of fish and crustaceans. This means that a higher percentage of chicks had crustaceans (80%) in their stomach when compared to the percentage that had fish in their stomach (60%). It also found that during winter, puffins were likely to incorporate prey of a lower trophic level like zooplankton and smaller crustaceans. Possible given explanations for this are seasonal fluctuations in prey abundance and/or the difference in energetic constraints during summer (breeding) and winter (non-breeding) (Hedd et al., 2010).

1.6.2 Feeding

Fish is mostly caught through underwater pursuit-diving after schools of fish, with average dive times being below 30 seconds and diving depths above 20 m (Nettleship, 1996).
Puffins can dive as deep as 50 or even 70 m. The horizontal swimming speed of this species can reach up to 5 km/h. Puffins are visual predators, hunting throughout the day with dawn and dusk being the peak times (Dunn, 2014).

During chick-rearing, foraging patterns are highly variable between areas and water systems. These animals sometimes feed close to the colony (3-5 km) but may also travel considerable distances (>100 km), depending on the location of the colony and the food availability in that area. Chicks are mainly presented fish, and later in the rearing period may also be fed invertebrates, although this may vary depending on location and colony. They are fed 3-9 meals per day with an average of 43-62 g daily (Dunn, 2014).

The young chicks are presented with small fish, which gradually increase in size as the chick grows. Adult puffins are generally more selective about the diet of their young than their own. During the first hunt in the morning, the parents tend to feed themselves significantly more than usual. On average, only 1 out of 10 caught fish is fed to the chick (Nettleship, 1996; Dunn, 2014).

1.7 Reproduction

1.7.1 Age of Sexual Maturity & Offspring Number

Puffins can start breeding at the age of 4 years, however the average starting age is 7 years. One couple produces 1 nondescript, white-coloured egg. This egg is approximately 6 x 4 cm and weighs around 15% of the adult body mass. Over the last 30 years, eggs have been getting progressively smaller. The total incubation period takes between 36-45 days, with an average of 42 days. An egg that is lost early can be replaced in 13-23 days, but with a low replacement rate of 9%, this rarely happens. Breeding success is highly variable, ranging from 28% to 93% in the northern Atlantic at different colonies throughout the years (this excludes years of total failure due to severe food shortage). The most predominant factors that have an influence on egg and chick loss are (Nettleship, 1996; Dunn, 2014):

- Parental neglect
- Mishandling during incubation
- Gull predation
- Food shortages during chick-rearing
- Disturbance

1.7.2 Time of Laying

Most laying occurs in May and early June. The exceptions to this are Eastern Scotland (earlier) and Labrador (later). The main rule is that northern colonies initiate their laying later than southern colonies. Fledging occurs during July and early August, except for in the low and high Arctic, where this happens later (Nettleship 1996, Dunn, 2014).

High spring sea temperatures and humid winter weather lead to earlier breeding. Previous reproductive efforts do not influence the time of breeding, and there is no relationship with fledging success or duration of the nestling year. First time breeders do generally lay later than experienced breeders (Durant et al., 2004).

Weight loss during the mating season is common. Females have to produce an egg which is relatively large compared to body mass. Also, both parents have to hunt for more prey and share food with the chick and their partner. The demands of the chick generally increase from 3 meals per day to 9 or 10 meals. Chicks reach a peak weight at the age of 4 weeks, after which they lose about 10% after fledging. Parents keep feeding chicks until fledging. It used to be thought that after fledging, parents stop caring for their chick and no longer respond to any vocalisations, meaning fledglings have to fend for themselves. Neighbouring adults would only alert surrounding puffins, including fledglings, in case of an incoming threat. However, there have been observations of parents still looking after their young post-fledging (Harris et al., 2011; Dunn, 2014).

1.8 Behaviour

1.8.1 Social Behaviour

Puffins are relatively quiet birds. Groans, growls and creaks and nasal moaning sounds are the main types of vocalisations produced by this species. The vocal range varies from approximately 1 kHz up to 5-6 kHz. The low frequency is possibly the result of adaptation to underground communication in breeding burrows (Dunn, 2014; Hutchins, 2002).

As mentioned in *1.7 Reproduction,* puffins live in colonies. In these colonies, puffins can be protective about their burrows. To defend their territory, puffin's neck feathers are ruffled to maximize the bulk and wings, and bill-gapes are flexed, with a stretched tongue. Another way puffins guard their burrow is by walking with an erect pose, tucked head and slow steps where every leg is raised as high as possible. This is known as the "*pelican walk*". Sometimes, physical fights break out where the animals wing-cuff one another. During these fights, the fighter can tumble downhill and even fall from a cliff. Once all pairs have picked or made a burrow, animals are generally more lenient towards one another and often allow neighbours to peek into their burrow (Harris et al., 2011; Dunn, 2014).

In the wild, puffins interact with various species. An overview of these interspecific interactions can be found in table 1.7.

Table 1.7: Interspecific interactions (Dunn, 2014; Nettleship, 1996; Blet-Charaudeau, 2010; Hutchins, 2002; Durant et al, 2004).

Interaction	Species
Predators	Peregrine falcon, gyrfalcon, great skua, eagle, rat, feral cat, dog, feral mink
Prey	Sandeel, Atlantic herring, Atlantic mackerel, gadids, sprat, capelin, wolf fish, crustaceans (euphausiids, copepods*),* polychaetes (nereids*)* and squid.
Disturbances	Black-backed gull, great black-backed gull, black-headed gull, jackdaw, seals, goats, sheep, rabbits
Coexists	Guillemots, murres, razorbills, Manx shearwater

1.8.2 Sexual Behaviour

Puffins are monogamous for as long as their partner survives and exhibit high site fidelity. Research has also shown that there is no evidence of extra-pair paternity within populations (Anker-Nilssen et al., 2008; Harris et al., 2011).

These animals are highly colonial breeders. Breeding in a colony allows puffins to carefully select their partner. This species is known to be picky when it comes to mate selection. A colony also decreases the chance of having to deal with predators in comparison to isolated breeding. Nests are mainly made in burrows which they excavate themselves, usually 1-2 m in depth and wider at the end for the nest. They are made in steep maritime slopes covered in turf, but also cavities in boulder fields, rock crevices, scree slopes and gaps on cliffs. The burrows are covered in scraped materials and lined with feathers and/or dry grass (Nettleship, 1996; Dunn, 2014).

To obtain a partner, males often swim besides a female and jerk their heads skywards rapidly and flutter their wings in short burst, accompanied by short vocalisations, and sporadically, by nibbling under the beak. At first, females act coy by diving to avoid male advancements and resurfacing in a crowd. Males approach multiple females and when a match is found, they briefly mount the female to initiate copulation (Harris et al., 2011; Dunn, 2014).

Sometimes, when partners already have an established bond, males will also nibble the rosettes at the mouth base. This is usually followed by clashing the broad sides of the beaks for a period ranging from a couple of seconds to 2-3 minutes. This produces a clacking sound which can be heard meters away. When a pair performs this practice, called billing, other pairs are likely to join. Performing this at sea can result in the animals rotating. On land, puffins can perform a specific gait, which is characterised by an erect pose, tucked head and slow steps where every leg is raised as high as possible. Copulation normally occurs at sea but can also happen on land, however this is often less successful. On land, head flicking is also used to initiate copulation. After hatching, vocalisations are a very important form of communication between offspring and adults, used during delivery of food (Harris et al., 2011; Dunn, 2014).

Normally, males spend more time maintaining and defending the burrow, while the female spends more time incubating. Both sexes incubate for variable periods up to 32 hours, but this can extend to twice this duration. They mostly switch in the morning and evening. Puffins brood by tucking the egg under one of the wings against a patch of bare skin with an abundance of blood vessels. Puffins have one of these patches on each side. Brooding can continue for a week after hatching for safeguarding and until the chick can regulate its own temperature. During an incubation shift, the puffin defecates at the tunnel entrance when necessary. This leaves a trail of faeces, which is an indication of an occupied burrow (Nettleship, 1996; Dunn, 2014).

1.8.3 Locomotion

At the start of the breeding season, puffins migrate from the open seas to rocky coasts. The time of arrival and laying varies between regions. The usual month is detailed for every region in table 1.5. The arrival in the northern Arctic is not included since this is not known exactly, but it is thought to be later than in the low Arctic region. (Nettleship, 1996; Dunn, 2014)

Table 1.5: Various regions and the usual month of puffin arrival (Nettleship, 1996; Dunn, 2014).

Region/Country	Typical arrival month
Eastern Scotland	February
Southern United Kingdom	March
Wales, Scotian Shelf, Gulf of Maine	Late March/Early April
Low Arctic (Murmansk (Russia), Norway (North), Newfoundland, Northern Gulf of St. Lawrence)	Mid-April
Northern United Kingdom	May
Labrador, Canada	Early June

This species spends winter offshore, sometimes off the continental shelf and even the continental slope, moving into the pelagic zone. Colonies disperse widely, resulting in relatively low densities. The usual winter migration is included in table 1.6. The exact southern movement of puffins is not known, but in general, the southern colonies move more southerly than northern colonies. Research has found that the winter distribution of puffins does not influence the survival rate of puffins (Nettleship, 1996; Harris et al., 2013).

Table 1.6: Most common winter migration in different colonies of Atlantic puffins (Nettleship, 1996; Dunn, 2014)

Origin	Migrates to
Greenland & Newfoundland	Offshore areas but stays within the Western Atlantic.
Ireland & North-Britain	Bay of Biscay, Mediterranean.
West-Britain	West-Atlantic and West-Mediterranean
East-Britain, South-west Norway	North Sea
Murmansk, Northern Norway, Iceland, European High Arctic, North-Britain	Western/South-western direction, younger animals can move as far as Greenland or Newfoundland

Research regarding the influence of winter dispersal and climate on the adult survival within puffin populations found that similarities in survival rate between various colonies did not reflect similarities in the wintering areas and geographic proximity of those colonies. It was also found that the hypothesis that survival rates within colonies are mainly determined by adult survival (since it takes several years before fledglings reach sexual maturity), is wrong. Despite a relatively consistent adult survival rate, population trends were still variable. The relation between sea temperature, survival and the presence of the main prey species was positive in areas where herring is the main prey species. This relation was negative in areas where the lesser sandeel and the capelin were the main prey species. This shows the possibility that sandeel and capelin recruitment decreases when sea temperatures increase, while herring recruitment does the opposite (Harris et al., 2005).

More recent research showed similar results, concluding that the influence of dispersal is minimal. Winter survival is more dependent on the condition of the animal at the end of the summer (Harris et al., 2005).

Section 2: Management in Zoos & Aquaria

2.1 Enclosure

2.1.1 Boundary

Puffins can be kept in both indoor and outdoor enclosures. Both of these are similar in appearance, differing mainly in the boundaries of the enclosure. Indoor enclosures have both regular walls, glass and substrates (mainly rocks) as boundaries. The main difference with outdoor enclosures is that these are in the open air. Outdoor enclosures should have fine netting installed to protect the puffins from health conditions such as avian malaria (Questionnaire B. Vernooij, 2015). The netting used at Rotterdam Zoo is made out of polyethylene, with a mesh size of 0,27mm x 0,77mm and weighs 140g per m^2, which limits access for mosquitoes.

Some zoos have only minor barriers between visitors and the animals, such as glass barriers as seen in image 2.1. Another option is a full glass barrier, leaving no open space. This has certain benefits, such as a more closed off-air space, which can allow for more effective climate control in indoor enclosures, less noise and less influence from visitors by trying to touch or feed the animals that can be a source of stress and cause disturbances during the breeding season. See image 2.2 for an example of such a barrier (Questionnaire B. Vernooij, 2015).

Image 2.1: Left - The barriers at the puffin enclosure in Oceanário de Lisboa (Source: Oceanário de Lisboa). Right: a similar open-style boundary in Tierpark Dählhölzli (Source: jakob.co.uk).

Image 2.2: Fully closed barriers in the puffin enclosure at Loro Parque (Source: Loro Parque).

2.1.2 Substrate

Various substrates can be used in puffin enclosures. Most enclosures resemble the natural habitat of the species, with artificial rockwork made from gunite, resin and cement, fiberglass, or a combination of gunite and shotcrete. Other substrates that can be used are pea gravel, textured rubber, plastic matting (this can be perforated for drainage), turf (both artificial and natural) and clay. Substrates used for nest boxes include nomad matting and coral gravel. It is important that these surfaces are free draining and dry quickly. Substrates should allow the puffins to adequately spread their weight over the entire weight-bearing surface of the lower limb. Hard substrates should be textured or uneven to allow puffins to distribute the weight variably across the foot sole, to prevent bumblefoot (Robinson, 2009; AZA Charadriiformes Taxon Advisory Group, 2014 [1]; Questionnaire B. Vernooij, 2015).

2.1.3 Furnishing and Maintenance

To make the enclosure resemble the natural environment of the Atlantic puffin, the most important type of furnishing is rocks and plants on a layer of turf. Nest boxes can be integrated into the rocks, this way the nest boxes more closely resemble the natural burrows that are usually used by puffins.

For maintenance of the enclosure, both the water and air in the enclosure must be filtered continuously. Clean water is essential for the health of the puffins. Contaminated water can damage the plumage and act as both a source of infection and be a breeding ground for mosquitoes. Good water conditions can be maintained using skimmers, sand filters and biofilters (Robinson, 2009).

To maintain good water quality, adequate installation of skimmers is necessary. The turnover rate should as a minimum be once every 1,5 hours, to ensure that fish oils are removed from the the pool. The number of skimmers should be determined based on the pool size. The frequency with which skimmers are cleaned should be increased during seasonal events such as moulting (AZA Charadriiformes Taxon Advisory Group, 2014 [1]).

Managing the air quality within an enclosure is very important for indoor enclosures. It is vital for proper respiration and helps combat sporulation of fungi such as *Aspergillus*. This can be achieved by circulating the air by ventilation in the indoor enclosure twice per hour. Ventilation can also be used in outdoor enclosures but is not a necessity due to the open air (AZA Charadriiformes Taxon Advisory Group, 2014 [1]).

In most zoos, the land areas in puffin enclosures are cleaned only using water. This can be done by daily cleaning with a hose and a brush, and cleaning with a high-pressure hose 2-3 times per week. This should be sufficient for this species, since the natural breeding habitat of these birds is covered in droppings. If it is preferred to clean with cleaning solution; however, the chemicals in the solution should not be harmful to the birds. For instance, chemicals that can damage the waterproofing of the birds. One recommended cleaning solution is hydrogen peroxide (H_2O_2) (Bruslund, 2015; Questionnaire B. Vernooij, 2015).

2.1.4 Environment

Swimming is an essential activity for this species, which makes a pool a necessity. It is recommended to make the pool area as deep as possible, with a minimum of 2 m depth, although it is very hard to match the natural diving depth of this species (20 m+). This allows the puffins to show their natural diving behaviour. The ideal water temperature is about 4-7°C. It is recommended to keep the puffin in salt water, to keep their salt glands active. The recommended minimum water: land surface ratio is 3:1, which allows the birds to spend more time in the water, which will decrease the chance of health conditions such as bumblefoot (Weingartz, 2007).

The climate in the enclosures should resemble the climate in the natural habitat of the species with temperatures ranging for 4°C to 15°C. Outdoor enclosures should stay within -2°C to 29°C, where the peak temperatures only occur rarely. Recent research regarding climate change in Europe mapped temperature distributions throughout the entire continent (Stainforth et al., 2013); this can be used as an indication of whether a zoo should build an indoor or outdoor facility. Image 2.3 shows the results of this research. The first map shows the probability of exceeding a daytime summer temperature of 28°C, while the second map shows the change in exceedance probability. This shows that throughout most of central Europe, warmer temperatures will occur more frequently. Various sources show that the frequency and intensity of heat waves in Europe will increase, with countries in central Europe expected to experience a number of hot days similar to southern Europe (Stainforth et al., 2013; Della-Marta et al., 2008; Fischer et al., 2010).

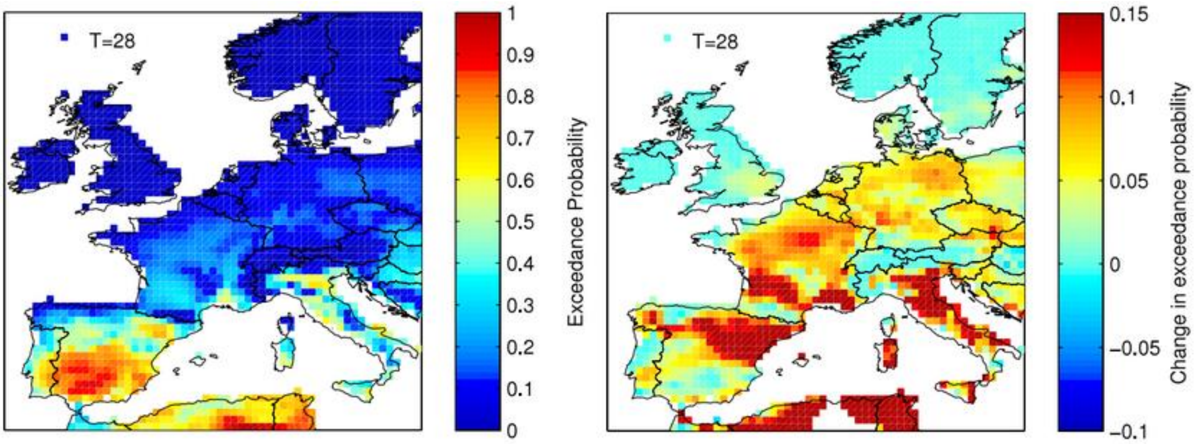


Image 2.3: The exceedance probability of a daytime temperature of 28°C (left) and the change in this probability (left) mapped across Europe (Stainforth et al, 2013).

Structures and vegetation within the enclosure can create shadow areas, which can be utilised by the puffins. The lighting periods can vary. Breeding can be stimulated by extending lighting periods when the breeding season commences. This should resemble the natural habitat of the species (AZA Charadriiformes Taxon Advisory Group, 2014 [1]).

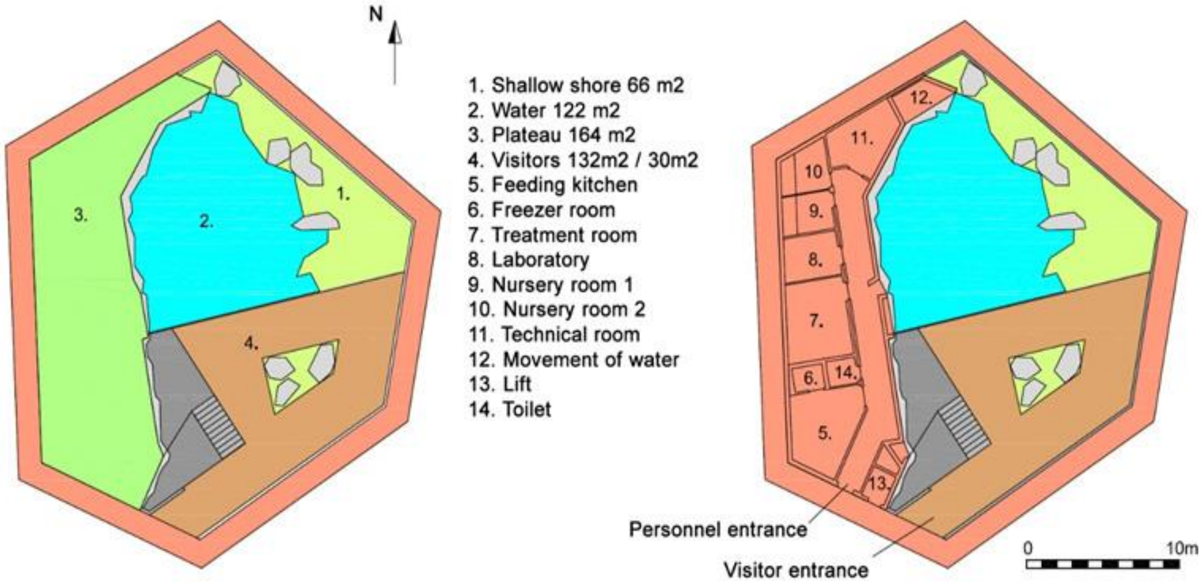
Table 2.1: Lighting scheme example (Questionnaire B. Vernooij, 2015)

Date	Fluor-escent lights on	Fluor-escent lights off	Halide bulbs on	Halide bulbs off	Date	Fluor-escent lights on	Fluor-escent lights off	Halide bulbs on	Halide bulbs off
1 Jan	8:45 AM	9:00 PM	11:15AM	3:15 PM	1 July	3:13 AM	11:57 PM		
8 Jan	8:30 AM	9:00 PM			9 July	3:31 AM	11:42 PM		
12 Jan	8:15 AM	9:00 PM			17 July	3:57 AM	11:21 PM	7:00 AM	7:00 PM
24 Jan	8:00 AM	9:00 PM	11:00AM	4:30 PM	25 July	4:17 AM	10:57 PM		
1 Feb	7:45 AM	9:00 PM			1 Aug	4:40 AM	10:35 PM		
8 Feb	7:30 AM	9:00 PM			8 Aug	5:02 AM	10:11 PM	7:45 AM	6:00 PM
16 Feb	7:15 AM	9:00 PM	10:00AM	5:00 PM	15 Aug	5:23 AM	9:47 PM		
23 Feb	7:00 AM	9:00 PM			23 Aug	5:48 AM	9:20 PM		
1 Mar	6:45 AM	9:00 PM			1 Sep	5:48 AM	9:00 PM	7:30 AM	5:00 PM
9 Mar	6:30 AM	9:00 PM	9:00 AM	5:30 PM	8 Sep	5:55 AM	9:00 PM	8:45 AM	4:45 PM
16 Mar	6:15 AM	9:00 PM			15 Sep	6:00 AM	9:00 PM		
23 Mar	6:00 AM	9:00 PM			22 Sep	6:15 AM	9:00 PM		
1 Apr	5:30 AM	9:00 PM	7:00 AM	5:00 PM	1 Oct	6:30 AM	9:00 PM	9:00 AM	4:00 PM
8 Apr	5:15 AM	9:00 PM			9 Oct	6:45 AM	9:00 PM		
15 Apr	5:04 AM	9:15 PM	6:30 AM	6:00 PM	16 Oct	7:00 AM	9:00 PM		
22 Apr	5:04 AM	9:30 PM	6:30 AM	6:30 PM	24 Oct	7:15 AM	9:00 PM	10:00AM	3:30 PM
1 May	4:56 AM	9:54 PM			1 Nov	7:30 AM	9:00 PM		
9 May	4:39 AM	10:20 PM	6:30 AM	8:00 PM	8 Nov	7:45 AM	9:00 PM		
17 May	4:13 AM	10:46 PM			15 Nov	8:00 AM	9:00 PM	10:30AM	3:15 PM
25 May	3:49 AM	11:11 PM			22 Nov	8:15 AM	9:00 PM		
1 June	3:30 AM	11:31 PM	5:15 AM	9:15 PM	1 Dec	8:30 AM	9:00 PM		
8 June	3:15 AM	11:49 PM			9 Dec	8:45 AM	9:00 PM	11:00AM	3:00 PM
15 June	3:05 AM	12:00 AM			16 Dec	8:45 AM	9:00 PM		
22 June	3:03 AM	12:04 AM	6:15 AM	8:15 PM	23 Dec	8:45 AM	9:00 PM		

One difference between indoor and outdoor enclosures is that puffins kept indoors have limited access to daylight. To compensate for this, an excellent lighting system must be used in the enclosure. A lighting scheme that has been used successfully is a combination of 4 metal halide bulbs and 36 Osram Vitalux UV Light bulbs. This can also be used as a foundation for lighting schemes with different lights (Bruslund, 2015; Questionnaire B. Vernooij, 2015).

2.1.5 Dimensions

It is difficult to name an exact guideline in terms of size per animal. This is not only due to a lack of literature on this subject, but also the influence of enclosure design on the perception and effectiveness of space. The amount of space should be sufficient to allow every animal in the colony to express natural behaviour. A general guideline that can be used is that the pool area of the enclosure should allow up to 75% of the colony to swim at the same time. Water: land surface ratio 3:1 (AZA Charadriiformes Taxon Advisory Group, 2014 [1]).



As an example of enclosure size, the above illustration shows the successful facility in Tierpark Bern Dählhölzli, Switzerland.

It is also important to keep the limited flying capabilities of this species in mind when designing an enclosure. The rocks that are included should not form a steep cliff that is nearly impossible to climb. By giving structures a flat slope, the animals can use these slopes significantly more. If it is desired to allow the puffins to fly, the enclosure should allow the puffins to paddle along the water and gain momentum, which is required for flight. This does have risks that the birds will get injured on walls and cliffs, due to the low manoeuvrability of this species (Robinson, 2009; AZA Charadriiformes Taxon Advisory Group, 2014 [1]).

2.2 Feeding

2.2.1 Basic Diet

The dietary standard for alcids in zoos and aquaria is a variation of three or more fish species with vitamin and thiamine supplements. This supplement is necessary because many vitamins, like vitamin D3, vitamin A, riboflavin, niacin, pantothenic acid, vitamin B6, vitamin B12 and choline are obtained via the intestines of various food species, which are missing from the fish that is usually fed in zoos and aquaria. These are missing because the fish that is being used is usually prepared for human consumption. This also causes lower lipids and carotenoid values. Further losses of nutritional value can be caused by transport, storage, preparation and feeding procedures. The supplements usually consist of fat-soluble acids like vitamin A, D and E. These along with carotenoids are essential for embryo development. If bones are removed from the fish, calcium supplements should be considered as well (Bernard et al, 2002; McWilliams, 2008; Klasing, 1998).

The two diets described below provide the birds with what they need, but transfers within the EEP would be made easier if we all used a consistent fish-based diet, because the birds must be raised on pellets in order for them to eat pellets.

Feeding Puffins at Copenhagen Zoo:

The Puffins at Copenhagen Zoo are feed on a mixed fish diet that changes over the season. The types of items used are:
Whole smelt *(Osmerus eperlanus)*
Whole capelin *(Mallotus villosus)*
Herring filet *(Clupea Harengus)*
Mackerel filet *(Scomber colias)*
Sandeel *(Ammodytes tobianus)*
Krill *(Euphausia superba)*
Sprats *(Sprattus sprattus)*

Maintenance diet is fed in the season where we see them spend more time in the water than on land (August – March)
The diet is made of whole smelt and capelin. Approx 60 – 80% capelin and 40 -20% smelt.
Supplements: Spirulina algae, Fish-Eater Tab, from Granovit Zoofeed

Breeding season diet (April – August)
50% Sprats
30% Sandeel
10% Herring filet (we filet them and cut them to strips)
5% Mackerel filet (we filet them and cut them to strips)
5% Krill
Supplements: Spirulina, Nekton R,from Nekton, Fish-Eater Tab

We increase the food items and the fat content in the diet for the breeding season.
Signs we look out for are:

- Moulting into breeding plumage
- The birds start to spend more time on land, in and around their burrows.
- The birds get more vocal.
- Beak bobbing between mates.
- Stiff walk, slightly bent heads to the chest while walking and vocalizing.

(H. Futtrup, 2024)

Feeding the adult birds in Tierpark Bern:
The puffins are consistently fed throughout the year with pellets [‘Lundi Ibis-See- (Eis-) Ente-Spezial’, Lundi Deutschland] , size 5, 25–30 g per animal per day. These pellets are soaked in water before feeding to ensure the correct consistency – neither too dry nor too mushy – providing an ideal texture for the puffins to consume.
The pellets are offered fresh twice a day so that they are available ad libitum – once in the morning around 8 a.m. and again in the afternoon around 4 p.m. They are placed in 3 food trays (diameter 20 cm, height 2 cm) distributed in the exhibit. Shrimps (whole body including head and shell, measuring approx. 7–10 cm in length) are added to the pellets, ensuring the puffins receive the important coloration molecules found in these crustaceans. An empirical observation in Tierpark

Bern showed that when young birds are fed shrimp from an early age, their beaks turn an intense red colour compared to birds raised without shrimp feeding (Figure 7).
In the early afternoon, fish (capelin (Mallotus villosus)) are offered as part of a public feeding. The number of capelins provided is roughly based on the amount of pellets consumed by the puffins the previous days and the size of the capelin. On average, each puffin receives around 2-3 capelin per day. (Pers. Comm Blatter and Huwiler)

Figure. 7: Beak colouration of two birds in 2017: Left: born in 2008, right: born in 2013. The latter has been fed with shrimp remains for the past 1.5 years (Photograph M. Rosset).

Proteins, lipids, carotenoids, vitamins and minerals are essential parts of any puffin diet. Proteins are necessary for good plumage. Cystine and methionine are especially important for the development of new feathers while moulting. While moulting, it is natural for puffins to lose weight. Lipids are one of the main energy sources for puffins. These are mainly obtained through unsaturated fats. An adult fish contains more unsaturated fats than juveniles. Dietary fats are also needed to keep the uropygial gland (preen gland) functioning properly. These secretions are preened into the feathers and provides a coating to maintain feather pliability and waterproofing. Besides the embryo development, carotenoids are a source of pigmentation and are the precursors of vitamin A, also acting as antioxidants and protecting against UV radiation. Crustaceans generally have higher carotenoid values, which makes them a valuable diet addition, especially during the breeding season. It should be noted that carotenoids in crustaceans can be lost to light, warmth, oxidation or environmental acidity levels (McWilliams, 2008).

At most zoos, frozen fish is used. To prepare frozen items for feeding, it is important to let them thaw in a fridge, instead of using water. Thawing fish in water will lead to loss of vitamins, is unsanitary and not compliant with most national zoo standards. The fish should be cleaned in cold running water before feeding, to minimise health risks. (Bruslund, 2015; Questionnaire B. Vernooij, 2015).

2.2.2 Special Dietary Requirements

Besides the focus points mentioned in *2.2.1 Basic Diet*, no additional special dietary requirements for this species have been found. However, multiple zoos have expressed that the amount of fish that is consumed fluctuates throughout the year. (Questionnaire B. Vernooij, 2015). If your birds are scale trained, it will be a great tool for vets and staff to hold their current weight up against earlier taken weights for this period.
During the breeding season it is normal that food intake will increase, especially if the birds are parent rearing the chicks (Questionnaire B. Vernooij, 2015).

2.2.3 Method of Feeding

In most zoos, puffins are fed ad-libitum by presenting the fish on plates. This is an effective way of providing all animals, including the less dominant ones, with food. However, this does not stimulate the natural foraging behaviour of these animals, which consists of underwater hunting. A more effective way of feeding these animals would be by providing fish with vitamins in the morning, preferably by hand, which is also done is some zoos. This does require significantly more time and the ability of the caretaker to tell individuals apart, which might be difficult for bigger colonies. This allows for the rest of the fish to be fed via the water, which is more a more faithful simulation of the natural foraging behaviour (Questionnaire B. Vernooij, 2015).
If you use scatter feeding in the water, it is necessary to remove fish-oil from the surface which will ruin the bird's plumage, so heavy surface skimmers on the filtration of the water are needed. Hand feeding is a good method to get a view of the overall health status of the individual bird, or to give an individual bird medication. (H. Futtrup, pers. comm.)

2.2.4 Water

Due to the aquatic nature of this species and the way water is implemented in general enclosure design, no separate drinking water facilities need to be provided for this species. Drinking water for puffins is an area that needs research; we don't know if they obtain moisture through their diet or whether they are able to drink salt water and excrete the salt through their salt glands. Some *ex-situ* populations are housed with saltwater pools with no access to fresh water without any problems.

2.3 Social Structure

This social species should be kept in groups. Groups can be mixed with other species (except for gannets), preferably other alcids. It is recommended to have an equal gender ratio which increases breeding efficiency, decreasing the chances of same sex couples. A larger group can stimulate the birds to reproduce, but the enclosure needs to be designed to offer all the couples the possibility to breed. An effective way of realising this is by combining a group of puffins with species that don't use burrows for breeding, which is further detailed in *2.3.2 Sharing enclosure with other species* (AZA Charadriiformes Taxon Advisory Group, 2014 [1]).

Introducing new species or new puffins into an existing colony seems to be unproblematic with minimal aggression in the early part of the introduction (F. Nielsen, pers. com).

Every zoo that currently has a thriving puffin population has more than 10 puffins. The recommended group size for alcids is 20 birds per species. This means that mixed colonies should be large in size. Puffins have been kept successfully with the following species. (Weingartz, 2007; Questionnaire, 2015):

- Razorbills *(Alca torda)*
- Black guillemots *(Cepphus grylle)*
- King eiders *(Somateria spectabilis)*
- Common murres, *(Uria aalge)* only reported conflict was with two birds in one location. After these were removed from the group there were no more problems.
- Tufted puffins *(Fratercula cirrhata)* only reported conflict was over burrow occupancy, but it was also mentioned that the enclosure did not have enough burrows to allow every couple to breed.
- Cassin's auklets *(Ptychoramphus aleuticus)*
- Common Eiders *(Somateria mollissima)*

At some zoos, puffins are also kept together with certain fish species. This could be considered enrichment. It is important that these species do not harm one another. In Oceanário de Lisboa, a large number of fish species is present in the puffin enclosure. No conflicts between puffins and these species have been observed, although there have been conflicts between murres and the fishes in the enclosure. It should be noted that when fish are kept in the same enclosure as puffins, these fish species are the limiting factor in terms of water quality. (Questionnaire B. Vernooij, 2015):

- *Conger conger*
- *Coris julis*
- *Dicentrarchus labrax*
- *Diplodus cervinus*
- *Diplodus puntazzo*
- *Diplodus sargus*
- *Diplodus vulgaris*
- *Gadus morhua*
- *Labrus bergylta*
- *Labrus viridis*
- *Pagrus pagrus*
- *Polyprion americanus*
- *Psetta maxima*
- *Raja brachyura*
- *Raja clavata*
- *Raja undulata*
- *Sarpa salpa*
- *Scorpaena* sp.
- *Scyliorhinus canicula*
- *Scyliorhinus stellaris*
- *Sparus aurata*

2.4 Breeding

2.4.1 Mating

To stimulate puffins to mate, various measures can be applied. These are meant to simulate the breeding season as closely as possible. Two common measures are increasing lighting periods and increasing the amount of food when the breeding season normally starts. Besides these two measures, others have been mentioned by various zoos.

Many zoos only give the puffins access to the nest boxes during the breeding season. In addition to this, many zoos that have been successful at breeding also provide the puffins with plants. These can either be natural or artificial. The way these are presented also differs from zoo to zoo. Some prefer to give the puffin plants, others prefer to present them with twigs, leaves, pine needles and hay instead.

Diversifying the diet by adding small crustaceans (such as krill) and opened mussels is also often seen (Weingartz, 2007; Questionnaire B. Vernooij, 2015).

Nesting materials do come with a risk. These materials, like hay and artificial plants, can be a source of infections like Aspergillosis. Nesting materials should be treated by heating in an oven at 200°C for two hours before these are presented to the birds. A cooling period before use is necessary to avoid unnecessary harm to birds or keeper staff. (H. Futtrup pers. comm.)

Male courtship behaviours are calling and providing a gift of nesting material to the female. The pair will dig out the entrance tunnel to the nesting chamber together as a part of their mating ritual. For that reason, it is important to provide this possibility in connection with the nest area.

Courtship behaviour signs to look for:

- Proud walk bent neck, high feet lifting
- Beak clattering
- More vocalization than normal
- Males tend to guard the nest entry
- Digging

(H. Futtrup/ F. Nielsen pers. comm.)


In the back access to nesting chambers and digging on top of the cliffs. Bern Zoo
(Photograph M. Rosset)


View of breeding section of the exhibit in Copenhagen Zoo. (Photo H. Futtrup)

Entrance access to the nests in the colony at Copenhagen Zoo. (Photo H. Futtrup)

Keepers access doors to the back of the nest chambers in Copenhagen Zoo. (Photos H. Futtrup)

2.4.2 Egg laying and incubation

To allow puffins to mate, nest boxes have to be added to the enclosure. These can be applied in a way which replicates natural burrows by adding PVC-pipes to rockwork with a length of approximately 60-120cm, which lead to the nest box. Having a hinged top allows for easy access by caretakers, which can improve breeding results. The ideal relative humidity is about 65-70%, which is similar to the humidity of burrows in the natural habitat of puffins (Harris M.P., S. Wanless, 2011). During the breeding season nest boxes should be inspected at least once every two days. Incubated eggs can be inspected through candling (Weingartz, 2007; Bech et al., 1987). You will be able to see an increase in weight of the female right before egg laying.

The clutch size of puffins is 1 egg which is incubated by parents in the nest or taken for artificial incubation and rearing; the egg is incubated for a range of 39-43 days. During this incubation period it is important to make sure that both birds in the pair help with the incubation. At Copenhagen Zoo it has been seen that some puffin males are not that willing to help on the incubation part - they stick more to the guarding of the nest entry. If a male behaves like this, it would be wise to supplement feed the female either on the nest or right outside the nest entryto make sure the female doesn’t lose too much weight with the risk of losing the egg because she abandons the nest (H. Futtrup pers.comm).

Artificial nest boxes used for fieldwork in breeding colonies of Puffins on the Faroe Islands. Useable for captive breeding too. Right small tube for camera access to the nest. Imbedded in the rock work or ground. Extend entrance onto 80 cm. Nest Ø 30cm, height 35 cm. Entrance Ø 10 – 12 cm. (Photos: F. Nielsen)

Left: Inside view of a PVC cylinder, Bern Zoo. which the puffins use as a nesting box. Right: Artificial nesting hole on the plateau. Under this concrete half-shell, the birds have dug about 80 cm diagonally downwards (Photograph M. Rosset).

2.4.3 Hatching

It is encouraged to try and let puffins breed naturally and raise their offspring themselves. With that said, it is uncommon for them to successfully parent-rear without some human support. However, bird collections have had good results with supplement feeding on the nest, and both parents and offspring seem not to take notice of this intrusion. Chicks will start eating by themselves around 48 hours after hatching.

Removal of eggs for artificial incubation does not lead to double-clutching. (F. Nielsen pers. comm.)

If it is decided to artificially incubate eggs, this can be done by using an incubator with a temperature between 36.6°C – 37.2°C and a relative humidity of 50-65%. The egg should be turned every two hours. As mentioned in *2.4.2 Egg laying and incubation*, relative humidity in nest boxes should also be around 60-70% (Weingartz, 2007; Bech et al., 1987).
The time from external pip to full hatch has been registered to be between 1 to 5 days. SeaWorld says the average day 4 for the parameters they incubate on

Puffin chick's development from newly hatched to fully feathered chick. (Photos. Kamilla Skov, Copenhagen Zoo)

2.4.4 Development and Care of Young

It is recommended to let newborn chicks stay with their parents for at least the first 14 days. During these days, frequent inspection can be useful, and chicks can be fed extra by providing food directly in the nest boxes. During these days it is important to pay attention to the following factors:

- Dry and fluffy appearance
- Alertness, response time
- Clear and bright eyes
- Clean cloaca.

Daily growth should be about 13% of total mass per day. Slower growth rates can be caused by inexperienced parents or health conditions. During the first couple of days chick can lose weight due to yolk absorption (Weigartz, 2007).

Research on the diet and growth of puffin chicks measured the mass and wing length of puffin chicks over a period of 21 years (1980-2000). The average values of these variables for each year can be found in table 2.2.

Table 2.2: Average growth rate in puffin chicks (Barrett, 2002)

Year	Atlantic puffin mass ($g\ d^{-1}$)	wing length ($mm\ d^{-1}$)	n
1980	11.4 ± 2.7	4.1 ± 1.5	32
1981	11.2 ± 2.3	3.5 ± 0.4	28
1982	11.9 ± 2.8	nd	23
1983	nd	nd	
1988	9.7 ± 4.2	2.9 ± 1.1	41
1989	11.2 ± 3.2	3.9 ± 1.2	30
1990	9.8 ± 3.3	3.8 ± 0.5	24
1991	10.4 ± 4.2	3.7 ± 0.6	26
1992	13.3 ± 3.6	3.9 ± 0.9	21
1993	12.7 ± 2.1	3.1 ± 0.6	19
1994	9.1 ± 2.0	3.8 ± 0.9	10
1995	10.6 ± 1.4	3.8 ± 0.3	25
1996	12.6 ± 2.5	4.1 ± 0.5	28
1997	11.3 ± 3.5	3.6 ± 0.8	24
1998	10.5 ± 3.8	3.6 ± 1.1	31
1999	11.6 ± 3,4	3.7 ± 0.7	25
2000	12.6 ± 2.5	3.7 ± 0.9	24

2.4.5 Hand-Rearing

As said before, parent-rearing is preferred but if hand-rearing is necessary, there are different hand-rearing methods available. Some zoos artificially incubate eggs and hand-rear the chicks from day one; other zoos let the eggs hatch naturally and commence hand-rearing after a few days or weeks. Other zoos prefer not to hand-rear at all, only interfering when necessary, e.g. when chicks fall ill, get abandoned or cannot swim. When it comes to hand-rearing, Table 2.2 details the hand-rearing protocol used at SeaWorld Orlando, where breeding success has been achieved for 20 consecutive years. This can be used as a foundation for a custom hand-rearing protocol (Questionnaire B. Vernooij, 2015).

Puffins tend not to imprint on humans if hand-reared. This might come from the fact that chicks eat by themselves 48 hours after hatching, which means very little human/chick contact is needed. Puffin chicks cannot tolerate each other so should be reared individually.

After hatching, chicks are left to dry in the incubator and are briefly rubbed down by hand, so that their down unfurls. Dry chicks are placed in boxes in a rearing room, which consists of open-top plastic frames (W 30 cm, L 40 cm, H 30 cm; nursery boxes) with a 5 mm mesh PVC net bottom. Five nursery boxes stand side by side on a table frame (Figure 8). A piece of black rubber mattingmeasuring 15 x 10 cm and 5 mm thick is laid in each bird's box.

The room temperature is 20°C and kept dark. For the first six days young birds are provided a heat lamp (surface temperature of the rubber mat under the lamp reaches a maximum of 35°C). Six days after entering the nursery box, the heat lamp is removed, as the young bird is now able to maintain its own body temperature. The bird stays in the rearing box until it jumps out on its own, which happens after about 50 days. (F. Nielsen pers. com.) (Rosset and Blatter, 2019).

Besides the points mentioned in *2.4.4 Development and Care of Young*, the following factors have been mentioned as important for hand-rearing (Questionnaire B. Vernooij, 2015):

- Never feeding more than 10% of the body weight.
- Frequent changing of the matting
- Daily weighing
- Check if the crop is empty before feeding

Nursery boxes, chick from 2017 (Photograph M. Rosset). Nursery at Copenhagen Zoo 2011. (Photo F. Nielsen)

Table 2.3: An example of a hand-rearing protocol (SeaWorld, 2007)

Day	Activities
1 Hatch Date	Do not feed chick until at least 48 hours post-hatch. Warmed Ringer solution (LRS) only (0.2 – 0.3cc max.) every 3 hours, but not through the night. Brooder temperature set at 34.4˚C. Weigh chick daily.
2	Use the equation (a.m. weight x 0.42 divided by # of feedings per day) to determine the maximum amount of fish to offer at each feeding. There will be 6 feedings per day, every 2.5 – 3 hours. Feed silversides only. Remove head, tail & fins. Soak in warm water before feeding. Give several drops of warmed Ringer solution at each feeding. Depending on the size of the fish, they may need to be cut into smaller pieces. Dangle fish to create interest from the chick.
3	Same as Day 2, but may need to lower brooder temperature (34.4 – 32.2 ˚C)
4	Same as Day 3 but may need to lower brooder temperature (32.8 – 31.7 ˚C). Feed whole silversides if appropriately sized.
5 & 6	Drop to 5 feedings per day. Continue to use equation for determining food amount. May need to lower brooder temperature (30.6 –27.2 ˚C).
7	Chick should be eating readily from tray. Hydrate fish. Brooder temperature ~ 27.2 – 25.6 ˚C.
8	Move to a kennel if chick is ready. Start vitamin regimen of ¼# Mazuri multi-vitamin, 25mg B-1 & 1/8 Calcium gluconate tab. Once a day.
9 & 10	Continue with 5 feedings (trays) per day. Feed whole, hydrated silversides per feeding
11-15	Drop to 4 feedings (trays) per day, silversides only. Move to nursery room with temperature set at 12.8 ˚C if chick is ready.
20	Fledging – Continue with 4 feedings (trays) per day. Each tray consists of 5 of each of the following: herring pieces, capelin chunks, and silversides. Weigh chicks every three days. Krill can be introduced on Day 30.
21+	Parent reared chicks are pulled on Day 21. Once chicks are mostly fledged, kennel doors can be left open for the day to allow the chick to venture out on own. Once fledged, kennels can be left open overnight. Once coming out on its own trays should be outside of kennel. At this point recording of food items eaten isn't necessary. Puffin chicks are introduced to the pool at or around Day 21. All puffin chicks are introduced into the alcid exhibit after the breeding season. Chicks have been moved at ages ranging from 55-80 days.

When introducing chicks, ensure these are properly waterproof and can eat independently. This is essential for them to be able to thrive within the colony. If possible, a chick can first be introduced to a smaller group of adult puffins to see how it functions within this group, before introducing it to the entire colony (Questionnaire B. Vernooij, 2015).

2.4.6 Population Management

An EAZA EEP for puffins has been created in May 2024 .

The majority of the population is the subspecies *Fratercula a. arctica*, coming from Icelandic founders, but 6 birds are of the subspecies *Fratercula a. grabae*, deriving from known Faroe-island founders. The studbook will focus on the development of the *F. a. arctica* population. The EAZA population has been established primarily through eggs collected from the wild followed by artificial incubation. The majority of the captive EAZA populations derives from import of eggs from the wild in Iceland and a few coming in from the Faroe Islands. It is not known how many eggs have been imported to EAZA but the population itself has not added birds from the wild since 2011. The population is fairly stable but not self-sustainable (F. Nielsen pers. comm.).

Field station with portable incubator during an egg collection trip to the Faroe Islands in 2011. (Photos F. Nielsen)

2.5 Behavioural Enrichment

To stimulate natural behaviours and better the general condition of the birds, a whole range of activity items can be used to enrich their daily life.

Literature on puffin enrichment is limited, although some types of enrichment are mentioned. These are wave simulation, rocks with live material (plants, shells, clams, etc.), a second, smaller pool, an area with soil to allow for digging and variety to the diet and feeding methods/dietary variation (King, n.d.).

As mentioned in *1.2 Morphology,* flight requires high amounts of energy. When circumstances and enclosure design allow the animals to fly without much energy input, they do appear to enjoy this. On windy days, many puffins can be observed soaring through the sky by leaning into a breeze, which allows them to stay airborne without the intense wing flapping (Dunn, 2014).

Additionally, the AZA Charadriiformes TAG published an article on enrichment which was used for other alcid species (parakeet auklets, horned puffins and thick-billed murres). This enrichment is meant to stimulate natural behaviour and redirect aggression to minimise conflict between the animals. The enrichment types that were mentioned in this article were (AZA Charadriiformes Taxon Advisory Group, 2014 [2]):

Enrichment technique/device	Description	Behavior(s) elicited
Bird vocalizations	Play recordings of bird vocalizations. *Do not use recordings that might unduly stress the collection, (i.e., do not use overt aggressive or territorial vocalizations).	Vocalizations and search behaviors
Scatter feed or use of PVC dispensers	Use methods to feed items such as insects or worms around exhibit *in lieu* of food bowls. Food can be broadcast or hidden in a variety of ways: (1) scatter on surface of exhibit substrate; (2) scattered amongst vegetation; (3) gently raked under an inch or less of exhibit substrates such as sand or dirt; (4) hidden along the edges of logs or stones; (5) placed in PVC dispensers that are either laid on the ground or hung overhead.	Natural foraging behaviors such as stitching, probing, etc.
Mirrors	Setup small mirrors in the exhibit or holding, change mirror locations if left in more than a day. *Watch for aggressive behavior towards mirror and remove if needed.	Vocalizations and display behaviors
Mists/showers	Mists and/or showers provided on a random schedule.	Bathing and preening
Rearrange exhibit furniture	Change location and arrangement of exhibit furniture (logs, rocks, plants, bathing pans, etc.).	Stimulates investigation of furniture as well as promoting the use of more of the exhibit
Water features: change depth or add movement	Change size of bathing pans, tidal changes, etc.	Foraging, wading, walking, probing, stitching
Offer food items on a variable schedule and/or offer different food choices	Offer random feeding times and/or different food choices.	Increased foraging
Use of live food	Offer live foods such as bivalves, insects, annelids, etc. Offer bivalves in the shell.	Walking, running, foraging (e.g., stabbing, pecking, probing, stitching, hammering). Increases time required for foraging and eating.
Turning over substrate or making small sand piles	Either turn substrate over with a shovel or create small mounds or hills. The latter can have live food such as mealworms added to them, or be created from pond sand with live saltwater organisms if available.	Walking, foraging (stabbing, pecking, probing, stitching). Increases time required for foraging and eating.

In the questionnaire, the following types of enrichment were mentioned (Questionnaire B. Vernooij, 2015):

- Ice
- Mirrors
- Artificial plants and pine needles
- Floating objects
- Live insects e.g. locusts and crickets etc.
- Frozen blocks of ice with fish
- Scatter-feeding in water
- Ice flakes with small pieces of fish
- Training

2.6 Handling

2.6.1 Individual Identification and Sexing

Since both sexes are indistinguishable from one another, gender cannot be determined by visual examination. It is common in zoos to determine this by DNA analyses. (Questionnaire B. Vernooij, 2015)

This can be done by taking feather samples from the bird, or a blood sample. This can be done by manual restraint: holding the wings close to the thorax of the animal with both hands and using the body of the handler for additional support. This provides good access to the v.metatarsalis to collect whole blood for genetic sexing without causing undue stress to the animal (Louise F. Martin Copenhagen Zoo 2024)

Birds can be identified individually by a simple band/ring system. Depending on the colony size, doing this purely based on colours of bands could prove difficult. To solve this, an easily readable code in combination with a colour and/or pattern scheme can be used. In addition to a band scheme, some zoos also use microchips. (Questionnaire B. Vernooij, 2015)

Puffin with Blue identification ring
Picture by Henrik Futtrup, Copenhagen- Zoo

2.6.2 General Handling

Some seabirds, including puffins, can cause wounds while handling. When handling puffins, gloves should be mandatory for the protection of the birds and the handler. Direct contact can damage the plumage. Manual restraint of a Puffin by holding the wings close to the thorax of the animal with both hand and using the body of the handler for additional support, this provides good and secure handling. When the beak has to be controlled, hold it between two fingers, leaving a gap of the size of a matchstick. (Robinson, 2009; Dunn, 2014; McCain, 2014).

When handling the puffins, keep a close eye on the bird's respiration and their eyes. Flickering pupils, and fast respiration indicates an unacceptably high stress level (F. Nielsen, pers. comm.).

2.6.3 Catching/Restraining

Catching puffins usually is not a problem. Depending on the animal, this can be done by hand or with a net with a soft layer on the rim of the net to avoid injury of the birds during catching. What is most important is that this is done quickly. When multiple attempts are necessary or a small chase occurs, this causes unnecessary stress for the animal. It is better to take a break to get the birds to relax.

2.6.4 Transportation

The requirements for international air transport are determined by IATA, the International Air Transport Association. This is detailed in a document called the Live Animals Regulations. It describes aspects of transport such as minimum space requirements, materials, design, preparations and caretaking. Image 2.4 includes an example of a seabird container as described by IATA (IATA, 2015).

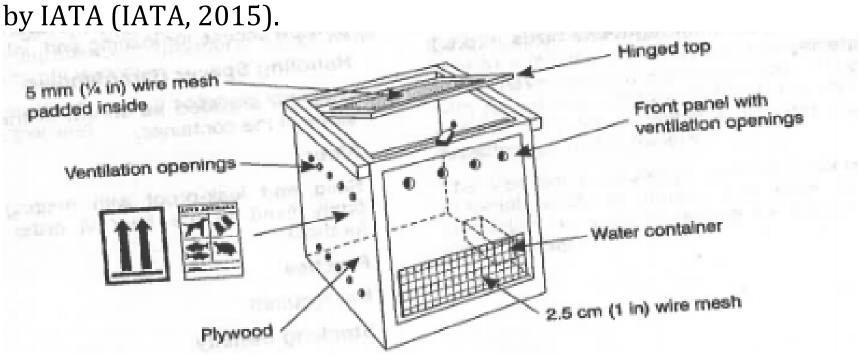


Image 2.4: An example of a suitable seabird container (IATA, 2015).

Crate used for two Puffins. Each room measuring 30 cm wide x 30 cm deep x 50 cm high. (Photo F. Nielsen)

2.6.5 Safety

A few safety precautions should be mentioned in regard to puffins. Readers should be aware of the puffin's beak, which has several "needles" to hold multiple fish at the same time. These can hurt when a bite occurs. This is another reason to wear gloves when handling puffins (Dunn, 2014).

2.7 Veterinary considerations for health and welfare

Besides the regular enclosure, it is necessary to have facilities to quarantine ill seabirds in. In this enclosure, it is recommended to have a saltwater pool, which is cooled at approximately 0°C and have filters for both air and water to minimise the risk of *Aspergillus* infection (Crosta et al., 2006).

When a puffin needs to be hospitalised it is important to determine whether the benefits of group housing are more important than the necessity to treat the condition it is suffering from. Sick birds often are reluctant to or don't get the chance to swim. If a bird has not swam for several days, it is important to moisten the legs manually. This can be done with the use of petroleum gel. It is important that this gel does not touch the plumage to avoid unnecessary damage. It is also important to pay attention to the number of droppings in the quarantine area. If this accumulates it can cause leg conditions and unacceptable atmospheric conditions due to the high nitrogen contents of droppings, which increases the susceptibility to respiratory conditions. When feeding is a problem for ill birds, table 2.3 can be referred to as an example of how/what to feed a sick bird (Robinson, 2009).

Table 2.3: An example of how to feed sick birds (Robinson, 2009).

When	What to do
Days 1 and 2	Oral rehydration fluid used either as part of rehydration therapy or as a bland base to start any dietary changes. This fluid should be changed with the following mixture (or a similar one) after 24 hours: 50 ml Lectade Plus (oral rehydration fluid), two tins of Hills A/D Diet (convalescent diet for canines/felines), 10 ml Ensure plus (human liquid nutrition product), ½ tab. aquavit (vitamin supplement), 1 x 200 mg ferrous sulphate tablet. This mixture should be given by tube-feeding at 10-20% of total body weight per day.
Days 3 and 4	From this day, whole fish from suitable size should be offered. Girth is more important than length in picking one, since this determines whether it can be swallowed or not. The selected fish species should have high caloric value.
Days 5 and onwards	If birds still do not self-feed, start force feeding from now on in addition to gavage. Up to 30% of total body mass can be given over up to 4 feeds per day. Keep force feeding to a minimum, unless weight loss is a problem.
Throughout treatment	Bird should be weighed daily and continue gavage until there is consistent weight gain over several days.

The most frequently used anaesthetics for seabirds of the Charadriiformes order are isoflurane and sevoflurane. Pharmacological data regarding puffins is limited and is usually based on sources regarding the Charadriiformes order as a whole (McCain, 2014).

Table 2.4 contains an overview of bacterial infection, parasites, viral infections, fungi, non-infectious conditions and briefly mentions clinical signs, treatment and prevention. The entries that have been found to be the relevant concerns for puffins through either interview with veterinarians or through a questionnaire (Questionnaire B. Vernooij, 2015) have been marked yellow. The most significant risks have been marked red.

Table 2.4: An overview of bacterial infections, viral infections, fungal infections and parasites (McCain, 2014; Crosta et al, 2006; Robinson, 2009; Shane, 2005; Schaftenaar, 2015; Questionnaire B. Vernooij, 2015). The entries that have been found to be the relevant concerns for puffins through either interviews with veterinarians or through the questionnaire, have been marked yellow. The most significant risks have been marked red.

Bacterial infections	Various bacterial infections are relevant for *Charadriiformes* species. The most important measure to prevent these is proper hygiene, frequent cleaning, and proper air and water conditions. Always ensure that new animals that are going to be introduced do not carry infections.
Campylobacter spp. (Zoonosis)	Causes apathy and increased chick mortality. Symptoms are pale droppings and yellow diarrhoea. Infections occur through droppings. To prevent this, clean frequently and ensure proper water conditions.
Chlamydophila psittaci (Zoonosis)	Causes influenza symptoms and can lead to lung disease. Pathological research, antibody tests and antigen tests can be used to detect infections. Infections occur through direct contact or through aerogenic drops/bubbles.
Clostridium perfringens	Causes acute mortality, where chicks are stiff within 1 hour after death. Infection occurs through contamination of food and the environment.
Erysipelothrix spp. (Zoonosis)	Causes sudden death. Post-mortem findings include haemorrhagic and friable liver and petechial haemorrhages in pericardial and subcutaneous fat. Infections occur through intake or a contaminated environment. This is mainly a problem when puffins are kept with non-piscivorous birds, since these are less immune.
Escherichia coli (Zoonosis)	Clinical signs include diarrhoea, dehydration, a dirty cloaca and plumage and sudden death. Contamination mainly occurs through droppings, but this can also be transmitted vertically by penetrating an egg.
Klebsiella pneumoniae	Possibly causes respiratory diseases and increased chick mortality, but this is not yet proven in puffins.
Mycobacterium avium (Zoonosis)	Mostly occurs in birds of 3 years and older. Causes tubercles and granulomatous lesions in multiple organs, along with bone lesions and tubercles in the skin. Infections occur via contaminated water or soil.
Mycoplasma spp.	Is often associated with conjunctivitis and respiratory disease (*Mycoplasmosis*). Infections occur through direct contact or by contamination via materials, feeds or caretakers.
Salmonella spp. (Zoonosis)	Causes sudden death and small yellow granulomas on the liver and spleen, both of which are swollen and dark. This looks similar to a *Yersinia* spp. infection. Infection occurs through small arthropods, direct contact and contaminations in the environment, food or caretakers. Bacteria can survive up to a year without a host.
Yersinia spp.	Causes acute mortality. Infected animals appear weak and have ruffled/rough plumage. Post-mortem analysis can find a swollen liver and spleen with yellow granulomas, similar to *Salmonella* spp. infections.
Viral infections	
Avian influenza (Zoonosis)	Can cause respiratory and neurological anomalies, along with mortality, but is often subclinical and not lethal. Infections are mainly caused by migratory wild birds and a contaminated environment or equipment. Treatment and elimination is difficult. Proper netting is required for outdoor enclosure to prevent infections.
Avian pox	Dry, elevated lesions underneath plumage. Infections are mainly caused by migratory wild birds and transmitted by vectors such as mosquitoes. Open wounds increase susceptibility. This virus in not capable of penetrating epithelial tissue. Proper hygiene, disinfecting and good netting are necessary as preventive measures and most importantly, still waters should be avoided, since this can form a breeding spot for mosquitoes. Proper netting is required for outdoor enclosure to prevent infections.
Infectious bursitis (Gumboro)	Causes depression, decubitus, rough plumage and white diarrhoea. Mainly spreads through contact between parents and chicks. Other sources of infection are contaminations in the environment or on caretakers and equipment. This virus can survive for up to 3 months in a contaminated environment.
Avian paramyxovirus -	Causes weakness, diarrhoea, respiratory distress, lethargy, paralysis of legs and wings, torticollis and incoordination. Spreads through direct contact and through

1 (Newcastle disease)	the air. Other factors that determine the susceptibility are age, immunity, general condition and the environment.
Reovirus	Clinical signs seem to vary. A certain outbreak showed depression, weakness, weight loss, oedema on both the head and legs and paralysis, while another outbreak showed mainly respiratory problems such as coughing and nasal discharge. It is important to ensure that any new animals that are planned to be introduced to the colony are not hosts to this virus.
Fungal infections	
Aspergillosis	Mainly caused by *Aspergillus fumigatus*, but *A. mucor* and *A. flavus* have also been found. Clinical signs include decreased appetite, respiratory problems and an open beak while breathing. Post-mortem analyses show dark spots on lung tissue. After 12-14 days, yellow lesions will form in air sacs. Stress caused by competition for food or nest boxes, etc. increases susceptibility. Proper hygiene and air conditions are essential preventive measures. Treatment is often futile but treating other animals in the colony could help minimise losses.
Parasites	
Capillaria (Nematodes)	Clinical signs include white diphtheria membranes in the oesophagus, crop and oral cavity. Mainly spreads through direct contact and small hosts (earthworms, snails and small invertebrates). Hygiene is essential in preventing (re)contamination.
Cestodes (Tapeworm)	Causes emaciation, diarrhoea and weakness. Rarely occurs in captivity due to a lack of vectors.
Cyclocoelum spp. (Trematodes)	Causes respiratory problems, infections and acute death. Prevention mainly consists of ensuring contact with vectors is not possible.
Eimeria fraterculae	Clinical signs include small changes to the kidney tissue, kidney failure and mortality. This parasite spreads rapidly through droppings, which makes proper hygiene and frequent cleaning essential for prevention.
Lice	Cause pruritus, but hardly affects plumage. Spread via direct contact. Factors like stress, diet, housing, population size, and resistance influence susceptibility. Proper hygiene, low density and immediate treatment of animals helps prevent unnecessary infections.
Plasmodium spp.	Causes avian malaria. Clinical signs include acute mortality, lethargy, dyspnoea and pale mucosa. Post-mortem analysis can find pulmonary oedema, hydropericardium and an enlarged liver. Prevalence of this disease is limited to habitats where vectors (mosquitoes) can survive. Good water circulation will prevent mosquitoes from breeding in the enclosure. Other areas in or around the zoo can still provide breeding areas for mosquitoes, which makes this a permanent threat.
Syngamus trachea	Causes dyspnoea, sneezing, head shaking and blood around the beak. Spreads through vectors such as earthworms, snails and beetles.
Non-infectious diseases	
Avascular necrosis	Caused by wires or other materials wrapping around digits. Easily prevented by ensuring this is not possible in the enclosure.
Bumblefoot (Pododermatitis)	Can be prevented by giving animals enough space to move around and proper substrates in the enclosure. Hygiene is also essential in prevention. Other factors influencing susceptibility are diet and stress.
Trauma	Can be caused by accident or aggression. Treatment is important due to increased susceptibility to other infections.

Problems around breeding/hand-rearing		
Bad weight gain	Hypothermia	Splayed legs
Constipation	Poor appetite	Trauma
Dehydration	Sepsis	Yolk sac infection and -retention

2.8 Management Training

Atlantic puffins are prone to stress related health issues, which makes management/day-to-day-care training highly beneficial. It allows the staff to get close enough to check for small signs of possible health problems.

The training enables the staff and veterinarian to follow the weight fluctuations during the year and to monitor possible feet issues without adding unnecessary stress to the birds by having to catch and restrain the birds for health check-ups.

2.8.1 **Recommended Guidelines for Training:**

EAZA recognizes that the use of evidence-based training technology can lead to improved animal welfare for animals in managed care. Because of this, training is considered an essential part of animal care (EAZA Standards for the Accommodation and Care of Animals in Zoos and Aquaria, 2022).

We recommend following the EAZA Animal Training Guidelines (Heidenreich et al., 2023).

Recommended Behaviours to Train:

Behaviours Useful for Day-to-Day Care:

- Recall training.
- Crate training.

Recall training
Depending on enclosure design, recall training is a beneficial behaviour to train puffins to make it easier to get close to them or to get a hold of them, health checks etc.
Recall training will often be a cue (a sound) that tells the birds to come into a specific area of the enclosure e.g., back area or where it would be easy to get access to the birds.

Crate training
Is valuable for transport to e.g., the veterinarian, to another location etc. Crate training consists of training the birds to walk into a crate voluntarily to avoid having to net or catch them.

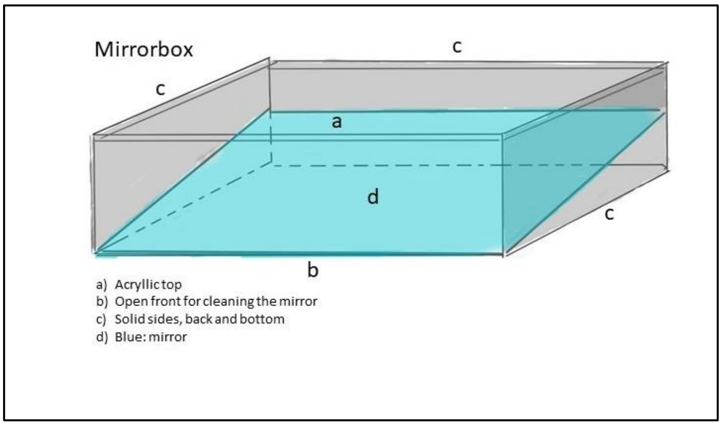
Behaviours Useful for Cooperation in Medical Care:

- Mirror box training.
- Scale training.

Mirror box training
Puffins are prone to getting foot problems such as cracks or bumblefoot; an easy way of monitoring the health of their feet, will be to train the birds to step onto a mirror box. The box works by reflecting the image of foot sole of the bird for staff or veterinarian to have an easy way of keep track of the feet's condition.

The mirror box used at Copenhagen Zoo has the measurements of width 60 cm x depth 40 cm x height 15 cm. The measurements are made to fit into the training area.

Mirror box (Photo: H. Futtrup)



Drawing of the mirror box (Katrine Friholm)

Scale training

Training puffins to step onto a scale is very easy. This behaviour makes it easy for staff or veterinarian to follow the weight fluctuations over the year as well as monitoring possible weight loss or gains due to health issues.

In the breeding season, their weight will increase right before egg laying, which will give a good indication of a possible egg laying occurring shortly.
Note that the birds' participation in training during the breeding season can decrease.

Scale Training (Photo H. Futtrup)

Common Behaviour Problems Observed

When keeping puffins in a mixed species enclosure, it can be observed that other species are too eager or bold and the puffins tend to withdraw themselves from the training area.

Specific Tools, Props, Apparatus that Facilitate Training

Contact the EAZA Animal Training Working group for more training recommendations or guiding. You can also find the EAZA Animal Training Guidelines here: https://www.eaza.net/assets/Uploads/CCC/BPG-2023/EAZA-ATWG-Training-Guidelines-3.pdf

2.9 Specific problems

All main problems with puffins have been discussed in *2.6.5 Safety.* It is worth mentioning that outdoor enclosures can have significantly more problems with avian malaria due to mosquitos entering the enclosure, even if the enclosure is equipped with nets. These nets can be damaged and because of this, require regular inspection multiple times per day and immediate fixing when necessary.

When an outdoor enclosure is being considered, it could be valuable to research which mosquito species are prevalent within the vicinity of the zoo. Most *Plasmodium* vectors belong to the *Culex* genus. Other genera that have been tested positive are *Aedes* (low percentage), *Coquillettidia, Mansonia* (low percentage). When *Plasmodium* vectors of the genera mentioned in table 2.4 are present, this could cause many problems in outdoor enclosures. An indoor enclosure generally decreases the chance of *Plasmodium* infections, but even indoors, this parasite poses a threat (Njabo et al., 2010; Huijben, 2007).

Also, *Aspergillus* (which has been mentioned before) is the main cause of death for puffins, due to the lack of this genus of fungi in the natural habitat of the species. This makes the animals very susceptible to an infection when held in a zoo or aquarium. If a zoo or aquarium is in a marine or coastal area, this could be less of a problem.

Both conditions have caused massive losses within EAZA's puffin population and should be taken into consideration by anyone keeping or planning to keep puffins in their collection.

2.10 Recommended research

Not much is known about the exact nutritional requirements of puffins. When more research is done towards this, accurate diet analyses can be made, allowing for more precise information.

Currently, the treatment options for *Aspergillus* infection is limited. Huge numbers of seabirds are lost due to this genus of fungi. By developing more effective treatment options and protocols, this number can be reduced, allowing for the captive puffin population to thrive better.

The migratory nature of puffins is not simulated in zoos. Copenhagen Zoo is planning on moving the puffins per season, to simulate the difference between the winter season and the breeding season. It is also interesting to see how limiting the amount of land area in an enclosure affects the puffins, since these spend the better half of a year on open water areas.

Multiple zoos have experienced significant losses in puffins. This has led to the disturbance of certain couples, but there is no literature available at all on the effect that the death of a partner might have on an individual. It seems likely that this has some impact, given the monogamous nature of the animal. Researching the direct impact of adult survival on reproduction in captivity would be good research to find one more possible cause of the problems that have been experienced with puffins.

Tierpark Bern uses nest boxes that are bigger than nest boxes used at other zoos. On top of this, there are not only PVC-nest boxes at this zoo, but also actual burrows made of rock. Researching the impact of these differences in breeding spots as compared to the nest boxes used in other zoos can help finding the ideal nest box for puffins.

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