Some enclosure design and management criteria for selected seabirds

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A seabird enclosure depicting Bass Rock in Scotland will be built in the next few years at Rotterdam Zoo as part of an extensive aquarium complex. Although a wealth of information exists about seabirds in the wild, few articles have been written about enclosures for seabirds being considered for this exhibit. It quickly became clear that not enough information was available from the literature to make educated decisions regarding enclosure occupancy and many aspects of design.

Zoos that had either reported hatchings of Alcidae, Shags Phalacorax aristotelis or Northern gannets Morus bassinus to International Zoo Yearbook between 1985-1991 or had reported such hatchings in the last 12 months as of June 1994 to the International Species Information System (ISIS, 1994) were sent a seabird enclosure survey asking questions pertinent to the enclosure design concerns. No zoos had reported hatchings of Kittiwakes Rissa tridactyla, a seabird of interest here, to either of these sources. Two institutions otherwise known to have extensive seabird experience were also sent surveys.

Additionally C. Swennen, a biologist that had undertaken a three year research project on captive seabirds at the Netherlands Institute for Sea Research (N.I.O.Z.), as well as having extensively studied seabirds in situ was interviewed and a questionnaire filled out. Thus, a total of eighteen institutions were surveyed; fifteen responses were received.

Some data were gathered from articles produced by the three institutions that did not respond to the questionnaire (Douma & Carlson, 1993; Monroe et al., 1993; Neistadt & Alia, 1994; Sebek & Wiegand, 1992) and by one additional institution that had hatched seabirds in the past but did not receive a survey (Marsault, 1975). Information was also gleaned from articles produced by another two zoos that had held seabirds but were not known to have bred them in recent years and were not sent a survey (Bell & Kelly, 1987; Wikenhauser; 1981)

For simplicity sake all of the institutions will hereafter be referred to as "zoos", although one is a research institute and several are aquaria.

SEABIRD TAXA HELD
Seabirds of interest were divided into seven species or other taxa (here refered to as seabird categories) according to the list of potential inhabitants being considered for the Rotterdam Zoo seabird enclosure, and zoos asked which of these they had held (Table 1). Murres and puffins were the most commonly held groups by zoos surveyed and also by zoos recently reporting to ISIS (ISIS, 1994).

The numbers of seabird categories held by the 15 zoos in the survey were as follows: one- four zoos, two- five zoos, three- two zoos, four- two zoos, and five- two zoos.

Four murre/guillemot species, three puffin species and three species of auklets were included in the June 30 1994 ISIS biannual inventory. The Common murre or guillemot Uria aalge was the most numerous in the murre/guillemot group, constituting 61 (59%) of the total 104 specimens. One Thick-billed murre Uria lomvia, 33 Pigeon guillemot Cepphus columba and nine Black guillemot C. grylle were also reported. The Tufted puffin Lunda cirrhata constituted 157 (61%) of the 259 puffins held. Only 16 Horned puffins Fratercula corniculata were found; the other 86 specimens were Atlantic puffins F. arctica . There were 27 Rhinoceros auklets Cerorhinca monocerata, 44 Parakeet auklets Cyclorrhynchus psittacula and two Least Auklets Aethia pusilla held.

RECOMMENDED GROUP SIZES AND COMPATABILITY

Respondents were asked to recommend a minimum group size for the seabird categories that they had held. Not all respondents answered this question, however results were still quite variable (Table 2).

Although only one respondent specified an even sex ratio, it is quite important to try to keep the ratio equal in order to discourage formation of same-sex pairs and hybridization of taxa. A hybrid chick was produced by a male Tufted puffin and female Rhinoceros auklet at the Seattle Aquarium where small, sex-skewed groups of both species were held together (Douma & Carlson, 1993). Same-sex pairing is a phenomenon not only known in zoos; it is even known to occur among colonial seabirds (e.g. Laridae) nesting in the wild.

Respondents were also asked whether any of the seabirds held at their zoo had proven to be incompatible with other seabirds. Four of the six zoos that held Northern gannets did not have them in enclosures with any of the other seabird categories included on the survey; the gannets were housed with Shags in the fifth enclosure, and this information is not known for the sixth. The only zoo known to have held Northern gannets in a seabird enclosure containing alcids had found them to be incompatible with all members of this group with which they were placed.

In situ breeding gannets are dominant among competing species for ledge space; they simply prod smaller seabirds such as guillemots out of the way, throwing their eggs overboard (Nelson, 1980). Nelson (1975) stated that "gannets habitually fight more damagingly than any other seabird, or perhaps any other bird", thus it might be risky to experiment with holding this species in such a mixed enclosure. Based on experience with seabirds in both captivity and the wild, C. Swennen also strongly advised against holding Northern gannets in a mixed seabird enclosure (pers. comm.).

Four respondents reported compatibility problems with puffins; two of which mentioned that Tufted puffins out-compete other species for nest sites, the other two reported that puffin aggression resulted in enclosure mate killings. Murres were found to be very aggressive at one institution that had held auklets, puffins and murres. One respondent noted that Kittiwakes can be rather aggressive but stated that small seagulls and murres would be ideal for this enclosure. Four respondents reported no problems with compatibility in mixed seabird enclosures.

A study of interspecific competition between Common murres, Atlantic puffins and Razorbills was carried out at the N.I.O.Z laboratory. Although jumping on the back of a victim resting on the water as the attacker emerged from a dive and underwater chasing were interspecific forms of aggression seen in all species, these were most seriously executed by puffins. The murres were found to be the most gregarious of the three species, maintaining only small inter-individual distances among conspecific groups. Puffins were the least social, avoiding other species and usually swimming as individuals, only occasionally forming conspecific groups. Puffins were also found to be the most aggressive species and murres the least. The recommendation resulting from the N.I.O.Z. research project was not to hold the above species together in a small and undifferentiated environment (Swennen, 1977).

ENCLOSURE SIZE

Area (length X width) of the 13 enclosures for which this information was provided varied between 27.3-1620 m^2 (Table 3).

Enclosure height was reported for nine covered enclosures, and varied from 2-10 m (Table 4).

Flying/diving possibilities should be a consideration in design of a seabird enclosure. Some seabirds plunge-dive and many smaller seabirds are quite acrobatic both under and above the water surface (Nelson, 1980). However, alcids are also awkward fliers (Kartaschew, 1975), and therefore may be more susceptible to injury in enclosures that allow room to gain speed but not to manoeuvre. Survey responses did not universally seem to reflect a concern about accidents related to enclosure size, although there was some indication that problems exist.

Douma & Carlson (1993) reported that the alcids at the Seattle Aquarium, unlike the other birds exhibited at this facility, are kept confined to their narrow, 13.7 m long enclosure as "through their inquisitive nature, clumsy attempts to fly and strong jaws they endanger themselves as well as the visitors". Five of six traumatic deaths in a 100 m^2 enclosure were attributed to barrier collision problems (Swennen, 1977). As the barrier was a solid wall rising ca. 1 m above the water surface, and therefore quite obvious, it may be that the enclosure's size and/or its square shape was a factor in these deaths. One respondent from a zoo with experience in keeping and breeding Northern gannets recommended that the water basin should be ± 20 m long, as this is long enough to speed up in order to submerge, but not sufficient for "take off" from the water.

The amount of space needed would of course depend on the number of seabirds to be held, or the contrary; the available area will dictate the number of specimens. Swennen (1977) kept the maximum number of alcids and kittiwakes in a 100 m^2 enclosure at 22, and Conway et al. (1977) found that keeping more than 18 Tufted puffins in a 83 m^2 enclosure appeared to result in unhealthy social pressures.

Area recommendations for minimum space requirements from the seven respondents that answered this question (one for two enclosures) were (length X width in m^2): 35, 100, 250, 260, 300, 300-400, 1,200 and 2,500. Six respondents recommended enclosure heights, these were (in m): 2, 4, 5.7, 6.5, 8, 10.

It may be better to house a mixed seabird group in an enclosure that is essentially rectangular or oval in shape so that the different species, pairs and individuals have a greater opportunity to space themselves out visually and spatially than they would in a more square or round enclosure. As serious aggression may develop, it is important that the width of both land and water areas preclude the possibility of an individual being trapped. Six of the eight area recommendations made were for a rectangular enclosure (length greater than width); two recommendations were made for a square enclosure (length and width equal); these were both for Northern gannet enclosures.

ENCLOSURE SUBSTRATES AND BARRIERS

The type of substrate used in seabird enclosures was asked; this information was provided for 14 enclosures. Sand was used exclusively in two enclosures; both of which housed Northern gannets. Rockwork only, either natural or artificial, was present in six enclosures and some combination of sand, rocks, gravel or pebbles, concrete, soil and grass was used in five enclosures. One enclosure had no permanent substrate; ledges made of a polyester material were available during the breeding season.

It was also asked whether foot problems had been encountered with the substrate used. Eleven of the 15 respondents had experienced foot problems, eight of which were specified to be bumblefoot. The respondent at a zoo that had experienced severe bumblefoot problems (responsible for 6 of 10 deaths) with Northern gannets housed on a sand substrate felt that the grade of sand was inappropriate. The sand was a coarse industrial grade; the respondent suggested that more rounded grains or no sand at all would be preferable. One respondent reported that no bumblefoot problems occurred after gunite ramps leading to the water in one enclosure were redesigned. Another respondent indicated that good substrate drainage was important in avoidance of foot problems.

One enclosure without foot problems had a sand and gravel substrate, one had a lacquered gunite substrate and another consisted of artificial rockwork "very carefully manufactured to [that zoo's] specifications". The other enclosure without foot problems had a fibreglass substrate. Sores initially occurred on the tibio-tarsal joints of Tufted puffins in this last enclosure, but were eliminated first by use of vinyl mats and later by covering the artificial rockwork with smooth fibreglass (Conway et al., 1977). C. Swennen (pers. comm.) also suggested that a smooth surface is important in avoidance of foot problems, and felt that this is more similar to natural conditions, as rocky ledges used by many seabirds are often covered with algae and are quite slippery.

The type of barriers used was not asked, rather it was asked whether any barrier type (e.g. glass, netting, wire-mesh, piano-wire) barrier design had been found to be unsuitable. Thirteen responses were provided; no barrier problems had been encounter in eight enclosures and another two enclosures did not have barriers. One respondent reported problems with acrylic glass, and another reported cracking of too thin, untempered glass. Mortality due to collision with walls in another zoo was mentioned above. One respondent suggested using soft nylon netting to cover temperate, outdoor enclosures in order to avoid head injuries when seabirds fly up, and wire-mesh on the enclosure sides. This arrangement was also used at another zoo that had experienced no barrier problems in an outdoor enclosure.
Glass or another transparent barrier is of course required for underwater viewing. This form of barrier is commonly used in indoor enclosures in which the lighting can be regulated so that the visitor viewing area is darker than the enclosure, thereby presumably discouraging birds to fly towards the barrier. It might be a less benign barrier form in outdoor enclosures in which the lighting is not controllable, and the presence of such a barrier less obvious to the birds.

LIGHTING REGIMES

Seven enclosures did not use an artificial photoperiod. All of these were outdoor enclosures above 47° in latitude; thus within the latitude range of northern-nesting seabirds. Northern Gannets were the only seabird category of consideration housed in three of four of these enclosures, and another housed this species with Shags. The eleven other enclosures for which photoperiod information was available through the questionnaire or articles did use an artificial photoperiod; the photoperiod imitated that encountered at Kodiak Island, USA in one of these enclosures (Sebek & Wiegand, 1992), Vancouver Island, Canada in another (Conway et al., 1977) and Iceland in two enclosures (Bell & Kelly, 1987; Wikenhauser, 1981).

Four respondents mentioned photoperiod as an environmental factor felt to be particularly important in breeding one or more seabird species at their zoo. Conway et al., (1977) reported that moult synchronization and breeding attempts of seabirds occurred within the first year after a photoperiod regime similar to that of the area where the birds had been collected was initiated at Bronx Zoo. As all institutions surveyed that either have indoor enclosures and/or are not found at latitudes that seabirds normally breed do work with artificial photoperiods, it can be concluded that photoperiod is generally acknowledged as important.

WATER QUALITY AND QUANTITY

Survey respondents were asked what percentage of the surface area in the seabird enclosure at their zoo was water, and what percentage they would recommend (Table 5). Twelve responses were provided for the percentage present and eleven responses for recommendations. In three of ten survey responses in which the percentage present was given and a recommendation made, the percentage was the same. In three cases the recommendation was for the same or a greater percentage water surface area than that experienced, and in four cases the percentage recommended was greater than experienced. One other respondent, that did not recommend a specific percentage water surface area, stated that it should be large enough to allow most of the collection to float at the same time.

Birds at the N.I.O.Z. laboratory were given access to land (in the form of breeding ledges) only during the breeding season, and only during this time did the birds develop bumblefoot (Swennen, 1977). Bumblefoot was the most frequently encountered health problem reported by survey respondents (see health problems and mortality section). Thus encouraging seabirds to spend much time on the water, as occurs in natural conditions, would seem highly desirable. A high water:land ratio may facilitate this. It would also result in a cleaner appearing enclosure. It may possibly help to reduce susceptibility to Aspergellosis, the second most commonly encountered health problem and foremost mortality cause reported, because of reduced stress and/or less exposure to Aspergillus spores not removed during cleaning of land areas.

Depth of the water was not asked in the survey but proved to be relatively shallow for the five enclosures included in the survey for which this information is known, being (in m) 1.0, 1.0, 1.0, 1.4 and 2.0 m. Water depth was only 0.2 and 0.4 m in two other enclosures (Marsault, 1975; Wikenhauser, 1981). Although the possibility existed to have a higher water level at the N.I.O.Z. laboratory, water depth was maintained at 1.0 m to facilitate cleaning and removal of dead fish after feeding, as feeding occurred in the water (C. Swennen, pers. comm).

The volume (area and depth) selected for an enclosure basin is guided by two somewhat diametric types of considerations: those that are generally quantitative, and those that are qualitative. The quantitative considerations are practical considerations such as the amount of labour required to clean the basin and underwater viewing windows, the amount of time required to empty and fill the basin, and the amount of water usage.

Qualitative considerations; e.g. aesthetic, wellbeing (avoidance of stress and health problems, provision of a suitably enriched environment) and educational (sufficient room to demonstrate natural locomotor skills), are more difficult to measure but equally, if not more, important. The resulting volume selected will most often be a compromise between the quantitative considerations that would result in a small basin and the qualitative considerations that would result in a very large one.

No questions were asked on the survey regarding type of water (fresh or salt) used or recommended, or water quality, however information provided on the questionnaires and in articles clearly indicate that the latter is of critical importance in maintaining a healthy, naturally behaving seabird group, and that the former may also be of significance.

Saltwater was used in five of the six enclosures for which water type is known and breeding of alcids has occurred. Respondents from an additional two zoos (both breeding alcids but for which water type is not known) emphasized the importance of saltwater as a special management consideration, one also mentioned that chlorine should not be used. A more thorough investigation might reveal whether use of saltwater for alcids results in reduced health problems, increased breeding success, or other desirable effects.

Loss of feather water repellency was found to be the major difficulty in keeping captive seabirds (Swennen, 1977). Research at the N.I.O.Z. laboratory on normal and oil contaminated seabirds demonstrated that a film of organic molecules accumulates when the quality of the water surface is inadequate, resulting in accumulation of these molecules on the feathers and loss of water repellency. Under normal conditions this is not encountered in situ as the natural vertical water turbulence created by waves and tidal action prevents such a film from forming (Swennen, 1977). It has indeed been found however that seabirds that do sit on a still ocean for a prolonged period also loose water repellency, and consequently suffer a higher mortality (Swennen, unpubl. data).

Rigorous skimming of the water surface and generation of turbulence are two methods of preventing formation of this film (Swennen, 1977). Conway et al. (1977) also found that constant skimming of the water surface was essential, and that water management could be aided by use of a "wave machine". It is important that the wave machine creates rolling, rather than upright waves, as upright waves can result in pockets of film forming between the waves (C. Swennen, pers. comm.).

Only two of the fifteen enclosures included in the survey had wave machines; two respondents from zoos without wave machines recommended use of these. Interestingly, the two enclosures with wave machines were also two of the four enclosures for which no foot problems were reported. It may be that the wave machines stimulate the birds to spend more time in the water (see environmental enrichment section), consequently decreasing susceptibility to bumblefoot.

A good filter system is of course important in maintaining high water quality, and diverse systems are available. There are many factors to consider in selection of filter system; a discussion of these constitutes an article in itself, and will not be attempted here. Some enclosure design features can also improve water quality. A slightly funnel-form basin floor design facilitates accumulation of dead fish and other large debris at one site where it can be more easily removed through drainage or suction (Swennen, pers. comm). One respondent also stated that excrements should not be allowed to flow into the water during cleaning, a problem also mentioned for another seabird enclosure.

There should be a sufficient number of sites for all of the birds to get out of the water in the event that plumage wetting does occur; this should not be a problem if perching possibilities, e.g. stacks and low ledges, are available. Availability of loafing areas other than the water basin are also necessary during periods that the basin is empty for cleaning or other operations (see environmental enrichment section).

MORTALITY AND HEALTH PROBLEMS

In addition to the question specifically referring to foot problems, respondents were also asked what the primary causes of seabird mortality had been at their institution.

Seven respondents reported aspergellosis as a primary death cause, five reported bumblefoot and four reported trauma.

Aspergellosis or other respiratory infections were also reported in the literature. Aspergellosis was responsible for the loss of 19% of the group of 85 Tufted puffins and 30% of a group of 20 Pigeon Guillemots at the Oregon Coast Aquarium (Monroe et al., 1993). Three of 20 chicks removed from nests in the wild and hand-reared at Glen Oak zoo died; one of Aspergellosis and two of suspected stress and respiratory problems (Wikenhauser, 1981). Obviously, all precautions possible should be taken to avoid stress or contact with Aspergillus spores that can lead to outbreaks of this devastating disease.

References to bumblefoot were made in the "Enclosure barrier" and "Water quantity and quality" sections. In summary, 11 of 15 survey respondents reported at least some problems foot problems, and eight of these were specified to be bumblefoot. Bumblefoot proved to be the second most prevalent death cause as well.

Some possible factors in incidence of bumblefoot have already been discussed. One source of foot problems found at both the N.I.O.Z. laboratory and among in situ seabird colonies was slivers of fish bone excreted in the faecal material of the birds; the slivers sometimes bacame lodged under the skin when the birds walked in their excrement (Swennen, 1977). Reasons for the high incidence of bumblefoot should be sought in enclosure design problems or management methods, and may be variable among zoos.

As previously mentioned, five of six traumatic deaths (three Common murre and two Kittiwake) at one zoo were attributed to collisions with barriers; the other Common murre traumatic death was a result of heterospecific aggression by Atlantic puffins. One other respondent also reported traumatic death through enclosure mate aggression; stomach perforation was a death cause at one zoo and the other respondent did not specify the form of trauma.

In addition to the specifically trauma-caused deaths above, a Kittiwake as well as some oystercatchers in one enclosure died when they became trapped in dense bamboo. Two Common murres died at another zoo when they became wedged in a technical device in the basin, and two adult Tufted puffin accidental drowning deaths occurred in another enclosure. These seabirds seem to have a propensity towards getting trapped, certainly a consideration in enclosure design.

Two reports were made of enteritis; one was accompanied by a strangulated hernia. Two respondents cited impaction as a cause of death; this was differentiated as cause of chick death by one respondent. Eviction from the nest was given as another source of chick mortality by the same respondent. Miscellaneous death causes included visceral gout, senility, oil intoxication through accumulation of oil in the stomach and intestines, air sac infection and trematodes.

Mosquito or gnat bites annually resulted in slight swelling around the eyelids or base of the bill of some Common murres, Atlantic puffins and Razorbills during July and August at N.I.O.Z. These usually disappeared without intervention, but in three cases the swelling became so severe that it was necessary to surgically remove the cheese-like contents of the protrusions (Swennen, 1977).

FEEDING

Most of the seabird categories considered here are predominately fish eaters; auklets and the smaller puffins primarily feed on plankton and other invertebrates. Several different feeding techniques are employed by seabirds, and are associated with the body and bill size. Northern gannets are specialized in plunge-diving, a prey capture method also occasionally used "as a hobby" by cormorants and alcids (Nelson, 1980). Shags and alcids often dive from the surface and pursue their prey underwater, some alcids also dive from above the water surface. Kittiwakes commonly surface-feed on small fish and plankton while flying. Kittiwakes on the North and Irish Seas also scavenge on fish waste thrown out to sea, and are particularly dependant on this food source during the first year of life (Nelson, 1980; Terres, 1980).

Food-size preference is also somewhat correlated with body and bill size, however research at N.I.O.Z. demonstrated that Common murres, Atlantic puffins, Razorbills and Kittiwakes all prefer fish sizes far smaller than what the birds are capable of consuming. For example, Common murres are able to swallow fish with a body depth of about 44 mm but prefer fish with a body depth of 16 to 17 mm (Swennen & Duiven, 1991; C. Swennen pers. comm.). Another respondent from an institution successfully breeding Tufted puffins reported that fish in the range of 2.4-9.6 cm are fed there.

Fish are fed to many young seabirds whole, thus small fish are necessary when the chicks are small. The preference for smaller fish proved to be a problem when the seabirds at N.I.O.Z. were breeding, as most fish offered to the birds were larger than preferred; due to competition among the birds for the smaller-sized fish some parents were not able to obtain these for the young. The chicks were unable to correctly handle larger fish cut into appropriately sized pieces, and hand-rearing was necessary (C. Swennen pers. comm.).

Diets are offered to seabirds in captivity will not be described here. Nutritional considerations in fish diets have been discussed at length elsewhere (e.g Crissey, 1990; Geraci, 1986; Stoskopf & Kennedy-Stoskopf, 1986). Based on the above mentioned food-size preference study, size of foods fed to seabirds can be an important factor in their acceptance and possibly in the seabirds' psychological well-being. A variety of food items offered can provide enrichment to seabird environments, as suggested by Neistadt & Alia (1994) and a survey respondent (see environmental enrichment section).

Methods of feeding can greatly effect seabird activity levels. A special feeding apparatus was used to carry out the above mentioned food-size preference studies at the N.I.O.Z. laboratory. Two dead fish attached by clips to separate nylon lines 60 cm apart on a rod were simultaneously lowered 40 cm below the water surface (Swennen & Duiven, 1991). It was found that the entire group of some 20 birds used most of the 100 m2 basin for swimming and diving for as long as the fish were offered; sometimes for a period of hours (C. Swennen, pers. comm.).

C. Swennen (pers. comm.) highly recommended the use of some form of feeding apparatus in seabird enclosures, and felt seabirds could be easily trained to activate the release of a fish by touching a release mechanism, e.g. an artificial fish. In addition to the obvious environmental enrichment aspects of such an apparatus, a number of other advantages also exist. Position of the releasing mechanism could be altered so that the birds are allowed to demonstrate different feeding strategies to some degree; this has educational as well as enrichment value.

The food could be kept refrigerated until it is released, thereby greatly delaying spoiling. This would make unnecessary the labour-intensive practice of feeding the birds several times a day, as is often done to ensure freshness of food. Use of such an apparatus would allow birds to feed in the water, as they naturally do, but without the accumulation of dead fish and oils that can occur when food is tossed in the water. It is also expected to result in a more even distribution of preferred food items among individuals, and may be important in encouraging parent-rearing of chicks.

NESTING REQUIREMENTS

Some of the seabirds considered here will nest on the ground, however all are by preference cliff nesters. Seabirds tend to have broadly typical preferences that maximize usage of available cliff sites, although some overlap occurs. Shags nest on the lowest 10-20 m of a cliff on broad ledges and low, stepped, flat-top stacks; higher nesting appears to be precluded by inability to reach higher sites when the plumage is wet (del Hoyo et al., 1992; Nelson, 1980). Shag nests are usually placed between boulders, in crevices, or in caves; these birds have a decided liking for "gloomy caverns" (Nelson, 1980).

Gannets prefer broad, flat ledges but can nest much higher than Shags. Common murres also nest on ledges, and have more reproductive success when the ledges are broad enough that they can cluster together rather than spreading out, apparently because there is more egg loss when birds become frightened in the latter situation (Nelson, 1980). Some murre species nest also nest in scrapes or crevices or under boulders (Terres, 1980).

Razorbills rarely nest in large groups, and prefer cracks, small ledges or projections; they also nest under boulders and have even been known to nest in puffin burrows. Puffins and auklets nest in burrows that are often curved and are camouflaged by having the entrance under or near a rock. They also sometimes nest in crevices and holes in rocks (Nelson, 1980; Terres, 1980). The Kittiwake is famous for its ability to stick its mud nest on unbelievably tiny ledges, sometimes no more than 10 cm broad (Cullen, 1957).

Although some seabirds, such as Common murres, Razorbills and many auklets do not build a nest, nest building and nest building displays are important in many other species. Most puffins and some auklets excavate burrows and line them with nesting material; Atlantic puffins use grass, feathers and seaweed. Shags use whatever loose organic materials are available, usually seaweed and grasses. Northern gannets and Kittiwakes pull grasses, seaweed and mosses from the sides of cliffs. Kittiwakes build a cupped nest of mud mixed with the organic material, and are quite unusual in that nest material collection is carried out in social groups (Cullen, 1957; del Hoyo et al., 1980; Nelson, 1980).

Four zoos included in the survey have hatched Northern Gannets, one has hatched Shags, one has hatched Kittiwakes, five have hatched Common murres, eight have hatched puffins (two having hatched two species) and none have hatched Razorbills or auklets. Ten zoos have had hatchings of one species of the seabirds considered here, one zoo has hatched two species and three zoos have hatched three species. Generally speaking these seabirds, particularly non-puffin species, do not reproduce frequently in captivity. The first captive alcid breeding probably did not occur until 1970, and was of Tufted puffins (Bell, 1971). Puffins were the only seabird category discussed in this paper that had bred in ISIS institutions in the 12 months preceding June 30 1994. Six breedings of Tufted puffins and one of Atlantic puffins were reported (ISIS, 1994).

Captive breeding group sizes, at least for puffins, have been disparate, recently ranging from four to 60 individuals. The average group size of breeding puffins was larger than the average for all puffin groups (non-breeding and breeding), being 26.1 (breeding) and 18.5 (all) respectively (ISIS, 1994). One respondent from a zoo breeding Northern gannets commented that no reproductive activity occurred at this institution until the group size grew to seven birds.

It is assumed that the larger the group is the greater the likelihood of some breeding occurring, although crowding and/or competition for nest sites presumably might inhibit all breeding if the group size far exceeds the enclosure potential. Marsault (1975) also suggested that enclosure size related to the number of inhabitants may be of importance for breeding purposes. Certainly survey results for enclosure and basin size did not suggest any generally ideal, or even preferable enclosure or basin sizes to promote successful reproduction, as breeding had occurred with diverse enclosure and basin sizes.

Availability of nest sites was mentioned by one respondent to be the factor limiting Tufted puffin group size, and as previously mentioned two other respondents also remarked that Tufted puffins tend to out-compete other species for nest sites. A Atlantic puffin chick was hand-reared at another institution when the parents were unable to establish a nest box, and consequently laid on the ground (Hori, 1994). One respondent noted that it was important to have many more nest sites than seabird pairs; this would seem to be a good rule of thumb.

Although many seabirds nest on quite high cliffs in the wild, this has not been true in captivity. Only one species in the survey, Common murres, nested above 3 m in height (at 3.7 m), and most nests were less 2 m or less in height (Table 6). Razorbills and Common murres both nested on the ground in a enclosure not included in the survey (Marsault, 1975).

Seabirds nesting in the wild have specific techniques for approaching and landing on their nests (Nelson, 1980), however practice of these techniques would certainly be affected by enclosure space in captivity. It was found that the seabirds nesting at heights of < 2 m at the N.I.O.Z. laboratory in 100 m^2 enclosures were unable to gain access to their nests on windy days without the aid of a ladder. Although wind would not be a problem in indoor enclosures, the limited space that the birds have to approach their nests is still be an important factor in height of nest sites provided.

The type of nest sites used in captivity were similar to those used by the relevant species in natural conditions (Table 7). It can be seen that ledges were used by the most categories of seabirds.

Dimensions and nest materials used was asked on the survey. Northern gannets at the different zoos used a combination of nesting materials, including straw (3 zoos), twigs (3 zoos), hay (1 zoo) Potentilla branches (1 zoo), algae (1 zoo), pebbles (1 zoo) and leaves (1 zoo) to construct platforms. The platforms measured 50-60 cm at the base at two zoos. One respondent recommended providing a variety of nesting materials for this species, and another recommended providing large quantities of materials. One respondent at a zoo that had used straw commented that this nesting material was not recommended because of mold problems.

Shags nested on self-constructed platforms of twigs and straw at the one institution where these had bred. Murres did not construct any nest; ledges used for nesting were constructed of concrete/artificial rock in two enclosures and polyester in another. Murres at another zoo bred in concrete crevices no larger than two times the diameter of the bird.

Tunnels for artificial puffin nests at five zoos ranged between 25 and 115 cm in length. Tunnels of burrows excavated by Tufted puffins at one zoo ranged between 58 and 288 cm. Diameter of artificial tunnels used for Common and Tufted puffins in one enclosure was 10 - 15 cm, and was 15 cm for Tufted puffins at another zoo. Tunnel height for Tufted puffins was 28 cm in another enclosure. Dimensions of puffin nest boxes used at six zoos were given (in cm): 45 x 30; 30 x 30 x 30; 45 x 45 x 45; 25 x 30 x 25; 46 x 30 x 46; and 28 x 28 x 115. Cavity size of nests excavated by Tufted puffins at one zoo was described as being just large enough to fit two birds.

Construction materials for puffin tunnels was reported by three respondents; a corrugated PVC or other pipe material was used in two cases and wood in the other. Wooden nest boxes were used for puffins in all five zoos for which this information was provided. Difficulties in achieving proper nest box humidity were reported by one respondent and in the literature; the wood was coated with "verthane" in the former case and plastic buckets were used as the nest cavities in the latter (Douma & Carlson, 1993). Two zoos reported that they used black materials to construct artificial puffin burrows.

Although 25 x 30 x 25 cm nest boxes built into the exhibit were also used, the most successful Tufted puffin nests at one institution were reported to be the much smaller "corners" added after the exhibit was finished. The corners, built on ledges, were constructed of fibreglass and camouflaged with paint. Another respondent noted that although artificial nest burrows were made available to Tufted puffins, most preferred to excavate their own burrows at one zoo where this opportunity was available.

Nesting materials given to puffins included pine needles in combination with other materials or alone (3 zoos) and grasses only (3 zoos, two of which specified that the grasses were dried) or in combination with other materials (1 zoo). Feathers (1 zoo), Oak Quercus leaves (1 zoo), sand (1 zoo), soil (2 zoos), pea gravel (2 zoos) and plastic vegetation (1 zoo) were all used in combination with other materials. Peat moss was glued into the bottom and sides of the nest box at another zoo to reduce the amount of material that ended up in the water. Nests for Kittiwakes at this same institution were man-made of mud and vegetation, again to limit the amount of material dropped into the water.

One respondent recommended provision of plenty of land mass in enclosures containing puffins because birds will become very territorial over nesting burrows and will monopolize an area if there is not enough room for other individuals to walk by, and another respondent recommended providing the largest possible ledges for seabirds to reduce territorial problems. Contrarily, aggression at another zoo was reduced among nesting murres by construction of partial physical and visual barriers between ledge nests, resulting in improved breeding success. Spacing between Kittiwake nests at the same institution was regulated by providing ledges only large enough for one nest; suggested ledge width (breadth) for alcids and kittiwakes was 20-30 cm.

The above differences in recommendations indicate that there are two different approaches to reducing dominance and competition associated with nests. Providing a great deal of land space may possibly also result in the birds spending more time on land. The other alternative is to provide a variety of ledge widths and lengths as appropriate for the species housed, so that individuals or pairs cannot dominate large areas. This form of partitioning also occurs in situ.

Although seabirds often nest in quite precarious positions, young are still susceptible to drowning. Two respondents commented that it is important to have some ledge space in front of puffin holes, as otherwise the chicks have a tendency to fall in the water. The respondent from the zoo in which murres had bred in crevices recommended high placement of the crevices, well away from the water.

A respondent from a zoo breeding Northern gannets advised placement of nest sites for this species in areas with no direct sunlight. Provision of shaded areas in outdoor enclosures of other seabirds has proved to be important (A. Lyles, M. Stevenson pers. comms.) and should most probably also be provided to the seabirds considered here. It is important however that structures that provide shade not interfere with flight of the birds, or accidents will most likely result. Overhanging cliff outcroppings over some of the nesting sites, as typically are found on nesting cliffs in natural situations (Nelson, 1980) could give birds the option whether or not to nest in shade in outdoor enclosures.

One respondent recommended provision of nest sites well away from the public, as visitor disturbance had proved to be a problem in the past. Another respondent recommended not disturbing the birds while they are breeding. Conversely, three respondents breeding a variety of seabirds commented that access to the nests to monitor chicks and eggs is important.

Provision of large amounts of fish was felt to be a factor in successful breeding of various seabirds at two zoos. It is reasonable to assume that food availability is a factor in breeding of captive seabirds generally, as it dictates the breeding cycles and number of young produced by seabirds in the wild (Nelson, 1980).

In summary, although seabirds that have bred in captivity do seem to tend to have some species specific-requirements, there appears to be some flexibility in group size, nest sites and nest materials required for successful breeding. Monitoring of nests may not be practical or desirable in all enclosures, but is considered an important management tool at some zoos.

ENVIRONMENTAL ENRICHMENT

The importance of environmental enrichment in ensuring the wellbeing of animals in captivity is now generally accepted as important, and should not be excluded for seabirds. Even fundamental additions to the enclosure that promote the wellbeing of the birds, such as provision of shade, are sometimes considered environmental enrichment.

Wave action, (e.g. generated by a wave machine) not only improves water quality but also serves as a form of environmental enrichment, as the seabirds greatly enjoy swimming and diving against waves (Conway et al., 1977; C. Swennen, pers. comm.). As previously discussed, wave action may also be a means of combating bumblefoot through encouraging seabirds to spend more time in the water. Furthermore, the appearance of waves more closely imitates aquatic habitats used by seabirds, thereby increasing the educational and aesthetic value of an enclosure.

As mentioned in the "Feeding" section, providing a variety of food types and sizes and using feeding methods that stimulate activity serves as environmental enrichment. For example, seaweed tossed into pools at the Oregon Coast Aquarium were shredded by Pigeon guillemots seeking arthropods that cling to the seaweed.

"Living rocks" were placed in the deep end of the pool in the underwater viewing area where visitors could enjoy watching the pigeon guillemots picking small plants and animals off of these (Neistadt & Alia, 1994). One respondent reported that feeding of unopened live clams and live herring provided environmental enrichment in an enclosure housing puffins, murres and auklets. As also previously discussed, use of a feeding apparatus can confer many advantages in seabird management, one of the most important being environmental enrichment.

It was found at the Oregon Coast Aquarium that all seabirds, even non-breeding and immature individuals, carry around dried grass, pine needles sticks and woodchips given as nest materials (Neistadt & Alia, 1994). Depending on the filtering system and cleaning protocols used, restraint in supplying some materials and food items may be called for however.

A small basin with drainage separate from the main basin, for example constructed to resemble a tidal pool, may be a suitable place to offer some enrichment materials that are undesirable in the main basin in large quantities. Such a pool would also give the birds access to water during emptying of the main basin, and would provide the birds with more options to separate in periods of high aggression, should these occur.

Providing possibilities for burrow-nesting alcids to excavate may also be a possible form of environmental enrichment, although this would almost certainly preclude monitoring of resulting nests. One respondent recommended furnishing enclosures for seabirds that plunge-dive with high projections from which this behaviour can be performed.

Mentioned here are just a few enrichment possibilities; certainly there are many more options for seabirds that could be explored.

SUMMARY

Little information has been available concerning captive management and enclosure design for seabirds considered here. Data gathered from a survey, an interview and the literature were compiled to define considerations and requirements in selection of seabirds to be held, their group sizes, enclosure and water basin dimensions, lighting regimes, water quality, health, nesting requirements and environmental enrichment.

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PRODUCTS MENTIONED IN THE TEXT

Verthane: A water resistant protective coating for wood that "seals and enhances wood grain", manufactured by several different companies.

REFERENCES

BELL, J. (1971): News from the Department of Ornithology at the New York Zoological Park. Avic. Mag. 77(1): 37-38

BELL, K. & KELLEY, C. (1987): The penguin and seabird building at the Lincoln Park Zoo. Int. Zoo Ybk. 26: 132-136.

CRISSEY, S.D. (1990): Supplememts available and nutrient content of fish fed to Humboldt penguins. Spheniscus Penguin Newsletter 3(1): 4-9.

CONWAY, W.G., BELL, J. BRUNING, D., & DOLENSEK, E. (1977): Care and breeding of puffins and murres Alcidae at the New York Zoological Park. Int. Zoo Ybk. 17: 173-176.

CULLEN, E. (1957): Adaptions in the Kittiwake to cliff-nesting. Ibis 99: 275-302.

DOUMA, B. & CARLSON, M. (1993): Captive Acid Breeding. AAZPA 1993 Annual Conference Proceedings: 71-77.

GERACI, (1986): Marine Mammals (Cetacea, Pinnipedia and Sirenia: Nutrition and nutritional disorders. In Zoo & Wild Animal Medicine: 294-313. Fowler, M.E. (Ed.). Philadelphia: W.B. Saunders.

HORI, H. (1994): Artificial incubation and rearing of the Atlantic puffin. Animals and Zoos 46(7): 4-7.

HOYO, J. DEL, ELLIOT, A. & SARGATAL, D. (1992): Handbook of the Birds of the World, Vol. 1. Barcelona: Lynx Edicions.

ISIS (1994): ISIS Bird Abstract as of 30 June 1994. Apple Valley: International Species Information System.

KARTASCHEW, N.N. (1975): Suborde Alcae. In Grizmek Het Leven der Dieren. Deel VIII, Vogels 2 : 263-269.

MARSAULT, B.M. (1975) Breeding guillemots Uria aalge and razorbills Alca torda in captivity. Int. Zoo Ybk. 15: 105-108.

MONROE, A., NOAH, P. & BROWN, S. (1993): Comparison of medical treatment regimes for Aspergellosis in captive Tufted puffins (Lunda cirrhata). AAZPA 1993 Annual Conference Proceedings: 78-82.

NEISTADT, N. & ALIA, C. (1994): Sea bird enrichment at the Oregon Coast Aquarium. Shape of Enrichment 3(3): 1-2.

NELSON, J.B. (1975): Functional aspects of behavior in the Sulidae. In Function and Evolution of Behavior: 313-330. Barends, G., Beer, C., & Manning, A. (Eds.) Oxford: Clarendon Press.

NELSON, B. (1980): Seabirds- Their Biology and Ecology. London: Hamilyn.

SEBEK, L. & WIEGAND, R. (1992): Behavior of captive Tufted and Common puffins during breeding and incubation. Animal Keepers' Forum 19: 351-359.

STOSKOPF, M.K. & KENNEDY-STOSKOPF, S. (1986): Aquatic birds (Sphenisciformes, Gaviiformes, Podicipediformes, Procellariiformes, Pelecaniformes, and Charadriiformes). In Zoo & Wild Animal Medicine: 294-313. Fowler, M.E. (Ed.). Philadelphia: W.B. Saunders.

SWENNEN, C. (1977): Laboratory Research on Seabirds. Texel: Netherlands Institute for Sea Research.

SWENNEN, C. & DUIVEN, P. (1991): Diving speed and food selection in Common guillemots, Uria aalgae. Netherlands Journal of Sea Research 27: 191-196.

TERRES, J.K. (1980): The Audubon Society Encyclopedia of North American Birds. New York: Alfred A. Knopf.

WIKENHAUSER, C. (1981). The hand rearing and captive management of Common puffins, Fratercula arctica. AAZPA Regional Conference Proceedings (Great Lakes): 302-306.

Table 1. Number of the 15 zoos included in the survey holding the selected seabird categories, zoos reporting these categories of seabirds to ISIS 30 June 1994, and the average number of specimens held per zoo included in ISIS.

	Gan	Sha	Kit	Mur	Puf	Raz	Auk
Survey	6	4	4	10	10	3	1
ISIS	6(9) 4(13)	1(1)	2(8)	15(7)	14(19)	3(7)	

Gan: Northern gannet Morus bassinus
Sha: Shag Phalacorax aristotelis
Kit: Kittiwake Rissa tridactyla
Mur: Murre or Guillemot Uria, Cepphus spp.
Puf: Puffin Cerorhinca, Fratercula, Lunda spp.
Raz: Razorbill Alca torda
Auk: Auklet e.g. Plautus, Aethia, Cyclorrhynchus, Cerorhinca, Synthliboramphus spp.
(): indicates the average number of specimens per zoo reported to ISIS.

Table 2. Recommended minimum group sizes for selected categories of seabirds

Gan- 6, 6-8, 7, 20
Sha- 4(2.2.), 5, 6-8
Kit- 2(1.1), 6-8, 20, 20
Mur- 2(1.1), 6, 6, 12, 20, 20,
Puf- 6, 10-15, 12, 20, 20, 20, 20,
Raz- 2(1.1), 20, 20
Auk- 6

Gan: Northern gannet Morus bassinus
Sha: Shag Phalacorax aristotelis
Kit: Kittiwake Rissa tridactyla
Mur: Murre or Guillemot Uria, Cepphus spp.
Puf: Puffin Cerorhinca, Fratercula, Lunda spp.
Raz: Razorbill Alca torda
Auk: Auklet e.g. Plautus, Aethia, Cyclorrhynchus, Cerorhinca, Synthliboramphus spp.

Table 3. The number of enclosures per area class in m^2.

area	1-100	101-500	501-1000	>1000
encl.	6	4	1	2

Table 4. The number of enclosures per height class in m.

height	2-3.9	4-5.9	6-7.9	8-9.9	≥10
encl.	3	3	1	1	1

Table 5. Present and recommended percentage water of surface area.

Percentage	12-50	51-70	71-100
Present	9	2	1
Recommended	5	3	3

Table 6. Height (in m) from ground or water level of nests for the seabird categories surveyed. Minimum and maximum heights were recorded for responses were ranges were given.

	Gan	Sha	Kit	Mur	Puf	Raz	Auk
Ground	3	1	-	-	1	-	-
>0-1.0	2	-	-	2	4	-	-
1.1-2.0	-	-	1	1	6	-	-
2.1-3.0	-	1	-	-	3	-	-
3.1-3.7	-	-	-	1	-	-	-

Gan: Northern gannet Morus bassinus
Sha: Shag Phalacorax aristotelis
Kit: Kittiwake Rissa tridactyla
Mur: Murre or Guillemot Uria, Cepphus spp.
Puf: Puffin Cerorhinca, Fratercula, Lunda spp.
Raz: Razorbill Alca torda
Auk: Auklet e.g. Plautus, Aethia, Cyclorrhynchus, Cerorhinca, Synthliboramphus spp.

Table 7. Types of nest sites used by the seabird categories surveyed.

	Gan	Sha	Kit	Mur	Puf	Raz	Auk
Grd/Wat	3	1	-	-	-	-	-
Ledge	1	1	1	3	1	-	-
Crevice	-	-	-	1	-	-	-
Tunnel	-	-	-	-	8	-	-

Grd/Wat: Built on ground or water level
Gan: Northern gannet Morus bassinus
Sha: Shag Phalacorax aristotelis
Kit: Kittiwake Rissa tridactyla
Mur: Murre or Guillemot Uria, Cepphus spp.
Puf: Puffin Cerorhinca, Fratercula, Lunda spp.
Raz: Razorbill Alca torda
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