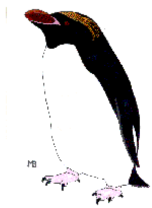
The Penguins of South America and the Falkland Islands



by

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PREFACE

My interest in penguins was sparked off when I was about seven years old, and I saw my first live penguin at Dudley Zoo. I was immediately fascinated by these comical birds, that looked so out of place in the real world, and seemed more akin to cartoon characters. Even as I grew older, it seemed hard to accept penguins as real wild animals: creatures that were able to hold their own in a harsh and dangerous environment. The more I learned about them, the more fascinated I became.

This childhood fascination with penguins fuelled my fight to save them, when in 1993 I was appointed Conservation Officer for the Falkland Islands, a position which brought me into conflict with the Falkland Islands Government and local business interests. In 1995 I led an island-wide penguin census which revealed huge population declines. Between 1984 and 1995 penguin populations in the Falklands had crashed to less than 20% of their former size, and the evidence pointed towards commercial fishing as the culprit. This was confirmed and published in 2002 in the peer-reviewed scientific journal:
Bingham M (2002). "*The decline of Falkland Islands penguins in the presence of a commercial fishing industry*" Revista Chilena de Historia Natural 75: 805-818.

The Falkland Islands Government insisted that the declines were part of a global trend, so in 1996 I led a penguin census in nearby Chile and Argentina, where the two species in greatest decline held the remainder of their world population. This census showed that these species had not declined in South America, and that the crash in penguin numbers was a problem restricted to the Falklands.

I was asked by my employers to cover up my findings, and when I refused to do so I was replaced as Conservation Officer. I set up the Environmental Research Unit in 1997, and continued my penguin research using independent funding. In 1998 oil exploration began in the Falklands, and poor environmental protection led to three separate oil spills, killing hundreds of penguins and other seabirds. I protested about the lack of environmental safeguards, and the unnecessary damage being done to Falklands wildlife by the Falkland Islands Government. The Falkland Islands Government decided that my research posed a threat to future wealth from fishing and oil development, and began a campaign to remove me.

I was arrested and prepared for deportation, but released when the Falkland Islands Police were forced to admit they had fabricated the evidence against me. The official explanation for fabricating evidence was “administrative error”. When I was arrested again, I turned to Amnesty International, who put me in touch with Index on Censorship. They exposed the corruption within the Falkland Islands Government, and the story hit the British newspapers in October 1999.

The Sunday Times, The Guardian, The Observer, The Daily Post and Birdwatch magazine all published the story, with titles such as “Arrested, framed, threatened - Researcher fights a one-man war in the Falklands”. The British Government sent a Police & Criminal Justice Advisor to conduct an investigation, and within 24 hours of his arrival I received an apology from the Chief of Police, and assurances that such things would never happen again. The Chief of Police later resigned.

The findings of the investigation were so serious that on 27th October 1999 the matter was raised in the Houses of Parliament in London, and John Battle MP made a statement on behalf of the Falkland Islands Government. He stated that

"Mr Bingham has every right to complain that incorrect information was used by the Falkland Islands Police. This was clearly an error. I regret any embarrassment caused to Mr Bingham." He added that "Falklands Conservation have unconditionally withdrawn any accusation they might have made."

Unfortunately this only meant a change in tactics by the Falkland Islands Government. Shortly afterwards the Governor of the Falkland Islands, Howard Pierce, wrote me a letter stating that I was to be dismissed from my employment and deported from the Falklands on the grounds that I had “*repeatedly sought to discredit and bring into disrepute the state of the Falkland Islands environment and the role of the Government in its protection*”.

The Falkland Islands is a British Overseas Territory, and the Governor Howard Pierce is an employee of the British government. There is a constitutional right to criticise the government in Britain, and in any British Territory, so to write such a letter was totally illegal, and I took the matter to the Supreme Court.

The case went before the Supreme Court in November 2003, with the Chief Justice and court officials being brought down from Britain to ensure a fair trial. On 25th November 2003 the Supreme Court gave its verdict. The verdict of the Supreme Court was that the Governor, Attorney General, Chief Executive, and the elected members of Executive Council had behaved in an illegal manner for improper motives, and that their actions were "*morally and constitutionally indefensible*".

Chief Justice Wood stated in his summing up: *"It is not in dispute that the Applicant has published a number of articles highly critical of the Government and its policies. There have been produced to me a number of extracts of the minutes of Executive Council and of papers produced by the Government Secretariat for consideration by the Executive Council all in connection with this application.*

"In a report dated 15th October 2002, the Principal Immigration Officer (Pete King) recommended to the Executive Council of 24th October 2002 that the application be refused, and added his own comment to the effect that he too was "concerned about the damage the applicant appears to be trying to inflict on the Falkland Islands Government, and the consequent impact it is likely to have on the Islands' reputation on the world stage". The report concluded with a number of observations regarding the possible consequence of refusal.

"I have gone on to consider a further report of the Principal Immigration Officer dated 28th November 2002. The minutes disclose what in my view is a particularly significant debate which took place. On that occasion, one member enquired as to whether "there was any legal way that the application for status by the Applicant could be refused". I note that, with what proved to be significant prescience the Attorney General observed that "the essential problem is that Mr Bingham will claim that he has been victimised because the Falkland Islands Government do not like what he is saying and that is a breach of his fundamental rights to freedom of speech". It is apparent by this time that other members of Executive Council were concerned regarding the possibility of legal proceedings and indeed one enquired as to whether or not minutes of Executive Council meetings might have to be disclosed.

"Finally the Governor recalls "I was not personally persuaded that they were relevant and appropriate grounds on which to refuse the application. I voiced my concerns in this respect to the Attorney General. I was advised that my letter should include them - I was told that it should accurately reflect the advice that I received at the meeting from Executive Council".

"The Governor goes on to say that he made it known to members of Executive Council his marked dissatisfaction with the grounds upon which to refuse the application but that he considered himself constrained to include in any decision the reasons and recommendation of Executive Council in communicating his decision to Mr Bingham.

"I begin by addressing the issue as to the identity of the person or body in whom the decision is vested by the legislation set out above. I

conclude that it is vested in the Governor, and the Governor alone, in consultation with Executive Council. There is, quite simply, no provision in the Constitution requiring the Governor to act on the advice of Executive Council. That he wrongly fettered the exercise of his discretion in such a manner would have led me to find that the decision was flawed for procedural impropriety, even had I not found the decision to be flawed on substantive grounds.

"I am drawn inescapably to the conclusion that the decision to refuse the application was permeated inextricably by constitutionally improper motive. Executive Council had formed the view that by reason of his criticism of the Government and of its policies and by reason of what might be termed his "anti-establishment" views, the Applicant did not deserve Falkland Islands status, and the only remaining issue was how the refusal consequent upon such a view might be justified.

"Section 10 of the Constitution guarantees freedom of expression, including the freedom to hold opinions without interference. This is a powerful and fundamental freedom underpinning democratic society. It is not qualified by allowing the expression of only those views which are acceptable to the Government or to any particular part of society. A freedom to praise Government but not to oppose it is a chimera; it is not a freedom at all. This is not what the Falkland Islands constitution is about. That principle was not adhered to in this particular instance.

"I have concluded that the hostility engendered by the Applicant's views underlay the whole of the decision making process within Executive Council. In reaching this conclusion I have had careful and detailed regard to the minutes and papers of Executive Council as disclosed in these proceedings. Executive Council does not emerge from this case with any credit. The fact that Mr Bingham has been penalised for his views is constitutionally and morally indefensible.

"James Wood, Chief Justice of the Supreme Court, 25th November 2003"

Now that the facts were out in the open, Falkland Islands residents were outraged, and demanded the resignation of the Governor and his corrupt officials. The newspaper was full of letters demanding a public apology from government, and an explanation as to how such corruption could have been allowed to occur unhindered at the very highest level of government. The radio station held a phone in, and during public meetings between the public and Councillors, the public continually demanded the resignation of those responsible.

The Editor of Penguin News, Jenny Cockwell, wrote an editorial which said "*Chief Justice Woods found Executive Council's decision 'morally and constitutionally indefensible'. That's a pretty strong sentiment. So will we see hands held up and an admission of 'Sorry we made a mistake'? It doesn't look like it. The statement issued by Executive Council this week in response to Chief Justice Wood's judgement didn't include the merest hint of an apology. The statement could have been the perfect opportunity to publicly take on board the Chief Justice's words and apologise to Mr Bingham for this gross breach of his constitutional rights, and to the public as a whole for this error. After all the judgement has come from the Supreme Court - the most authoritative court in the land.*" (Penguin News 28th November 2003)

The following week she wrote "*The public's angry response to the lack of apology from councillors following the Bingham judgement is clearly reflected in this week's letter page and by the number of calls we've had to the office over the past few days.*" (Penguin News 5th December 2003)

The Penguin News was full of letters of support for me, condemning the Falkland Islands Government for their treatment of me and their failure to apologise. The letters included the following statements:

- "*The total disregard by Councillors for Mr Bingham's constitutional rights is what should be at the front of all our minds when we call upon our Councillors to justify their actions. They have acted, and continue to do so by their unwillingness to apologise, in a manner more akin to some tin-pot dictatorship than a community that likes to think of itself as democratic. If this community really wants to be democratic, and perhaps more importantly to be seen to be democratic, then we must demand that the relevant Councillors explain their actions publicly. Many people died liberating these islands so that we might be free. That freedom was hard won, don't let politicians take it away without a fight. Today it was Mike Bingham, tomorrow it might be you or your children.*" (Penguin News 5th December 2003)

- "*Councillor Summers is completely wrong when he says that the Bingham case was about the right to choose who becomes a citizen. The case did not concern the right of government to make choices. The case actually concerned the need for government to act within the law when exercising its powers, not to impose personal prejudice on its choices, and not to abuse its authority. In acting as it did, Executive Council abused the trust we as citizens put in Government to act fairly, impartially and properly.*" (Penguin News 12th December 2003)

- "*In response to the penguin deaths, we tried to tell Falklands Conservation but no one bothered to come out to look. The problem* *started in April 2002 when we lost 500 gentoos and 2000 rockhoppers. Falklands Conservation wouldn't come out, so we called Mike Bingham who did come out.*" (Penguin News 20th December 2003)

- "*I accuse certain members of this administration of the unjust treatment handed out to Mike Bingham. In fact it is against the Haig Convention of Human Rights which this administration has signed up to. I understand the reason Mr Bingham is being treated so is that he had the audacity to question imaginative accountancy by Falklands Conservation regarding penguin numbers. I, like Falklands Conservation, am not an expert on penguins, but what does it take for these people to realise that there is a problem? Emaciated penguins outside the Falklands Conservation office with a begging bowl, squawking up 'Please can we have some more'? For evil to triumph requires only that good men do nothing.*" (Penguin News 20th December 2003)

- "*Could the Attorney General tell us if he was aware that the decision by Executive Council to refuse Mike Bingham's application on the grounds that he was critical of government was a breach of his Constitutional rights to freedom of speech. If he was aware of this, could he please tell us what action he took to defend Mr Bingham's Constitutional Rights?*" (Penguin News 12th December 2003).

The British government offered three years funding to extend my penguin research program to include Chile and Argentina, which allowed the entire world breeding range of these penguins in decline to be studied and compared. This research verified that the penguin decline was only occurring in the Falkland Islands, and was indeed the result of the Falkland Islands' commercial fishing industry.

The British government funding allowed the existing long-term penguin monitoring program to become established, and since then the program has been funded entirely by our Penguin Adoption program at www.seabirds.org

PART 1: An Introduction to Penguins

The first bird to be named a penguin was not in fact a penguin at all, but a Great Auk. The word came from the Welsh “pen gwyn”, which means white head. Although the Great Auk belonged to the auk family, it was flightless and similar in appearance to true penguins. Being flightless, and therefore easy to catch for food, the Great Auk was hunted to extinction by sailors in the 19th Century. When sailors later encountered similar flightless birds in the southern hemisphere they also called them penguins, since when the name has been used to describe flightless birds belonging to the family *Spheniscidae.*

World-wide there are 17 species of penguin, all of which breed in the Southern hemisphere. Three of the five species which breed in the Falkland Islands, also breed in South America, but the Pacific waters of South America also hold two further species which are found nowhere else in the world.

Penguins differ from birds which are able to fly, by having a much heavier and more robust skeleton. Birds that fly must have a skeleton which is as light as possible, in order to make flight possible. This is achieved through bones that are paper-thin or hollow, with internal honeycombing that combines adequate strength with low weight. For flying birds that also dive, such as Auks, this low density skeleton means that birds must work hard to overcome considerable natural buoyancy when diving below the water surface. For penguins that do not have the power of flight, such light weight skeletons hold no advantage, and they therefore have bones which are considerably denser, giving greater strength and reduced buoyancy.

The penguin skeleton is also markedly different from other birds around the furcula and breast bone, due to the differing movement and muscular requirements of penguin flippers compared to bird wings. Such differences in bone structure provide vital clues to the ancestry of penguins, since bones are often the only parts that remain as fossils.

In 1861, the fossilised skeleton of a bird-like creature was found in a limestone quarry near Solnhofen, southern Germany. Given the name *Archaeopteryx lithographica,* it was considered to be the missing link between birds and their reptilian ancestors, dating back 150 million years. Archaeopteryx had both wings and feathers, but was still reptilian in many other ways, and was too heavy to fly. It probably lived in woodlands and used its wings to aid short glides from tree to tree, gaining height once more by climbing up through the branches with the help of the claws on its wings.

Throughout the Cretaceous Period, evolution reduced the skeletal weight, and modified the bones and muscles of the wings, furcula and breast bone, until true birds with the power of flight took to the skies to seek an abundance of insect prey. It is generally believed that this radiation of birds took place about 65 million years ago following the demise of the dinosaurs.

It is also believed that penguins evolved sometime after this radiation, from birds that had the power of flight, although this is by no means certain. The first penguin fossil to be discovered was that of *Palaeeudyptes antarcticus,* found in rocks that were around 25 million years old, in New Zealand during the 19th century. Since then penguin fossils have been found that date back around 50 million years, which show many of the typical features associated with modern penguins. No penguin fossils have ever been found in the northern hemisphere. The largest penguin ever to have been discovered was similar in size to a man.

Despite a long evolutionary history, today's species have much in common. They mostly have blackish upper-parts and whitish under-parts on both the abdomen and flippers. This helps to camouflage the penguin against the lighter sky when viewed from below, and the darker waters when viewed from above, making them harder to spot by both predators and prey. The feathers are waterproof and interlocking, providing an effective barrier to water. Each feather has small muscles which allow them to be held tightly down against the body whilst swimming, to form a thin water proof layer. Little air is therefore trapped in the plumage when swimming, preventing excessive buoyancy which would hinder diving. When on land, these muscles hold the feathers erect, thereby trapping a thick layer of warm air to provide the best insulation against cold wind.

The insulation provided by the plumage is further aided by thick fat deposits beneath the skin, and a counter-current blood supply to the exposed legs and feet. The blood vessels supplying warm blood to the legs and feet are surrounded by the vessels returning cooler blood back to the body, enabling much of the heat lost from the warm blood to be recovered. This vascular system is also able to severely restrict the amount of blood flowing to the flippers and feet, which may be kept as cool as 6 degrees Celsius despite a body core temperature of 39 degrees Celsius. This considerably reduces the amount of heat lost during cold weather, but the process can also be reversed so as to aid heat loss during hot weather.

Penguins also have a counter-current heat exchange system in the nasal passages, whereby air from inhalation and expiration are mixed in a common chamber. This allows recovery of much of the heat lost from the blood capillaries during respiration. This process can also be reversed to aid heat loss during periods of hot weather.

Air is a poor conductor of heat, and all adult penguins in the Falkland Islands and South America are able to maintain their body temperatures on land without the need to increase metabolic activity. By contrast, water is a very effective conductor of heat, and despite their adaptations most penguins do rely on increased metabolic activity to maintain their body temperature at sea. In the comparatively mild waters around the Falkland Islands and South America however, the increased metabolic activity resulting from swimming and foraging is sufficient to meet these needs.

By comparison to adults, chicks have very different types of plumage, which serve completely different purposes. Newly hatched chicks have a protoptile plumage, which is very sparse, and provides inadequate insulation from the cold. However, at this period of development chicks do not require insulation, because they are brooded by the adult, and the sparse plumage enables rapid transfer of heat from the adult brood patch to the chick. Only when chicks near the end of the brood period, do they need a plumage with better insulation.

As chicks grow larger, and demand more food, it is necessary for both adults to go to sea to forage. Prior to being left by both adults, chicks grow a thick, fluffy plumage called the mesoptile plumage, which traps a thick layer of air and provides excellent insulation. This plumage provides better insulation against cold wind than the adult plumage, however it is not waterproof and is only effective when dry. Normally this is not a problem, since chicks do not enter the water at this stage. The insulation properties of the mesoptile plumage can be seen in breeding colonies during periods of hot weather when chicks often suffer from heat stress. By contrast, the breakdown of this insulation when wet is evident during periods of heavy rain, when some chicks can become saturated, and die from hypothermia.

Despite these drawbacks, the mesoptile plumage provides the best possible compromise under a wide range of climatic conditions. Its development coincides with other physiological changes, which enable the chick to regulate its own body temperature without the need for being brooded. When the chick becomes fully developed, further physiological changes occur, and the mesoptile plumage is shed and replaced by a waterproof plumage similar to that of the adults. This plumage needs to be kept waterproof in order to maintain an adequate level of insulation at sea, and in order to retain these properties, the plumage must be renewed regularly throughout adult life. This is usually performed during an annual moult, when birds come ashore for a period of 2 - 4 weeks, while the old feathers are pushed out by the new ones growing from underneath.

Adults suffer from greater levels of heat loss during their annual moult, as a result of the breakdown of the plumage. They are able to partially compensate for this by increasing their subcuticular fat deposits prior to moulting, which occurs during a period of intensive feeding at sea. Nevertheless adults must then come ashore to undertake the moult, since the plumage looses its waterproofing qualities during the moult, and would become waterlogged. The birds are unable to re-enter the water again until all the new feathers have grown in, and their plumage is entirely waterproof once again. Since their food is caught entirely at sea, it means that a period of fasting is required during the moult period.

During normal fasting, such as during periods of incubation or brooding, penguins are able to reduce their metabolic activity in order to reduce the rate at which body fat reserves are used. However, during the moulting period they are unable to do this, since the reduced insulation resulting from losing feathers, creates a need for additional metabolic activity to maintain body temperature. Some additional energy is also required for the growth of new feathers, and proteins must be broken down to provide essential amino acids for the synthesis of the new feathers.

The waterproofing qualities of the adult plumage is maintained by constant preening. A waxy substance is produced from the uropygial gland at the base of the tail, and this is spread onto the feathers during preening to maintain their waterproofing qualities. Preening also realigns the feathers, which interlock through microscopic hooks. Plumage around the eyes and head can only be preened by the feet, so penguins may often be seen preening each other around these areas. This is called allopreening, and it not only allows the preening of inaccessible areas, but also forms part of the pair bonding behaviour. Not all penguin species allopreen however.

All penguins look rather ungainly on land, but in the water they are truly graceful. Evolution has made their wings small and sturdy in order to "fly" in the dense medium of water, but these adaptations have meant the loss of flight in air. In water, penguins use their flippers with much the same action as other birds do in air, using their tails and webbed feet for steering and braking. Penguins can reach speeds of up to 14km. per hour in short bursts, although half this is a more normal cruising speed.

The need to breathe while swimming means that penguins often swim using a porpoising action; travelling just below the surface and periodically leaping above the surface to take short breaths without slowing. This is the quickest mode of travel, and the preferred technique of Rockhoppers and Macaronis, which can average 10km per hour for prolonged periods.

An alternative technique is to travel below the surface for periods of up to 2 minutes, followed by a short surface rest of up to 30 seconds. Average speeds of up to 6km per hour can be attained using this technique, and it is the preferred mode of travel for Gentoos and Magellanic penguins, unless pursued by predators. It has often been claimed that penguins porpoise when pursued by predators, because leaping from the water confuses predators. This may be true, but it is equally feasible that penguins porpoise simply because it is the fastest means of escape.

The penguin body is the perfect shape for reducing drag under water and is unmatched by any man-made design. The drag co-efficient of the penguin body is so low, that despite its very much greater size, a penguin the size of a Gentoo creates less drag through the water than a £1 coin. This is of great significance for research scientists wishing to attach devices to penguins in order to study penguin behaviour. Even very small devices may greatly increase the drag co-efficient of the penguin, requiring it to exert much more energy during swimming, and therefore affecting the behaviour and parameters being studies.

Penguins dive in search of prey, and then having located it they chase it, and swallow it whole under water. To locate and capture prey therefore requires good underwater vision, but the differing refractive indexes of water and air require different shaped lenses. Penguins therefore are able to alter the shape of the lens considerably, enabling them to compensate for the differences in refractive index, and allowing good vision in air and water.

Penguins generally feed during daylight hours. Even at depth, sufficient light still penetrates to allow them to locate their prey, especially when searching from below where prey are silhouetted against the light from above. Even so, light at the blue-green end of the spectrum penetrates to much greater depths than reds and yellows, it is therefore unsurprising that penguin eyes are more sensitive to blue-green wavelengths.

King Penguins are known to forage at night-time, although such foraging dives tend to be very shallow. The main prey of King Penguins are bioluminous Lantern Fish, and the bioluminescence of these fish allows the penguins to locate them in the absence of daylight.

The diet of most penguins consists of varying proportions of fish, cephalopods and crustaceans, determined by variations in local abundance and by the size of prey each penguin species can swallow. Penguins also swallow small stones, and it is likely that these help in mechanically breaking up the food in the stomach.

It is often supposed that prey, such as fish and squid, are more or less evenly distributed throughout the water, but that is not generally the case. Rather like herds of wildebeest or antelope on an Africa plain, fish and squid group together in high concentrations, with only low concentrations being found in the surrounding ocean. Penguins are therefore not so much seeking individual prey when they begin to forage, but rather searching for patches with a high concentration of prey where they will remain to feed. These patches tend to move around, but are generally found within a particular area at certain times of year.

During chick-rearing, few species forage more than 40km from their nest-site in search of food. Breeding sites are therefore situated near to areas of high prey concentration. The result of this is that very large colonies, for example Rockhopper colonies, have so many penguins feeding in these few areas, that competition is high. Breeding success, and in turn the population size of colonies, is often very dependent upon the amount of food available within these critical areas. Clearly any long-term reduction in prey abundance within these areas is likely to result in population decline.

Different species of penguin favour different prey, and the depths to which they dive is related to the location of such prey. All penguins are capable of diving to depths of 100m, but the larger penguins, such as King Penguins, can dive to depths of over 500m. The pressure exerted on the penguin's body increases by one atmosphere for every 10m depth, penguins therefore need a number of physiological adaptations to enable them to dive to such great depths.

The main problem penguins face is being unable to breathe underwater. Having a relatively small body size compared to seals and cetaceans, penguins are more restricted in the amount of oxygen that they can store to sustain them during underwater dives. The underwater pressure compresses the air held in the lungs and air-sacs, and consequently these airways only provide about a third of the oxygen requirements needed for each dive.

The haemoglobin in red blood cells holds a certain amount of oxygen in all animals, in order to circulate oxygen from the lungs to all parts of the body. In penguins, the blood has a much higher concentration of haemoglobin than is necessary solely for circulatory needs, and this is used as an oxygen store during underwater dives. In addition the muscle tissues have high concentrations of myoglobin, which also stores oxygen in the very place that it is most needed for underwater swimming.

Water becomes colder with increasing depth, and during foraging dives the core body temperature of penguins can decrease substantially as a result of heat loss, and the ingestion of cold food and water. This cooling of the body core also helps to reduce the oxygen requirement during dives, by suppressing the metabolic activity of organs that are not required for foraging.

As oxygen is used up during respiration, carbohydrates and fats are burned off to provide energy, and the by-product of this process is carbon dioxide. During underwater dives this carbon dioxide builds up in the blood stream due to the lack of fresh air entering the lungs and air-sacs. Under normal circumstances this excess carbon dioxide would combine with the blood to become carbonic acid, raising the acidity of the blood. It is actually the build up of carbon dioxide which causes the sensation of suffocation, rather than the lack of oxygen. Even small increases in the acidity of the blood can be metabolically damaging, and penguins therefore have an ability to buffer the blood, preventing the blood from becoming too acidic in the presence of increased levels of carbon dioxide.

Even despite these adaptations, penguins are often unable to hold sufficient oxygen to sustain the deepest dives, and they have therefore evolved physiological adaptations that enable them to use anaerobic respiration (the production of energy in the absence of oxygen). In humans, when muscles become overworked and lack sufficient oxygen to sustain their energy requirements, the build up of lactic acid resulting from anaerobic respiration quickly causes pain and muscle fatigue. In penguins however, the muscle tissues contain high levels of an enzyme called lactate dehydrogenase which allows muscles to continue working anaerobically, by neutralising the build up of lactic acid. This lactic acid is later expelled from the body when normal breathing is resumed, during periods of surface rest or shallow diving.

Penguins must all come ashore in order to breed, and the sites they choose for this vary considerably between species. Some species remain around the breeding colonies throughout the year, whilst others desert the colonies completely during the non-breeding season. The latter species generally remain at sea throughout the non-breeding season, and their foraging ranges are often difficult to determine during this period. Pre-breeding birds of most species also tend to remain at sea, except during their annual moult.

Some penguin species may commence breeding when just 2 years old, while other species do not breed until 6 or more years of age In most species the males arrive at the breeding site a few days before the females, and this is due to the fact that there are more males than females. Despite popular belief, many penguin species are not faithful for life, and the rules of partnership are complex.

Both partners generally return to the same breeding site each year, and many species use the same actual nest, which they refurbish each season. The male usually seeks out his previous partner in order to breed with her once more, but if the female arrives at the nest site first, and cannot find her previous mate, she will quickly pair with any unattached male nearby.

This makes sense, since if she delays breeding too long for a mate that may never arrive, she is likely to loose her opportunity to breed that season. It is therefore essential that the male arrives at the nest site before the female, since it is much harder for an unpaired male to find a replacement female, and he cannot run the risk of losing his previous partner.

On occasions a female may arrive at the nest site first, and not finding her previous mate will proceed to copulate with another male, only to reform her partnership with the previous years partner when he finally appears. This leaves her unsuspecting partner to incubate and rear the offspring of another male. This is an added incentive for the male to arrive first, in order to ensure that his partner does not attempt to copulate with any other males.

Pair bonding is reinforced, and new partnerships formed, by ritualised displays and nest building. Penguins display a number of behavioural rituals to display territorial defence, aggression, submission, and to enhance the pair bonding. Such rituals include head and flipper waving, bowing, presenting gifts, allopreening, and vocal calls. Aggressive postures are designed to avoid the need for physical contact, but fights do still break out within the colony during the establishment of mates and territories. Such fights can be aggressive, with birds using bills and flippers against their rival. Birds generally defend a territory within pecking distance of their nest.

Mating takes place within a few days, and most species lay two eggs at an interval of around 4 days. Breeding in colonies allows synchrony of egg laying, which in turn reduces the sustainability of eggs and young for dependent predators which are also trying to raise young. More evenly aged colonies are also easier to defend, since they offer less opportunity for predators to prey on younger chicks. Penguin colonies are sometimes called "rookeries", a term which actually refers to breeding colonies of rooks, a member of the crow family.

Both parents take turns to incubate the eggs and care for the chicks once they have hatched. An area of skin on the lower abdomen lacks feathers, and is called the brood patch. This allows sufficient transfer of heat to eggs and small chicks as the bird lies over them in the nest. During incubation, the brood pouch becomes swollen and diffused with blood to aid heat transfer. When the birds are not incubating, the patch can be closed, so that the feathers around it join and exclude water during feeding periods at sea.

Prior to hatching, the chicks call to their parents from inside the egg. The chicks use a small point on the tip of the bill, called the egg tooth, to break through the egg shell. Hatching can often be a prolonged process, lasting a couple of days.

When the chicks reach about two weeks of age, the original protoptile plumage, which is thin and readily transmits warmth from the parent bird, is replaced by a thicker mesoptile plumage. This provides good insulation, and in association with metabolic changes, it allows the chick to maintain its own body temperature. This allows both parents to go to sea in search of food, in order to meet the growing demand for food from the larger chicks. In most surface-nesting species, chicks whose parents are at sea form into creches, and this provides them with a certain degree of protection from cold weather and predators.

Returning adults identify their chicks by recognition of their distinctive calls. Chicks must beg for food in order to initiate a feeding response from the parent, and this is usually done by constant pecking around the parents bill. Penguins, unlike most other birds, do not have crops and regurgitate partially digested food directly from the stomach. Generally it is the adults who must be convinced that they are receiving feeding demands from their own chick, since hungry chicks will happily beg from any passing adult, or even other chicks.

Mortality amongst chicks is generally quite high, and varies from species to species according to different breeding strategies. Some species lay only one egg, or lay two eggs of different size, concentrating all their efforts into raising just one healthy chick. Such species are generally longer-lived, do not begin breeding until several years of age, and use a strategy of slow reproduction but lower adult mortality. Species adopting such a strategy often show lower annual fluctuations in breeding success and population size. Nevertheless, lower reproductive rates mean that they are slower to recover from population crashes or human exploitation.

Other species lay two equally sized eggs, and put equal effort into rearing both. This allows them to achieve very high reproductive rates during seasons of high food abundance, but they may also suffer from low reproductive rates when food is scarce. These species tend to be shorter lived, begin breeding at an early age, and use a strategy of rapid reproduction but variable adult mortality. Such species tend to show high annual fluctuations in both breeding success and population size. Because they can achieve high reproductive rates, they are perhaps more able to recover from natural disasters and direct exploitation, but would still be vulnerable to a long-term reduction in food abundance.

When chicks are ready to leave the nest site and take to the sea, they shed their mesoptile plumage and develop their adult waterproof plumage, allowing them to enter the water for the first time. The term "fledging" normally applies to the stage when young birds take their first flight from the nest, but in penguins the term refers to chicks changing into adult plumage. Some parental responsibility may still remain after fledging, but before long most adult penguins return to the sea in order to build up their body fat reserves in preparation for their annual moult.

These foraging trips usually last up to about four weeks, and allow the build up of thicker layers of sub-cuticular fat, which will provide better heat insulation during the forthcoming moult. This is particularly important, since adults are unable to feed during their 2 - 4 week moult period, and must sustain heat loss by burning up body fat. If insufficient body fat exists, adults may starve to death prior to completion of their moult. In practice this very rarely happens, but it has been observed in the Falkland Islands where the commercial fishing industry leaves insufficient fish stocks for the penguins.

Healthy adult penguins have few natural predators on land, although on occasions Sea Lions have been known to come ashore to take adult penguins. At sea however, penguins are often killed by Leopard Seals, Sea Lions and Killer Whales. Skuas and gulls are regular predators of eggs and small chicks during the breeding season, but are unable to over-power healthy adults.

Penguins are the major avian top-predators in the southern oceans. The entire world population of all penguins consume around 20 - 25 million tons of fish, squid and crustaceans every year. By way of comparison, the world's commercial fisheries remove around 70 million tons per year. However, because penguins breed in very large numbers at particular sites, and generally forage within a range of 40km, there is considerable local competition for food. Breeding colonies therefore rely on highly productive feeding areas within their daily foraging range, in order to sustain chick production. Any significant reduction in food abundance within this foraging zone is likely to have adverse affects on chick-rearing ability.

This makes such areas particularly susceptible to commercial fishing operations, which are also trying to target the same highly productive feeding areas. This situation is exacerbated when commercial fishing takes place just prior to or during the breeding season, as is currently the case in the Falkland Islands. Even if fishing is managed in a sustainable manner, the results of such timing can be very detrimental. A reduction of prey in these all important foraging areas, at a time when penguins are unable to forage further afield, and when extra food is required for chicks, can seriously reduce chick survival rates. Whilst commercial fisheries are generally reluctant to curtail activities in the interests of preserving wildlife, in some instances rescheduling of activities can be of enormous benefit to wildlife without being economically damaging.

Reliance on such areas of high productivity varies from species to species. Gentoo Penguins breed in small colonies, rarely exceeding a few hundred pairs in any one colony, and as such exert less competition on the foraging zones around their colony than Rockhoppers, which often nest in huge colonies numbering tens of thousands. In addition, Gentoos are able to move the location of the colony in response to environmental changes, whereas Rockhoppers generally remain at the same breeding sites, whether the foraging zones around those sites are productive or not. Such factors explain why Magellanic and Rockhopper penguins in the Falkland Islands have declined by 90% since the establishment of the commercial fishing industry in 1988, whilst the Gentoo penguins have not.

Commercial fisheries are not the only threat posed by human activities at sea. It is estimated that 40,000 penguins are killed by oil pollution along the coast of Argentina every year. This oil mostly comes from deliberate operational discharges, such as the emptying of oily ballast water, rather than from accidents. Pollution in Falklands waters has mostly been restricted to the occasional oiled bird caught up in small scale spillage from fishing and transport vessels. However now that oil exploration has become likely around the Falklands, there is a real risk that Falklands penguins could become affected in a similar way to those in Argentina.

Because oil tankers are designed to function when fully laden with oil, empty tankers returning to collect another load, must fill the empty tanks with sea water to act as ballast. This oily water should then be discharged at the terminal prior to loading up with fresh oil, in order to prevent oil being discharged into the sea, but this practice is often ignored. Because it is time-consuming to pump the oily water from the tanker at the terminal, the water is often discharged directly into the ocean a few miles before reaching the terminal, in order to make reloading faster. The consequences of such malpractice can be devastating to the local wildlife, but enforcing better practices can be almost impossible, even for willing governments.

Oil tankers are governed not by the country whose waters they sail in, but by the country with whom the tanker is registered. Not surprisingly, tankers are often registered under countries which have the most minimal of safety and environmental safeguards, and therefore operate virtually beyond the law. Not only do they continue to discharge oil without fear of prosecution, in order to save money, but often the tankers themselves are poorly maintained, and operated by crews that are untrained in emergency procedures.

Adequate safeguards must be taken to ensure that the highest standards of environmental protection are put in place, to reduce both operational discharges, and to prevent accidents. The problem lies in the fact that governments often claim that they are doing just that, up until the point that an accident proves otherwise. Following major spills around the world, experts often claim to identify the reasons behind the incident, and make changes to regulations to ensure that such accidents cannot happen again. Whilst such measures should be commended, it does allow for complacency to return once more.

It should always be borne in mind that shipping accidents are like car accidents: despite continuous improvements to design and regulations, accidents will inevitably happen. It is therefore essential to have adequate contingency plans to deal with such emergencies, and plans that will be effective in all weather conditions. Most accidents occur in rough weather, and contingency plans must be able to operate under such conditions. It is amazing how many rescue plans cannot be put into operation following a spillage, because they can only be executed in fair weather.

Penguins are amongst the most sensitive of birds to marine oil pollution. Being flightless and having to surface regularly to breath, they are unable to avoid being coated by oil in their vicinity, even when in the open ocean. In addition, because penguins' line of sight is at sea level, they are often unable to see surface oil ahead of them until its too late.

The majority of penguins polluted by operational discharges, are coated in oil out at sea, without the oil ever being noticed on the beaches. Attention is only drawn to the affects of oil pollution when major spills occur, and birds become polluted ashore in large numbers, but in actual fact, the daily mortality of penguins by small scale discharges is far more damaging than a one-off disaster.

Oiled penguins that have been rescued and cleaned, have been shown to have a much higher survival rate than other seabirds. Oil coats the feathers of all birds and breaks down the insulation given by the plumage, however penguins have layers of subcuticular fat which help prevent hypothermia. In addition, penguins are more tolerant of handling than most birds, and are very sociable, which allows them to be housed in large numbers without causing excessive stress. Nevertheless, although cleaning oiled birds can be fairly successful on a small scale, it rarely saves more than a tiny proportion of the victims from a large spill, and can never be considered as a serious proposal for mitigating the damage of large scale oil pollution.

A host of land-based human activities also pose threats to penguin populations, including farming, tourism, industry, poaching, guano removal and introduced predators. Such threats are often specific to certain species, and are therefore discussed separately under each species.

Although all penguin species share many common features, they are also uniquely different from one another. They each occupy different types of coast, and even different regions and climates. They have different lifestyles, have adopted different life strategies, and utilise different resources. Such variations reduce direct competition between species, by allowing them to forage for different sizes or species of prey, and to utilise different nesting sites. These characteristics also give them their individuality, and form the basis of the remaining chapters.

Throughout the book, population sizes are quoted as numbers of breeding pairs. This is the basic unit used for determining breeding populations of birds for one reason. The total number of actual individuals changes day to day, as penguins come and go, and as chicks are born and die. A number that changes on a daily basis is useless for comparing population changes. The number of breeding birds, determined by the number of occupied nests with eggs, is a number that allows detailed comparison of population size from year to year and place to place.

King, Gentoo, Rockhopper and Macaroni penguins breed above ground in colonies that have nests close together at high density at a specific location. The exact location of these breeding colonies is indicated on each map by numbers, with number 1 being the largest colony, etc. Magellanic, Humboldt and Galapagos Penguins do not congregate in such high density colonies, breeding at low density over much larger areas. Their breeding distribution is shown by hatching along the areas of coast where nesting occurs.

WEALTH

No virtuous beauty can life bestow,
on men who great starvation know.
But those of wealth should see things true,
that life is more than me and you.

As penguins fish and eagles fly,
does life`s mystique not catch your eye?
Without their spectre to behold,
what purpose be to all grow old?

Should cars and TV take the place,
of all we lose of nature`s grace?
To crave more wealth than we can spend,
we risk a world we cannot mend.

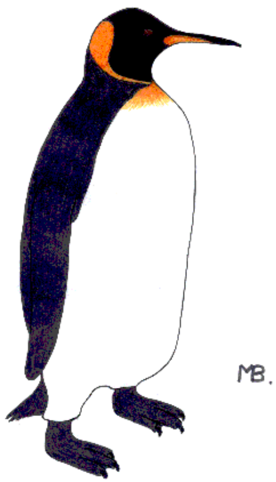
When oil and penguins both are through,
and children ask us what we do.
Perhaps recall what once we had,
and why we thought is was so bad.

Mike Bingham (May 1996)

PART 2: Diversity of the Species

KING PENGUIN (*Aptenodytes patagonicus*)

Despite the scientific specific name *patagonicus*, King Penguins no longer breed in Patagonia, or any other part of South America, expect for a tiny colony of less than 50 pairs near to Porvenir in Tierra del Fuego. King penguins used to breed on Islas de los Estados (Staten Island) until the colony was wiped out by sealers in the 19th Century, and moulting adults still come ashore there on occasions. There is a breeding population of about 500 pairs on the Falkland Islands, but this is very small indeed in comparison to the estimated world population of one and a half million breeding pairs. The major breeding sites are found on the islands of South Georgia, Crozet, Prince Edward, Kerguelen, Macquarie and Heard, which all lie close to the Antarctic Convergence.



KING PENGUIN by Mike Bingham

The King Penguin is the largest of the penguins found in the Falklands or South America, with a typical weight of 12 - 14kg, and an average length of 90cm. Length is measured from the tip of the bill to the tip of the tail, in an outstretched bird. This is a more reliable measurement than height, since it is not affected by variations in stance. The King Penguin is second in size only to the Emperor Penguin, which rarely strays far from the frozen waters of the Antarctic.

The King Penguin has distinctive orange patches on each side of the head, which extend down and meet beneath the chin, where they become yellow and fade into the silvery-white breast plumage. The mandibular plates on either side of the bill are also orange in colour. The female is slightly smaller than the male, but has similar plumage.

King Penguins make no nest, and instead lay a single egg of around 310g, which they hold on their feet for the entire incubation period of about 55 days. This allows breeding in much colder terrain than would be the case for species that lay their eggs on the ground, and negates the need for nesting material. The eggs are brooded by both parents in turn, with shift changes of 6 - 18 days; the non-brooding parent going to sea on extended foraging trips.

The newly hatched chicks are also held on the parents feet for the first 30 - 40 days, by which time they have developed their mesoptile plumage, and are able to regulate their own body temperature. During chick-rearing, parents continue to take turns at brooding, but change over periods vary from 3 - 14 days, so chicks may have fairly prolonged waits between feeds. The King Penguin is known to travel far from the Falkland Islands in search of food during chick-rearing.

Chicks are eventually left in creches, to allow both adults to go to sea on prolonged foraging trips, with chicks being fed even less frequently. During the austral winter chicks may go for periods of up to 3 months between feeds, and healthy chicks have been shown to be able to survive for up to 5 months without a feed. Chicks can loose up to 50% of their body weight during the winter.

Despite this lack of food, King Penguin chicks are still able to survive prolonged periods of extremely cold weather. This is achieved by increasing metabolic activity through the burning of body fat in muscle tissue, despite remaining inactive. Stored body fat reserves are usually adequate to maintain the chicks for at least 3 months, but as body fat reserves become depleted, chicks must begin to break down body protein to provide energy. Weight loss then becomes more rapid, and starvation would eventually result unless the chick was fed. Nevertheless, starvation does not usually result until a chick, which perhaps weighed around 10kg at the start of winter, has gone down to just 3kg. Very few animals are able to survive a 70% loss of body weight, and still be capable of recovery.

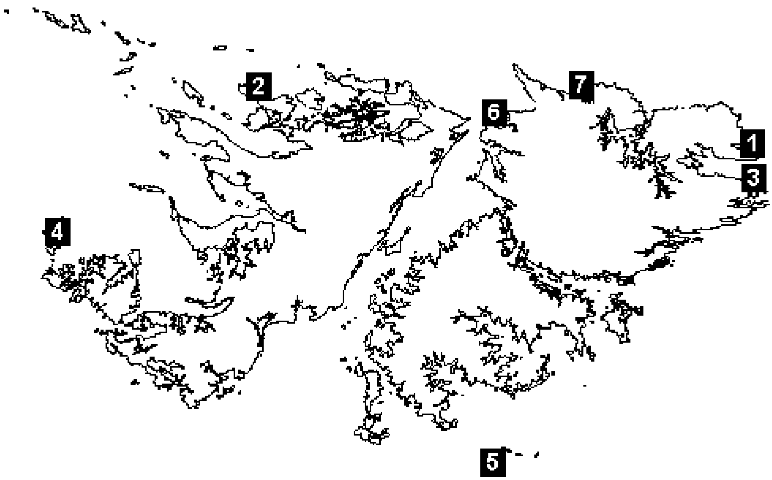
Preferred breeding sites are flat coastal plains within easy reach of the ocean via a sandy beach. The breeding cycle is different to that of other Falklands penguins, with chicks taking the better part of a year to fledge. This requires them to over-winter at the breeding colony, and during this period the chicks remain in creches, and are well insulated from the cold by their long brown downy coats. They eventually fledge the following summer, and will not return to breed until they are at least 3 years of age.

King Penguins can live to over 30 years of age in captivity, and in the wild they normally return to the same site to breed throughout their life. Breeding is preceded by the annual moult, which lasts 4 to 5 weeks. Their return to the breeding colony is poorly synchronised, and hence birds often change partners each breeding cycle.

A complete breeding cycle lasts over a year. This tends to result in individual birds having their following breeding cycle out of phase with other birds, thus large chicks and eggs may both occur in a colony at the same time. Because the Falklands population is so small, at several sites there are insufficient breeding birds to form a colony. When adult numbers drop below about 15 individuals, they tend to merge with Gentoo Penguin colonies. This presumably offers some of the benefits of colony life, such as greater protection from predators, but because Gentoo chicks fledge by February, King Penguin chicks are left to over-winter alone.

King Penguins are remarkably curious of humans, and the chicks in particular will approach to investigate people who are sitting quietly, using their bills to probe boot laces, hair, or anything else that takes their fancy. By contrast the adults can be quite aggressive towards each other in the colony, pecking and beating each other with their flippers. Adults announce themselves by extending the neck to look skywards and giving out a trumpet like call. The chicks by comparison usher a squeaky piping call.

King Penguins generally forage at depths of 150 - 300m, with dives of 500m being recorded for this species. These are the deepest dives of any penguin, except for the Emperor Penguin which is not found outside the frozen waters of Antarctica. King Penguins mainly feed on small bioluminous Lanternfish, and some squid, (including *Gonatus antarcticus, Onychoteuthis sp.* and *Moroteuthis sp.*). Deep dives are only made during the daytime, but King Penguins can also feed at night by making shallow dives. Presumably they can still hunt by sight at night because of the bioluminous light emitted from their prey. Since light penetration does not appear to be the only factor determining foraging depth, it could be that foraging depth is largely determined by diurnal migration of prey species in response to day and night. In the Falkland Islands the foraging range extends to the edge of the Antarctic Peninsula, to the Atlantic coast of South America as far north as Buenos Aires, and across to South Georgia and perhaps beyond.



Map of King Penguin colonies in the Falkland Islands

King Penguins at Volunteer Point are sometimes preyed upon by Orcas (Killer Whales), which patrol close to shore in search of Gentoo, Magellanic and King Penguins. Sea Lions and Leopard Seals also take penguins around Falkland waters. There are no terrestrial predators which pose a threat to adult King Penguins, but birds such as skuas and gulls will take eggs and small chicks if they get the opportunity. This is particularly the case when just one or two pairs of King Penguin breed in a Gentoo colony, since the King Penguin chicks lack the protection of a creche when the Gentoo chicks leave in February.

Human impact is currently very low, despite King Penguins being a great tourist attraction. They are very tolerant of human presence, and are not alarmed by the presence of tourists provided that they remain at the outskirts of the colony. There is no direct exploitation of King Penguins in the Falkland Islands, and they are seldom caught as a result of commercial fishing, other than through the occasional discarded net. There is very little overlap between the prey of King Penguin, and the commercially harvested species of squid and fish. The Falklands fishing industry is therefore unlikely to greatly influence King Penguin population trends. By contrast, the fact that virtually the entire Falklands' population exists at Volunteer Point makes it very susceptible to an incident such as an oil spill in that vicinity.

The tiny colony in Tierra del Fuego has been in existence since 2004, gradually growing from about 5 individuals to about 40 pairs by 2020. It has quite a large number of visitors each year, and care is needed to ensure that such a small fragile colony is not adversely affected by tourism.

GENTOO PENGUIN (*Pygoscelis papua*)

The Gentoo Penguin is numerous and widespread in the Falkland Islands, but has only two very tiny breeding colonies in South America, one on Staten Island (Isla de los Estados) with about 200 breeding pairs, and one on Hammer Island (Isla Martillo) with under 50 breeding pairs as of 2020. World-wide there are about 380,000 breeding pairs of Gentoo, with about 100,000 pairs in the Falkland Islands. Other populations are found on the Antarctic Peninsula, and the islands of South Georgia, Kerguelen, Heard, South Orkney, Macquarie, Crozet, Prince Edward and South Sandwich.

GENTOO PENGUIN by Mike Bingham

Gentoos are the second largest Falklands penguin, with an average length of 80cm and an average weight of 5kg. They have a reddish orange bill, apart from the black culminicorn, and orange feet. White patches above each eye meet across the crown, with white speckling in the adjacent black plumage around the head. Females are slightly smaller than the males, but have similar markings.

Breeding colonies are scattered throughout the Falklands, and rarely consist of more than a few hundred breeding pairs. When colonies exceed this size, they break up into smaller subcolonies adjacent to each other. The preferred nesting sites are low coastal plains, fairly close to a sandy or shingle beach, which is used to gain access to the open ocean. A substantial amount of guano and waste accumulates around the nesting area during the breeding season, and colonies usually move a short distance onto fresh ground each season, retaining the same path to the sea.

Gentoos are ground nesting birds, making rudimentary nests from stones, sticks, grass, feathers, or practically any material that they can find suitable for the purpose. Egg-laying is usually completed by late October, with two equally sized eggs of about 130g being laid. Incubation takes about 34 days, with both parents sharing incubation duties, and nest changes occurring every 1 - 3 days. Despite the two eggs being laid 4 days apart from each other, they both hatch within the space of 24 hours.

The female's reproductive tract actually produces three eggs, and she can lay these at 4 day intervals, however the third egg is only laid if she loses her first two eggs. This enables the third egg to be laid within just 4 days of losing the first eggs, and if it is not needed, the third egg is re-absorbed into the body. Even if the third egg is also lost, the female can still produce a completely new clutch of eggs within a month. This is a truly remarkable adaptation to egg-loss from avian predators, and helps to explain the Falkland Islands folklore that Gentoo penguins fare better when colonies have the first eggs removed.

The young chicks remain in the nest until they grow their mesoptile plumage at about 3 - 4 weeks of age. During this period both parents brood the chicks alternately, feeding the chicks and changing over on a daily basis. Adults usually set out to forage in the early morning, returning later the same day, and foraging generally occurs within 20km of the breeding site. The time spent foraging increases as chicks get larger, and their demand for food gets greater.

After the brood period, chicks are able to leave the nest and form into large creches, allowing both parents to collect food to meet the ever increasing demand. The mesoptile plumage has similar markings to the adult plumage, except that the dark areas are a browny grey rather than black, and there is no white head patch.

Gentoos put equal effort into raising both chicks, and have the ability to produce large numbers of chicks in seasons of high food availability. During such seasons of plenty, even deformed chicks which are unable to walk properly, may be reared to the point of fledging. By contrast, when food is scarce there is strong competition for food between chicks, and only the strongest survive. Adults are often observed running through the colony, closely pursued by one or two hungry chicks. This may well be part of the selection procedure, whereby the strongest, hungriest or most determined chick gets fed first.

Chicks fledge at around 14 weeks of age, but may continue to be fed by the parents for several weeks after fledging. This is possible because Gentoo penguins do not migrate during winter. After completion of the breeding season, adults spend time at sea building up body fat reserves prior to undergoing their annual moult. The moult takes around 2 to 3 weeks, and during this time birds spend considerable amounts of time tending to their plumage. Gentoos do not allopreen.

Gentoo populations are characterised by large annual fluctuations in population size and breeding success, with the later ranging between 0.5 and 1.5 chicks fledged per breeding pair. Gentoos are capable of breeding at just 2 years of age.

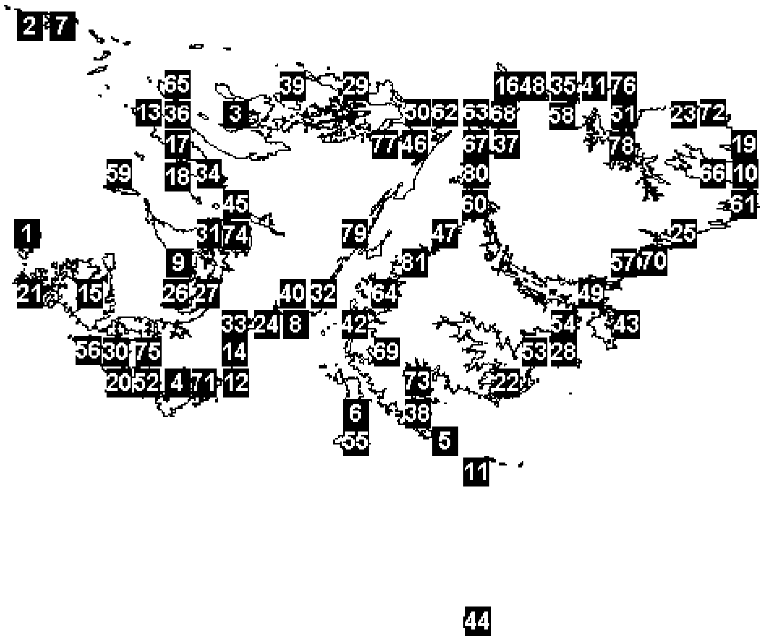
Because Gentoos at most sites tend to move the colony a few metres each year, they do not retain the same nests from year to year. On occasions whole colonies that have remained at one site for years, will up and move to a new site many kilometres away, for no apparent reason. This may happen suddenly during a single year, or gradually over a number of years.

By comparison with other penguins, Gentoo pair-bonds are often long-lasting, despite annual nest changes. Many adults remain around the colony throughout the year, whilst others take the opportunity during the winter months to make longer foraging trips further afield.

Gentoos generally forage close to shore at depths of 20 - 100m, although they have been recorded diving to depths of more than 200m. Gentoos may make as many as 450 dives during a single days foraging. Penguins all look clumsy on land, but in fact Gentoos can out-run a man over short distances, and often make their colonies 1 or 2 kilometres from the sea.

Gentoos are opportunistic feeders, and around the Falklands are known to take roughly equal proportions of fish (such as *Patagonotothen sp., Thysanopsetta naresi* and *Micromesistius australis*), lobster krill (*Munida gregaria*) and squid (especially *Loligo gahi, Gonatus antarcticus* and *Moroteuthis ingens*).

There are 81 breeding sites in the Falkland Islands, with a total of around 100,000 breeding pairs. Breeding populations at these 81 sites range from less than 10 to over 5000 breeding pairs, but sites of more than a few hundred pairs consisted of several sub-colonies of less than 500 nests each.



Map of Gentoo breeding sites in the Falkland Islands

At sea, Gentoos are subject to predation by Sea Lions, Leopard Seals and Orcas. On occasions Sea Lions have been known to come inland after penguins, and even Fur Seals can disrupt breeding colonies on occasions. Nevertheless such incidents are rare, and Gentoo colonies are usually placed far enough inland to avoid such threats.

On land healthy adults have no natural predators, but skuas, gulls and birds of prey, such as caracaras, will steal eggs and small chicks if they get the opportunity. Chicks are also at risk from fluctuations in food supply and weather. Mesoptile plumage provides good insulation when dry, but if it becomes saturated by prolonged rain, chicks can die from hypothermia.

By contrast in periods of very hot weather, chicks become too hot, and may die from heat stress.

Although human activity has greatly modified the landscape around the Falklands, Gentoo Penguins prefer open plains to breed, and consequently have not been greatly affected by the loss of the tall tussac grass. Gentoos are also very tolerant of grazing animals, such as sheep, cattle and horses, which often wander around Gentoo colonies without causing alarm.

The expansion of roads throughout the Falklands, along with the increase in resident population and tourism, has greatly increased the level of disturbance at many Gentoo colonies. Nevertheless, studies of population numbers and breeding success show no evidence that Gentoos are at risk from current levels of disturbance. Gentoos become tolerant of human presence, and do not generally become alarmed unless people approach within about 15m of the nest.

For many years the rural communities of the Falkland Islands took Gentoo eggs for food. Until recent years these eggs were an important supplement to the diet of many people in the Falklands, but now with regular supplies of hen eggs the tradition is gradually dying out. Penguin eggs are always taken at the start of incubation, and the birds rapidly re-lay, so that colonies which have had eggs taken show little difference in productivity by the time chicks are ready to fledge. This observation, along with the way that Gentoo colonies fluctuate in size without apparent cause, has led to much speculation about the merits of egging.

Many landowners believe that hatching rates are higher for the second brood, because a higher proportion of first brood eggs are infertile, but there is no scientific evidence to support this theory. Another theory is that because all the first brood eggs are removed at the same time, the second brood is more evenly aged than the first, which makes it more difficult for skuas and gulls to pick on smaller, weaker members of the colony. In addition the later brooding puts the colony out of phase with the needs of the predators, which are denied their food source at the start of their brooding period.

This second theory is harder to evaluate, and there could be some merit to it. On balance however, after much study of sites which are egged and those which are not, there is no obvious difference in chick rearing success rates either way, and this centuries old tradition probably has little impact one way or the other, provided it is not abused.

Human impact at sea is more difficult to evaluate. There is considerable commercial fishing activity in Falklands waters for squid and fish. Diet analysis shows that there is 6% overlap between those species being commercially harvested, and those which make up the diet of Gentoo Penguins. Whilst it is true to say that the Falklands fisheries industry is well managed by international standards, the main aim of this management is to ensure that stocks are not over exploited commercially, rather than to consider the effects on wildlife.

Food abundance does not so much control penguin populations through the occasional mass starvation, but rather through subtle changes in how effectively penguins are able to raise chicks, survive into adulthood and breed into old age. Any reduction in the abundance of prey will effect the ability of penguins to gather enough food to live and breed.

Life for a penguin is a constant balance between the energy expended hunting for food, and the energy gained by the food caught. Even a small reduction in food abundance means that penguins spend longer, and use more energy, searching for prey. This balance becomes critical during the early stages of chick rearing, when just one adult from each pair can feed at any given time, and yet food is required by both adults and growing chicks. The situation is further complicated by the fact that the foraging range is restricted to how far each penguin can travel in a single day. During chick-rearing Gentoos rely on feeding areas within 20 km of their nest-site.

The Falkland Islands are internationally important as both commercial fishing grounds and seabird breeding sites for essentially the same reason; the richness of the marine food resource. Prior to any commercial fishing activity, seabird and marine mammal population sizes would have been largely controlled by food abundance. Within the overall ecosystem, there would have been many interacting cycles of predator-prey relationships, but all these food webs would have depended on the overall food availability. Any reduction in this level of food availability, be it from natural or human factors, will inevitably lead to a reduction of the populations which it can support.

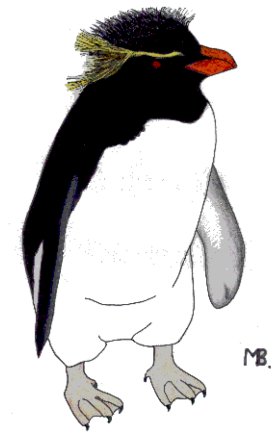
Prior to the establishment of the Falkland Islands commercial fishing industry, Gentoo penguin populations averaged about 120,000 breeding pairs in the Falklands. This dropped to 65,000 pairs by 1995 following the establishment of the commercial fishing industry in 1988. However Gentoo penguins are very adaptable, and managed to modify their diet to use species not caught by commercial fishing, thereby reducing direct competition for resources to just 6%. This adaptation has allowed the Falklands population to return to a current population of about 100,000 breeding pairs.

Direct mortality from human activities has generally been low. Few penguins are caught by fishing vessels, other than through discarded nets and marine refuse. There has been very little pollution around the Falkland Islands, except during 1998 when a brief period of oil exploration led to three separate oil spills that killed several hundred penguins. Standards must be improved if oil exploration is ever resumed in the Falklands.

SOUTHERN ROCKHOPPER (*Eudyptes c. chrysocome*)

World-wide there are 3 subspecies of Rockhopper Penguin; Southern Rockhopper being the name given to the subspecies *Eudyptes chrysocome chrysocome,* which resides in the Falkland Islands and South America. The current world population of Southern Rockhoppers is about half a million pairs, with about 300.000 breeding pairs in the Falkland Islands, and about 200,000 pairs in South America (Chile and Argentina).

South Georgia is also known to hold a few breeding pairs, but only around 10 pairs have been recorded.



ROCKHOPPER PENGUIN by Mike Bingham

Rockhoppers are amongst the smallest of the world's penguins, having an average length of around 52cm, and an average weight of about 3kg. A yellow stripe above each eye projects into a yellow crest, and these are joined behind the head by a black occipital crest. The eyes are red, the short bulbous bill is reddish brown, and the feet and legs are pink. The

Southern Rockhopper is distinguished from other Rockhoppers by having black skin around the bill, and a shorter occipital crest. The females are slightly smaller than the males, but have similar plumage.

Rockhopper breeding colonies may be very large; up to a hundred thousand nests may be present at a single breeding site. Nesting densities range from 1.5 to 3 nests per sq.m., and colonies are often shared with nesting albatross or cormorants. Rockhoppers return not only to the same breeding site each year, but also utilise the same nest, which they refurbish with stones, sticks, vegetation or any other suitable material.

The preferred nesting sites are steep rocky gullies, above approaches into deep water. Such sites may be vegetated by grasses or dwarf shrubs, but long-established colonies will generally have destroyed most of the natural vegetation surrounding the colony, and worn a pathway from the sea up the rock face. Rockhoppers regularly bathe and drink fresh water, and most breeding sites are close to natural springs or freshwater puddles.

The breeding cycle begins in early October, with males arriving at the breeding site a few days earlier than the females. Copulation begins as soon as the females arrive, and egg-laying takes place in early November. Two eggs are laid 4 - 5 days apart, with the first egg hatching later than the second. The first egg, at around 80g, is considerably smaller than the second egg of around 110g. This strategy aims to rear just one healthy chick under a wide range of circumstances. The second egg is generally brooded at the rear, where the temperature is more stable, and where it is less prone to being lost or stolen.

In other subspecies of Rockhopper it is almost unheard of for both chicks to ever be reared, but the Southern Rockhopper is capable of rearing both chicks to fledging when conditions are exceptionally favourable. Even so, Southern Rockhoppers have low annual fluctuations in population size and chick rearing success, and annual productivity never exceeds 1 chick fledged per breeding pair.

Incubation of the eggs takes around 33 days, and is divided into three roughly equal shifts. During the first shift both parents are in attendance. The male then goes to sea to feed while the female takes the second shift, and he returns to relieve the female for the third shift. The male remains on the nest until the eggs hatch, and continues to brood the chicks for the first 25 days, while the female brings food for the chicks.

Such a system of extended shift duration requires lengthy fasts for both parents, but allows them to forage further afield than would be the case if they had a daily change-over. The newly hatched chicks may have to wait for up to a week before the female returns with their first feed. During this period chicks are able to survive on existing yolk reserves, after which they begin receiving regular feeds of around 150g in weight.

By the end of the 25 days of brooding, chicks have developed their mesoptile plumage, and are receiving regular feeds averaging around 600g. By this stage they are able to leave the nest and creche with other chicks, allowing both adults to forage to meet the chicks' increasing demands for food. Rockhopper creches are not as large as those of Gentoo Penguins, possibly due to the more rugged terrain, and the chicks creche into numerous small groups scattered throughout the colony.

Chicks completely lack the yellow markings of the adult birds, and even the bills are black. As chicks moult into adult plumage, the colony is joined by pre-breeding birds arriving to moult. These birds are distinguished from newly fledged chicks by a faint yellow stripe above the eye, and a reddish brown bill. The crest does not develop until the birds mature. Rockhoppers do not breed until at least 4 years of age, but have been shown to live for up to 25 years in captivity.

Despite being the smallest of the penguins found in the Falklands or South America, they are perhaps the most aggressive. They show little fear of people, or of birds and animals larger than themselves. Anything that comes within range of an incubating bird will be pecked, including any other Rockhopper, or the long wings of neighbouring albatross. This is perhaps one reason why King Cormorants (*Phalacrocorax atriceps*) prefer to nest amongst Rockhoppers, benefiting from the Rockhoppers' aggression towards potential predators that might try to steal eggs or small chicks. Nevertheless, Rockhoppers can be very gentle with their partners, and allopreening is common.

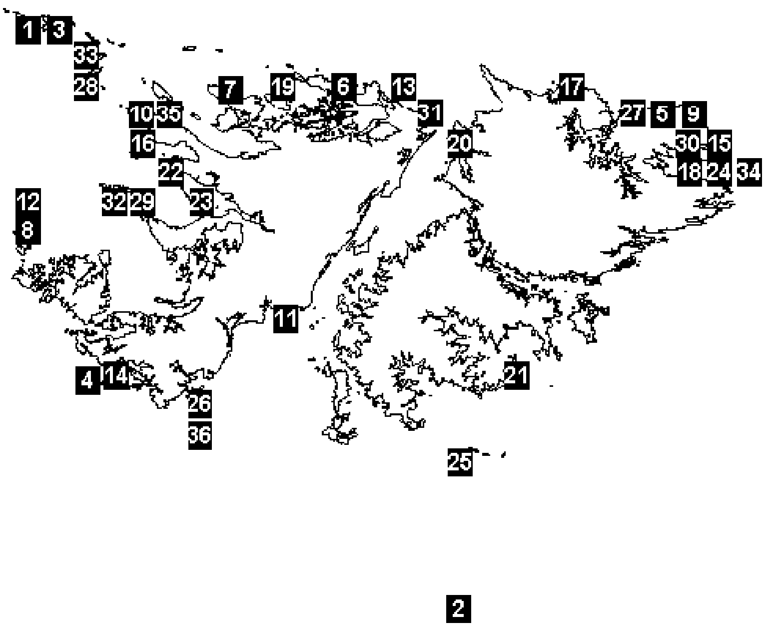
Chicks fledge at around 10 weeks of age, and adults then spend 20 - 25 days at sea building up subcuticular body fat reserves in preparation for their annual moult. The moult lasts for around 25 days, and the birds then abandon the breeding site and spend the winter feeding at sea, prior to returning the following spring.

Rockhoppers are opportunistic feeders, and around the Falklands are known to take varying proportions of crustaceans (*Euphausia lucens, E. vallentini, Thysanoessa gregaria* and *Themisto sp.*), squid (*Gonatus antarcticus, Loligo gahi, Onychoteuthis sp,* and *Teuthowenia sp.*) and various small fish. Foraging dives rarely exceed 100m depth, but feeding in groups is common.

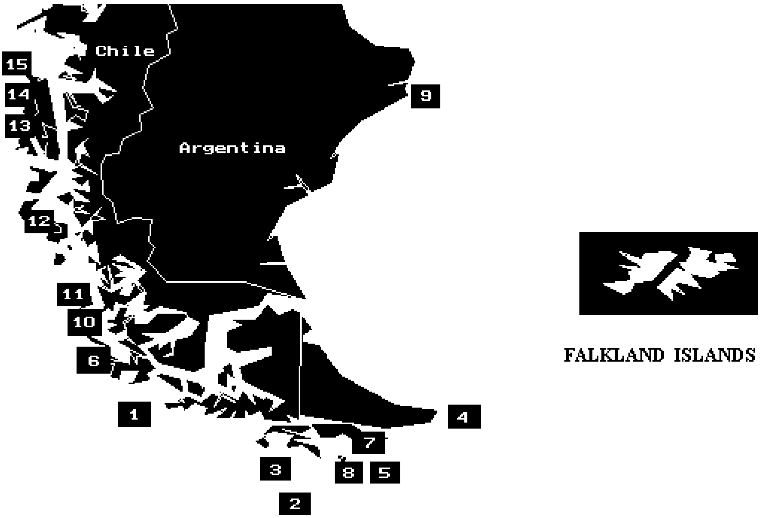
A complete census of Southern Rockhopper penguins was conducted by the author during 1995 (Falklands) and 1996 (South America). These censuses recorded a total of 297,000 breeding pairs at 36 sites in the Falkland Islands, and 175,000 breeding pairs at 15 sites in South America, giving a world total of 472,000 pairs.

In 1984 the British Antarctic Survey had recorded a Falklands population of 2,500,000 pairs, which means that an 88% decline occurred between 1984 and 1995 years, following the establishment of the Falklands commercial fishing industry in 1988. Nearby populations in South America, which are not subject to commercial fishing, have shown no signs of decline during this period. Indeed, the population on Staten Island in Argentina has increased dramatically. The decline is unique to the Falklands.

Since 1995 the Falklands population has remained steady at around 300,000 pairs. In addition to the 88% reduction in food demand caused by their decline, Rockhopper penguins have also modified their diet and reduced their dietary overlap with commercial fishing to just 11%. This has allowed the population to establish a new equilibrium, albeit at a much lower population size.



Map of Rockhopper breeding sites in the Falkland Islands



Map of Rockhopper breeding sites in South America

Evidence of their massive decline can still be seen from the breeding sites themselves. Falkland Islands colonies are all old colonies, where the ground has generally been cleared of vegetation by years of occupation. At most sites, a pocket of nests now lie at the centre of an area cleared by a colony that was once much larger. By contrast, breeding sites in Chile and Argentina contain new, middle-aged and old colonies, indicating a natural cycle of fluctuation and regeneration. In particular, populations on Staten Island (Argentina) and Isla Noir (Chile) are expanding into new areas of dense vegetation, indicating population increases.

Healthy adults do not have any predators on land, although skuas, gulls and caracaras will take eggs and young. Predators such as Sea Lions and Orcas take Rockhoppers at sea; indeed it is not unheard of for Sea Lions to come into Rockhopper breeding sites that are too close to the sea, but such natural predation cannot explain the Rockhoppers decline. In actual fact their main predator, the Southern Sea Lion, has declined in the Falklands at a greater rate than the Rockhoppers, with Southern Sea Lion populations in the Falklands now standing at just 1% of their former size.

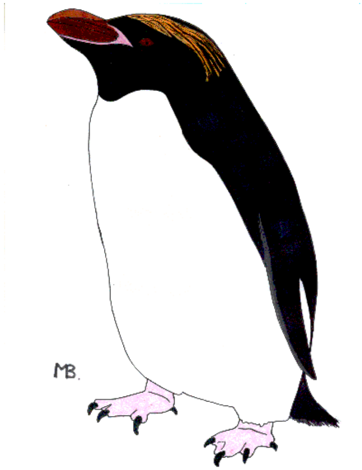
With the entire world population of Southern Rockhoppers being restricted to the Falkland Islands and southern South America, serious measures need to be considered in order to ensure that human activities do not further reduce population size. Even so, Rockhoppers are very tolerant of human presence if care is taken. In the Falkland Islands, Rockhopper Penguins are a major tourist attraction, and a number of sites have large numbers of visitors every year.

Comparison of sites which have large numbers of visitors, with those that have none, show no differences in breeding success or population trends. Rockhoppers have no fear of people, treating all invaders into their space with the same aggression as that shown to a trespassing neighbour. Provided that visitors do not try entering the colony, breeding birds will generally carry on with their business as usual, and a calm approach to within about 5m of the colony is likely to leave one surrounded by inquisitive birds. This tolerance provides an excellent opportunity for a sustainable tourist industry, which could give added incentive to safeguarding future populations for more than just their intrinsic value.

The large decline of Rockhopper Penguins in the Falkland Islands is of such magnitude as to justify treating the species as globally threatened (Vulnerable), according to the new IUCN criteria.

MACARONI PENGUIN (Eudyptes chrysolophus)

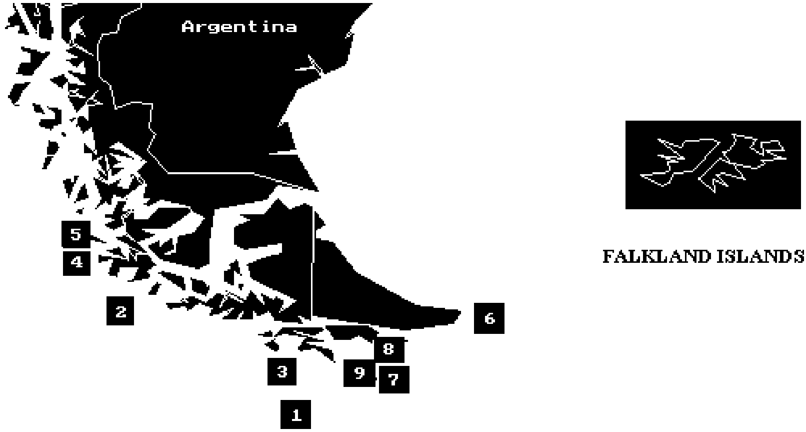
The Macaroni Penguin has an estimated world population of over 6 million breeding pairs at more than 250 breeding sites. The main breeding sites are found on the islands of South Georgia, Crozet, Kerguelen, Heard, McDonald, Prince Edward and Bouvetoya, with other notable colonies in the South Shetlands, South Orkneys and islands off the coast of Southern Chile. The Falkland Islands has a population which averages less than 50 breeding pairs, whilst the South American population stands at around 12,000 breeding pairs.



MACARONI PENGUIN by Mike Bingham

Macaronis are substantially larger than Rockhoppers, having an average length of around 70cm and an average weight of 5.5kg. They are the largest members of the genus *Eudyptes.* The head and upper parts are bluish black, and the under parts are white. The large reddish brown bill has exposed pink skin at its base; the eyes are red and the legs and feet are pink. The most distinctive features are the golden yellow crests which extend from the centre of the forehead and sweep backwards above the eyes. Females are smaller than the males, but have similar plumage. Juveniles lack the elegant crests, and have dull brown eyes, and browny black bills.

In South America there are nine sites with Macaroni breeding colonies, but only the islands of Diego Ramirez, Ildefonso and Noir hold more than a thousand breeding pairs. There are no Macaroni breeding colonies in the Falklands, due to the population being too small. Instead Macaronis may be found breeding individually amongst Rockhoppers in any of the Rockhopper colonies. Macaronis begin breeding about two weeks later than Rockhoppers, but choose similar sites on rocky coasts and low cliffs. Nesting densities range from 0.7 to 1.4 nests per sq.m.



Map of Macaroni Penguin breeding sites in South America

Two eggs are laid with a period of 4 - 5 days between the two. The first egg weighs about 93g and the second egg about 150g. The first egg is not only considerably smaller, but takes longer to incubate, and is rarely successful. Studies have shown that the first egg is often lost prior to the laying of the second egg, making it of little value as a backup. If both eggs are lost Macaronis do not re-lay.

Incubation takes about 5 weeks, and incubation duties are divided into three roughly equal shifts. Both parents remain at the nest for the first shift, after which the male goes to sea, and the female remains to do the second shift alone. When the male returns to do the third shift, the female goes to sea and does not return until the chicks have hatched. Regardless of the time spent at sea during incubation, Macaronis always come ashore during daylight. On occasions the chick may have to wait for up to a week after hatching to receive its first feed. Meal sizes for the chicks averages around 200g during this initial stage.

The male continues to brood the chick for the first 24 days, while the female collects food for the chick. The chicks are fed on a daily basis, with the females leaving the colony in early morning, and returning with food later the same day. The time spent foraging increases as the chicks get larger, and they require more food to maintain their growth. Macaronis rarely forage more than 40km from the nest site during early chick-rearing.

By the end of the 24 days, the chicks have developed their mesoptile plumage, with dark grey upper parts and creamy white under parts. The mesoptile plumage, along with internal physiological changes, allows the chick to maintain its own body temperature away from the nest, and both parents are then able to forage at sea. This is important, since chick meal sizes can now be up to around 1000g per feed. When both parents are away at sea, the chicks gather into creches in order to gain protection from predators and cold weather.

Chicks develop their waterproof plumage and fledge at about 11 weeks of age. They still lack the crests of the adults, and have instead a scattering of small yellow feathers. They also differ in having blackish brown bills and brown eyes. Once the chicks have left, the adults spend a period of about three weeks at sea feeding in preparation for their annual moult. The moult lasts about 25 days, and adults then leave the breeding sites completely, and spend the winter months at sea.

Females can begin breeding at 5 years of age, but the males do not normally breed until at least 6 years old. This may be a consequence of there being a greater number of males than females, allowing females to select more experienced males as partners. By contrast females can usually find a partner from amongst the surplus of males, as soon as they are physically able to attempt breeding. During their breeding life Macaronis show high site and mate fidelity.

Macaroni penguins feed on a wide variety of krill and crustaceans (*Euphausia sp., Thysanoessa sp., Munida gregaria* and *Themisto gaudichaudii)*, squid *(Loligo gahi, Gonatus antarcticus*) and fish *(Notothenia sp.,* and *Champsocephalus gunneri)*. During chick-rearing, foraging for food is generally conducted on a daily basis, with adults returning to the nest site before dark. Macaronis normally forage at depths of 15 - 70m, but have been recorded diving down to 100m on occasions. Some night foraging does occur, but dives are much shallower, ranging from only 3 - 6m depth. Dives rarely exceed 2 minutes in duration at any time.

The South American and Falkland populations of Macaroni Penguins are very small in comparison to the world total, and are found in remote areas where human impact on land is minimal. Natural predators such as Sea Lions and Orcas take adult Macaronis at sea, whilst gulls, skuas and birds of prey patrol breeding sites for eggs and young. Despite current populations being high at around 6 million breeding pairs, the world population has declined from about 9 million pairs in the late 1990s. Climate change and the reduction of food supply due to commercial fishing are the main reasons.

<u>MAGELLANIC PENGUIN (Spheniscus magellanicus)</u>

Magellanic penguins are found only in Chile, Argentina and the Falkland Islands. Population studies estimate that the world population of Magellanic penguins is about 1.7 million breeding pairs, with approximately 700,000 pairs in Chile, 900,000 pairs in Argentina and 100,000 pairs in the Falkland Islands (Bingham 2020). Breeding colonies range from north of Peninsula Valdes in Argentina, southwards down the entire coast of Patagonia, around the southern tip of South America, and northwards up the Pacific coast of Chile as far north as Chiloe.

MAGELLANIC PENGUIN by Mike Bingham

The Magellanic Penguin is around 70cm long, and has an average weight of about 4.5kg. The head and upper parts are black apart from two broad white stripes beneath the throat; one running up behind the cheeks and above the eye to join the pink-coloured gape, the second running adjacent to the white under parts with which they merge above the legs. Females are slightly smaller than the males, but have similar plumage. The males have a slightly more pronounced forehead than the females, but the difference is very subtle and difficult to distinguish unless one is very familiar with the species.

Penguins of the Genus *Spheniscus*, to which Magellanic, Humboldt and Galapagos Penguins all belong, are much more loosely colonial than other penguins. They generally nest in burrows when soil conditions permit, and are consequently spaced much further apart than surface-nesting penguins. Magellanic Penguin colonies in particular often extend over several kilometres of coastline, at densities ranging from 0.001 to 0.1 nests per sq.m.

Magellanic Penguins are widely distributed throughout the Falkland Islands, both on East and West Falklands, and on offshore islands. Magellanic Penguins particularly like islands with tussac grass, and even very small tussac islands may hold colonies. The numerous offshore islands around Tierra del Fuego and the Pacific coast of Chile provide similar nesting habitat.

By contrast, the main islands of East and West Falkland generally have very little remaining tussac grass as a result of livestock grazing, but Magellanic Penguins also nest on these coastal plains. These breeding sites have more in common with Patagonia, where livestock has also altered the natural vegetation.

The largest breeding sites in South America are at Punta Tombo with 170,000 breeding pairs and Cabo Virgenes with 150,000 pairs (Bingham 2020). Magellanic Penguins excavate burrows in any suitable soil type, and when conditions do not favour burrowing they will nest on the surface in shallow depressions, cracks in rocks or under bushes. On Penguin Island in Argentina they even nest on the rocky surface mixed with Rockhopper Penguins, with no protection from the weather or predators.

Adults arrive at the nest sites to breed in September, and after a period of burrow excavation and repair, they begin egg laying around mid October. Two equally sized eggs are laid 4 days apart, each with a weight of around 125g. Incubation takes about 42 days, with the male and female taking turns at incubating whilst the other goes to sea to forage. The average change-over period is about three days, with the main cause of nesting failure at this stage being the result of penguins abandoning the nest when their partner takes more than 8 days to return (Bingham and Herrmann 2008).

Both parents continue to brood the chicks in turn, on a daily basis, for a period of 25 to 30 days. In most colonies the adults leave the colony in early morning, and return with food later the same day, with foraging trips lasting about 14 to 18 hours. However in the Falkland Islands the reduction of fish stocks caused by the commercial fishing industry means that the average foraging trip is well over 30 hours, with adults returning the following day and chicks getting fed once every two days (Bingham 2002). Magellanic Penguins mostly forage within about 40km from the nest site during chick rearing.

By the end of 30 days the chicks have developed their mesoptile plumage, and are able to venture out of the burrows. At this stage they look very different from the adults, being a browny grey above, and creamy white below. Living in burrows, chicks have good protection from both predators and cold weather while both parents are away feeding, and consequently they do not form creches in the way that most surface-breeding species do. In colonies where the penguins nest under bushes, small creches can form when several penguins share a large bush.

Whilst burrows offer good protection from most weather conditions, heavy rain can result in flooding of the burrows in some areas. Chicks rarely drown in such circumstances, but often become wet and cold. The situation can be worst when nests are made under bushes. Mesoptile plumage provides excellent insulation when dry, but it lacks the waterproofing qualities of the adult plumage and looses much of its insulation properties when wet. Consequently some chicks can die from hypothermia if heavy rain occurs shortly after hatching.

Living in burrows also means that the chicks become infested with penguin fleas and ticks. Chicks and adults are able to groom themselves to get rid of these parasites over most of their body, but are unable to reach areas around the head and neck. If food is plentiful, adults are able to return to the nest late afternoon, which gives them plenty of time to groom the chicks to remove these parasites. However in the Falklands where adults have very little time to spend with the chicks due to the shortage of food, many chicks have so many parasites feeding on their blood that they become weak and anaemic.

The two eggs hatch a few days apart and adults give feeding priority to the strongest chick, which is usually the first to hatch, resulting in a higher rate of mortality amongst second chicks. In nature it is better to have one strong chick than two weak ones. Nevertheless Magellanic Penguins do rear both chicks successfully when sufficient food can be caught. Normal healthy breeding success ranges from 0.8 to 1.6 chicks fledged per breeding pair, with just 1 chick per pair being necessary to sustain a healthy population. Magellanic Penguins do not usually re-lay if they loose their clutch.

When the weather is fine larger chicks often sit outside their burrow entrances, but will rapidly return to the safety of their burrows at the first sign of danger. Fledging occurs at 9 to 17 weeks of age, depending on how much food they receive. Chicks are able to slow down their growth rate when food is less available in order to increase their chances of survival. Fledglings look similar to the adults, except for being greyer and lacking the clearly defined banding of the adults.

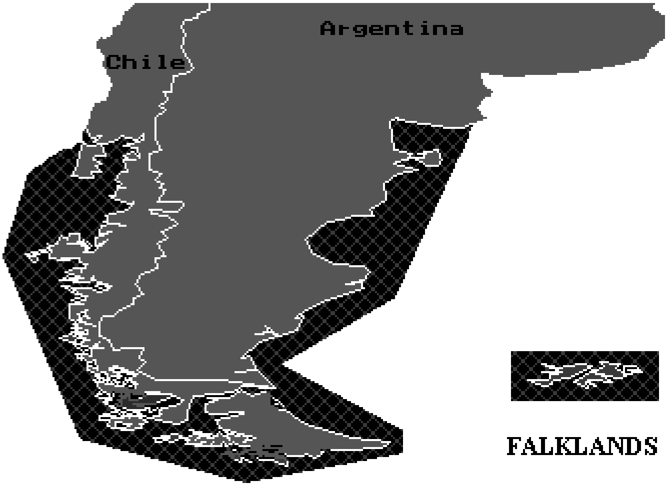
After the chicks leave the colony, the adults spend a few weeks at sea, recovering the weight that they lost during chick rearing and feeding up in preparation for their annual moult during March, April or May. Moulting takes 3 to 4 weeks, after which the adults leave the breeding site, and migrate northwards as far as northern Brazil to avoid the short gloomy days of winter. The penguins remain at sea throughout their migration. Magellanic Penguins can live to over 30 years of age, with many individual birds having been monitored for well over 20 years of annual nesting.

Females can begin breeding at 4 years of age, but the males do not normally breed until they are at least 5 years old. This is quite possibly a consequence of there being more males than females, making it easier for inexperienced females to find partners than for inexperienced males. Magellanic penguins generally show strong site and mate fidelity, and pair-bonds are reinforced by allopreening to get rid of each other's parasites.

Where food supply is not altered by commercial fishing, Magellanic penguins feed almost exclusively on fish. In the Straits of Magellan where large-scale commercial fishing is banned, over 90% of their diet is made up of just one species of fish (*Sprattus fuegensis*).

In the Falkland Islands, the commercial fishing industry has forced the penguins to modify their diet, taking roughly equal proportions of fish (*Micromesistius australis*, *Sprattus fuegensis, Engraulis anchoita, Merluccius hubbsi, Patagonotothen sp.*, *Austroatherina sp.*, *Myxinus sp.*), squid (*Loligo gahi, Gonatus antarcticus, Moroteuthis ingens, Onychoteuthis sp.*) and Lobster Krill (*Munidae gregaria*). Lobster krill should not be fed to the chicks as it is too indigestible, but shortage of fish often forces penguins to do so. Many other substitutes fed to the chicks are also far less nutritious than fish (Bingham 2002).

During chick-rearing, foraging trips are generally conducted on a daily basis during daylight hours, except in the Falklands where food is harder to find. Birds generally forage at depths of less than 50m, but on occasions may dive up to 100m. Winter foraging for prey takes them way beyond their normal breeding range. With no chicks to feed, the penguins have no need to remain close to their nests, and travel northwards as far as Brazil to avoid the short hours of daylight during the winter. Good light is important for penguins that catch fish by sight.



Map showing world distribution of Magellanic Penguins

Magellanic Penguins have declined severely in the Falkland Islands since the 1980's, which coincides with the establishment of the Falkland Islands commercial fishing industry for fish and squid. The current Falklands population of about 100,000 pairs stands at barely 8% of its pre-fishing industry level of over 1,300,000 pairs. This decline is still continuing. These declines have occurred in the Falklands, whilst nearby colonies in Chile and Argentina have increased.

Comparisons of colonies in the Falklands, Chile and Argentina by the author confirm that competition with commercial fishing is the major cause of the Falklands decline. (Bingham 2002 “The decline of Falkland Islands penguins in the presence of a commercial fishing industry”. *Revista Chilena de Historia Natural 75: 805 - 818.*)

Adult penguins in Chile are able to return with food for their chicks on a daily basis, with foraging trips averaging 14 to 18 hours. By contrast adults in the Falkland Islands take approximately 35 hours to find the same amount of food. With only half the amount of food being fed to chicks, lower chick survival rates would be expected, and this is confirmed by our research. Over recent years breeding success and chick survival rates have been substantially higher in Chile and Argentina (average 1.2 chicks per nest) than in the Falklands (average 0.6 chicks per nest). This huge difference in breeding success is sufficient to account for the gradual decline in the Falklands population, with insufficient chicks being reared in the Falklands to replace natural adult mortality.

Diet sample studies in areas with no commercial fishing show that Magellanic Penguins have a 90% dietary overlap with the Falkland Islands commercial fishing industry. In the Falklands, the lack of preferred prey caused by commercial fishing has forced Magellanic penguins to feed on squid and crustaceans, and their consumption of preferred species has been reduced to just 26%. Chicks are fed less food, and are fed on species that are at best less nutritious, and occasional harmful to chicks, as is the case of Lobster Krill. As a result the decline of Magellanic penguins has not levelled out in the way that it has for Gentoo and Rockhopper Penguins, and Magellanic penguins continue to decline in the Falkland Islands (Bingham 2020).

The colony at Punta Tombo in Argentina has also experienced a decline as a result of commercial fishing for similar reasons. However further south Magellanic Penguin colonies have increased during the last 20 years. Population studies by the author show that many colonies in southern Argentina and Chile have had population increases since the 1990s, whilst the Falkland Islands was loosing 92% of its population (Bingham 2020).

Fishing vessels are not the only man-made hazard faced by Magellanic Penguins. An active offshore oil and gas industry make pollution from oil a constant risk to penguins. Oil is discharged into the sea both through accidental spillage, and through deliberate operational discharge of oily ballast water from tankers.

Oil exploration around the Falkland Islands could mean similar mortality amongst all species of Falklands penguins, unless considerably higher standards to those employed in Argentina are demanded. Unfortunately early indications are not good. During a 5 month period of oil exploration around the Falklands in 1998, no less than three oil spills occurred, killing several hundred penguins, cormorants and other seabirds.

Magellanic Penguins face little natural predation at sea. The major predators of penguins, such as Leopard Seals, live further to the south nearer to Antarctica. Sea Lions do kill some penguins at some locations, but it does not appear to be normal predation in most cases. The Sea Lions that kill penguins are mostly single males that have been unable to secure females, and they rarely eat the penguins that they kill.

Magellanic penguins have no predators on land, but they do face predation of their chicks and eggs by avian predators (such as skuas), foxes and armadillos. When the penguins nest in burrows this predation is greatly reduced. Magellanic penguins have a fierce bite that deters even large predators like foxes from coming near.

Studies show that predation is reduced in the presence of tourists. The penguins adjust to the presence of people, whilst skuas, foxes and other predators do not, allowing penguins that breed in the presence of tourism to have slightly higher breeding success (Bingham 2020).

The Dutch explorer Oliver van Noort records visiting Magdalena Island during the 16th Century, to collect penguin eggs for food. Egging of Magellanic Penguins used to occur in the Falkland Islands, but this has now virtually stopped. Magellanic Penguins are also occasionally killed by crab fishermen around the remoter parts of southern Chile, the penguin carcasses being used to bait crab pots. This activity is illegal but difficult to control since it occurs in remote locations. It has had little impact on the overall penguin population, since this crabbing industry is small scale, but it has seriously damaged some individual breeding sites.

Magellanic Penguins are the most accessible penguins for tourism in South America. Visitors that approach breeding sites which do not normally have many visitors will send the penguins scurrying into their burrows for safety. However Magellanic Penguins readily adapt to regular visitation so long as there is a marked path that stops people from walking amongst the nests.

Simple fences stopping people from walking amongst the nests is all that is needed, and this arrangement can benefit both penguins and tourists. Not only are the penguins protected from people stepping onto their nests, but they also rapidly learn that humans will not enter beyond the fence, and will confidently remain sitting outside their burrows for all to see. Many penguins become so used to visitors that they barely open an eye as people walk right by them, sometimes even sleeping within the tourist path. By contrast, visitors to unfenced sites will generally see little more than distant penguins scurrying away, or faces looking out from inside their burrows.

In the Falkland Islands Magellanic Penguins prefer to nest amongst tussac grass for protection, but most of this has now been lost from the mainlands of East and West Falkland, as a result of over-grazing. Tussac grass does still remain on many of the offshore islands however, and efforts are now being made to fence off some mainland sites from livestock, in order to allow regeneration. In areas where this has been done, Magellanic Penguins are often quick to re-colonise, as can be seen around Gypsy Cove near Port Stanley.

There is a certain degree of symbiosis between Magellanic Penguins and tussac grass. Not only do the penguins benefit from having dense cover for their nests, giving protection against predation and bad weather, but the tussac grass also benefits. Penguins feeding at sea later deposit their guano around the burrows, providing nutrients that promote lush growth. In addition, abandoned burrows create traps for seeds, where seedlings can get a foothold, and where they are partially sheltered during the initial stages of growth. This is particularly important in enabling tussac grass to colonise new areas, or enabling re-colonisation of old areas that had been converted to heathland by overgrazing.

HUMBOLDT PENGUIN (Spheniscus humboldti)

The Humboldt Penguin has a fairly limited distribution, being found only along the Pacific coast of South America, in an area of very low rainfall. The principal breeding range is from Isla Foca off the coast of Peru, down to Algarrobo in Chile. There is also one small isolated colony much further south on Isla Punihuil, where Humboldt penguins mix with Magellanic penguins: the most northern breeding site for Magellanic penguins and the most southern breeding site for Humboldt penguins.

The total world population of Humboldt Penguins currently stands at around 12,000 breeding pairs, with about 8,000 pairs in Chile and the remaining 4,000 pairs in Peru. The population is currently undergoing a serious decline, and the major causes of the decline are over-fishing of prey species, entanglement in fishing nets and commercial guano removal.

HUMBOLDT PENGUIN by Mike Bingham

The Humboldt Penguin is similar in size to the Magellanic Penguin, having an average length of around 70cm., and an average weight of 4.5kg. The plumage is also similar, except that the two white bands merge to form one thick band across the throat of the Humboldt. The eyes are reddish brown, and the bill is also slightly larger than that of the Magellanic Penguin. The females are slightly smaller than the males, but have similar plumage.

Egg-laying can occur at any time of year between March and December, although two peaks of activity occur around April and September. It is quite common for Humboldt Penguins to rear two successive broods in a single season, when conditions are favourable. This can result in a yearly cycle which comprises of a 2 month moult period, followed by two 5 month breeding cycles. As a consequence, Humboldt Penguins can be seen around their breeding sites throughout the year.

The exception is on Isla Punihuil to the south, where Humboldt penguins follow the breeding cycle of the Magellanic penguins with which they share the colony.

Humboldt Penguins strengthen their pair-bonding by allopreening. Two equally sized eggs are laid with a four day interval, in burrows, rocky crevices or surface scrapes. Incubation takes about 40 days, with both adults changing incubation duties regularly. The major causes of egg loss are from flooding of nests during ocean storms, accidental breakage, nest desertion, and predation by gulls.

Chicks hatch about two days apart, and are fed on a daily basis, with adults leaving the colony in early morning, and returning with food later the same day. The time spent foraging for food increases as the chicks become larger, and require more food, but adults rarely forage more than 35km from the nest site during chick-rearing.

Chicks remain within the nest until they have fully developed mesoptile plumage. Even then, chicks rarely stray far from the nest prior to fledging. The fluffy mesoptile plumage is browny grey above and creamy white beneath, and in conjunction with metabolic changes, it enables the chick to maintain its own body temperature. This allows both adults to leave the burrow to feed, in order to meet the ever increasing demands placed upon them by the growing chicks. When living in burrows, the chicks have no need to form creches in the way that surface breeding birds do. The very arid climate of the region means that Humboldt nests are not generally at risk from being flooded by heavy rain, except under extreme conditions, but burrows close to shore are occasionally flooded by ocean swells.

The chicks fledge at about 10 to 12 weeks of age, and leave the breeding site for several months to forage at sea. The fledglings have similar markings to the adults, except that they are drabber and lack the black line down the sides of the abdomen. Breeding success rates can be very variable, but are generally in the range of 0.5 to 1 chick fledged per clutch. Adults show high pair fidelity, with most pair-bonds enduring unless one partner dies. They also show high site fidelity, with males showing higher site fidelity than females.

Once the second brood of chicks have fledged, the adults undertake a two week period of foraging at sea, before returning to undergo their annual moult, which lasts around three weeks. After the moult, adults again leave the colonies for about two weeks, to regain weight and condition, prior to returning to begin courtship once more. Humboldt Penguins are capable of breeding at just 2 years of age, and can live to over 30 years.

Adults feed close to shore, currently taking various species of fish *(Engraulis ringens, Sardinops sagax, Odonthestes r.regia, Normanichthys crockeri, Scomberesox sp.),* squid *(Todarodes fillippovae)* and crustaceans. Historically their diet comprised of mostly Peruvian Anchovies (*Engraulis ringens*), but the collapse of fish stocks caused by over-fishing during the 1970s has forced Humboldt Penguins to survive on what remains, causing a huge population decline that threatens the species with extinction. Adults are now forced to feed chicks on less nutritious species with a consequential reduction in chick survival and breeding success.

Most foraging is done at depths of less than 60m, often amongst weed beds, but they have been known to reach depths of up to 150m. Foraging rarely occurs more than 35km from the colony during the breeding season, but during the austral winter, birds may migrate several hundred kilometres from the breeding site before returning to breed again.

Map showing world distribution of Humboldt Penguins

The coastline along which the Humboldt Penguin is found is particularly susceptible to the influences of El Niño Southern Oscillation (ENSO) events, which occasionally bring seasons of extreme food shortage. During such years, cool nutrient rich waters which normally flow northwards along the coast of Chile and Peru, become displaced by warmer nutrient poor waters flowing from the central Pacific. This loss of nutrients results in a slowing down of primary production by phytoplankton, which in turn affects the entire marine food chain. Being top predators within the marine ecosystem, penguins are amongst the worst affected species, and often face complete abandonment of breeding, and even possible starvation. The Humboldt Penguins are particularly dependent on the availability of fish, which are forced to move further offshore in search of cooler currents.

Such events are often accompanied by severe weather patterns, which can bring heavy rain and flooding to areas that normally receive little or no rain. Under such conditions, Humboldt breeding sites may be completely washed out, as happened along the coast of Peru during the ENSO of 1997/98.

In addition to natural predators, such as gulls, vultures, caracaras, foxes, pinipeds (seals) and cetaceans, Humboldt Penguins also face a number of man-made hazards. Commercial fishing reduces breeding success and survival rates through depletion of food resources. Over-fishing of the Peruvian Anchovy (*Engraulis ringens*) led to its population collapse in the 1970s. This fish was a major component of the Humboldt Penguin diet, and penguin populations suffered as a result.

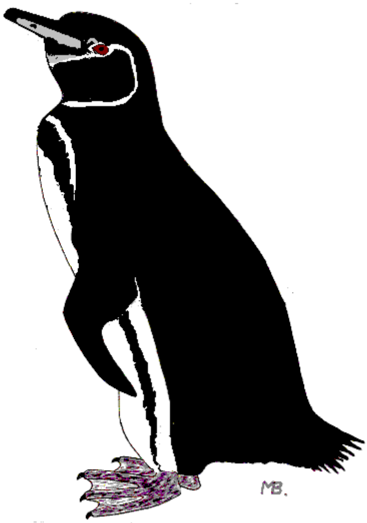
Hundreds of Humboldt Penguins are also caught and drowned in the nets of local fishermen every year. Accidental entanglement in gill-nets, and the deliberate hunting of adults for food and fishing bait, are the main causes of adult mortality in some areas. Eggs are also taken from many breeding colonies, resulting in disturbance and reduced breeding success.

The breeding habitat of the Humboldt Penguin is also damaged by human activity. The guano which builds up around certain breeding colonies due to the arid climate, is scraped off down to the bare rock for use as fertiliser, leaving nothing for the birds to burrow into. Introduced predators, such as wild dogs, also prevent successful breeding on many mainland sites, restricting most breeding populations to offshore islands or specially protected areas.

Because Humboldt Penguins have such a limited geographic distribution, their numbers are naturally low, and this makes them particularly vulnerable to human disturbance. Unless mitigating measures are taken to reduce the impacts currently being exerted on this small population, the species will be extinct within a few decades.

GALAPAGOS PENGUIN *(Spheniscus mendiculus)*

The Galapagos Penguin has the smallest breeding range and population size of any penguin, with less than a thousand breeding pairs. It only occurs in the Galapagos Islands, with 90% of the population being restricted to the western islands of Fernandina and Isabela.



GALAPAGOS PENGUIN by Mike Bingham

The Galapagos Penguin is the smallest of the South American penguins, with an average length of less than 50cm, and an average weight of less than 2.5kg. It has a black head and upper parts, with a thin white line running from the throat, up around the head to meet the corner of the eye. The under parts are white, but are bordered by a black line which extends down to the blackish legs. The females are smaller than the males, but have similar plumage.

Unlike other penguins, Galapagos Penguins have no particular breeding season, and may have as many as three clutches in a single year. This is an adaptation that allows them to take advantage of periods of high food abundance, and to cope with a very variable and unreliable food resource.

Galapagos Penguins undergo their moult prior to breeding, and may moult twice in a single year. Moulting penguins generally avoid the water, but because the equatorial waters are warm, Galapagos penguins that become underweight are able to go to sea to feed, rather than face starvation.

By moulting prior to breeding, Galapagos Penguins are able to ensure that early failure of their food resources will not result in starvation during the moult. Should food supplies disappear prior to the completion of breeding, then breeding success will suffer, but the adults will have the highest chance of surviving the shortage. It is the survival of the adult population that ultimately ensures the survival of the species.

Sea surface temperatures around the Galapagos Islands can vary between 15 - 28 degrees Celsius. During periods of high surface water temperature, primary production is low as a result of the nutrient poor waters, and food becomes short. Such periods of extreme food shortage are called El Niño Southern Oscillations (ENSO), and during such seasons penguins postpone breeding completely. It is better to delay breeding than to risk adult starvation, which is still the main cause of adult mortality.

El Niño means "The Boy", and was so named after the Holy Child Jesus Christ because it usually peaks around Christmas time. During ENSO events, cool nutrient rich waters flowing northwards up the coast of Chile and Peru become displaced by warm nutrient poor waters from the central Pacific. The drop in primary production resulting from the low nutrient levels, works its way up through the food chain, causing food shortages for many species that depend on the ocean. The affects of ENSO events are not restricted to the ocean, since weather patterns are also disrupted right across South America and the Caribbean, usually associated with heavy rains.

Breeding is stimulated amongst Galapagos Penguins by a drop in sea surface temperatures to below about 24 degrees Celsius, which corresponds with the presence of nutrient rich currents, and in turn an abundance of prey. Nests are made along turbulent rocky shores within about 50m of the water, mostly on the islands of Fernandina and Isabela. Burrows are sometimes dug in suitable volcanic deposits, but often nests are in caves or crevices in old fissured larva. Adults remain around the breeding sites throughout the year.

Two eggs are laid 4 days apart, but adults do not normally re-lay if the clutch is lost. Incubation of the eggs takes 38 - 40 days, and is shared equally by both parents. Chicks are brooded for the first 30 days, and this is performed by both parents, with daily change-overs. By the end of the 30 days, the chicks have developed a mesoptile plumage that is brown above and white below, which serves more to protect the chicks from the strong sun than to keep them warm. Both adults are then able to forage for food, but chicks do not form into creches.

Chicks fledge at 60 - 65 days of age, and fledging may occur at any time of year. Fledglings have greyish black upper parts and white under parts, but lack the white lines of the adults. Instead they have paler cheeks which indicate where the thin white head line will later develop.

Pair-bonds are long-lasting, and this allows rapid reproduction when conditions become favourable. Pair-bonding is constantly reinforced by allopreening and bill duelling.

The main problem that Galapagos Penguins face in relation to weather, is from the strong sun. Entering the water enables penguins to cool off, but when on land they have a number of behavioural adaptations that help them to keep cool. Birds can lose heat from the exposed areas of skin on their feet, and the under parts of their flippers, aided by increases in blood flow to these areas. Birds are often seen standing with out-stretched flippers, hunched forward to shade their feet from the sun. They also lose heat by evaporation from the throat and airways through panting.

Galapagos Penguins do not leave the archipelago, and generally forage close to shore in the cooler Cromwell Current, returning to the land at night. Their diet comprises almost entirely of small schooling fish, particularly mullet and sardines of 1 - 15 cm in length, although some crustaceans are also taken. Co-operative feeding in groups is often employed, and foraging is restricted to daylight hours since it is necessary for the penguins to see the prey in order to catch it. Foraging rarely occurs more than a few kilometres from the breeding site.

During periods of food shortage, penguins tend to forage individually, and make no attempt to breed until surface waters drop in temperature once more. During 1982/83, an ENSO event hit the Galapagos Islands so badly that around 77% of the penguin population starved to death, and the population has only gradually been showing signs of recovery.

Unlike larger penguins which have few natural predators on land, Galapagos Penguins must guard against crabs, snakes, owls and hawks, although predation from such sources is generally low. At sea Galapagos Penguins may be killed by sharks, fur seals and sea lions. On Isabela, introduced cats, dogs and rats are also predators. In addition to predation, and other natural hazards associated with an unreliable food resource and volcanic activity, they face a number of man-made hazards.

Tourists and illegal sea cucumber fisherman create disturbance, and affect the marine ecosystem. The illegal fisherman chop down and burn mangrove trees in order to cook the sea cucumbers, affecting the penguins' nesting habitat, and both fisherman and tourists discard refuse that regularly entangles and kills unsuspecting birds. Penguins are accidentally caught in fishing nets, and in 2001 an oil spill hit the islands when a tanker ran aground.

The Galapagos Islands are small, and careful management will be required to balance the increasing pressures from human activities, with the needs of sustaining the fragile and unique ecosystem. With such a small remaining population, Galapagos Penguins face the possibility of extinction, unless such a balance can be successfully achieved.

PART 3: Penguins and the Environment

Far from being comical birds, ill-adapted to the rigours of a hostile environment, penguins are in fact the most successful avian predators of the southern oceans, and have remained so for at least 50 million years. Their overall design has changed little during that period, and each of the penguin species are similar in appearance. Nevertheless, each species has adopted individual characteristics which hone their life cycle to the individual nature of their selected niche.

The southern oceans are immensely rich in plankton, and these form the platform upon which all southern ocean food-webs are built. Penguins sit upon the pinnacle of this food-web, alongside other seabirds, cetaceans (whales and dolphins) and pinipeds (seals). Whilst it is true that orcas and sealions will occasionally take penguins for food, around South America such predation is very low and forms only a tiny proportion of their normal dietary composition.

Healthy adult penguins have few natural predators on land, but penguin breeding colonies do help support populations of avian predators and scavengers. Such species generally utilise other food resources during their non-breeding season, when their daily food demands are low, but the increased demands of breeding and chick rearing can be met by rich pickings from penguin colonies.

Penguin chicks are messy feeders, and often drop food scraps during food transfer from the adult. Food dropped onto the ground is not retrieved by the penguins, but is eagerly snatched by waiting gulls, such as Dolphin Gulls (*Larus scoresbii*) and Kelp Gulls (*Larus dominicanus*). In addition, the digestive tract of penguins is not very efficient, and some items of food, such as crustaceans with a hard ectoskeleton, may pass through virtually undigested. Gulls and Snowy Sheathbills (*Chionis alba*) are able to scavenge such scraps, and receive sustenance from them.

In addition to food scraps, penguin eggs and young chicks also offer easy targets for avian predators. Birds such as skuas and caracaras continually watch over penguin colonies in search of unguarded eggs and chicks. Penguin colonies are constantly active, and during the course of territorial squabbles, eggs and chicks are inevitably left unguarded momentarily. Such a brief lapse in concentration is all that a waiting predator needs, and swooping down onto the unattended nest, it will remove the egg or small chick with its bill, and take it to a nearby perch to be eaten.

This time of plenty is essential in providing for the young of such predators, which schedule their own chick-rearing to correspond with this abundance of prey. Nevertheless, such predators are generally opportunistic feeders, being equally at home taking smaller prey, such as invertebrates, or scavenging on dead bird or mammal carcasses. This adaptability is essential around penguin colonies, which are mostly deserted during the remainder of the year, and other sources of food are needed to sustain such predators. During these winter months there is less live prey for such species, and carcasses or invertebrates become the primary sources of food.

Penguins link the highly productive marine ecosystems of the southern oceans with the comparatively impoverished terrestrial ecosystems of the subantarctic islands. Feeding entirely at sea, they remove large quantities of energy and nutrients in the form of fish, squid and crustaceans, and allow a large proportion of this to be passed on to terrestrial scavengers, predators, parasites and detritivores.

It is not only the terrestrial fauna that benefits from the presence of penguins. The ground around a penguin colony receives a large input of nutrients as a result of the penguin guano and food scraps that are deposited, and this in turn alters the floral composition.

At the point of deposition such a high concentration of nutrients may kill off some vegetation, but the overall result of this input to the ecosystem is a considerable increase in plant growth. Not only does such an input of nutrients increase overall growth, but it also favours species which are better adapted at converting higher concentrations of nutrients into faster growth. Such species are often excluded under conditions of low nutrient input, since the very qualities that allow them to compete under high nutrient levels, make them poor competitors under low nutrient levels.

The numerous islands of the Falklands and the southern tip of South America have no woodland cover, and are generally dominated by heathland comprising of dwarf shrubs and grasses. Plants adapted to low nutrient levels survive under such conditions by having low rates of growth and metabolism. Such plants are generally of comparatively low nutrient value, often with a high proportion of dead material, making the vegetation look brown or pale in colour. A greater proportion of actively growing cells would require a greater metabolic rate, which cannot be supported by the impoverished soils.

By comparison, the vegetation found around penguin colonies is generally greener, due to the higher proportion of actively growing cells, indicative of species adapted to more rapid growth. Such vegetation is not only comparatively species-rich, but is also more nutritious to grazing birds and animals.

These nutrient rich patches are often called greens, as a result of their brighter colour, and can become mini-ecosystems in their own right. Grazers such as geese and rabbits utilise such areas, and by grazing the vegetation and recycling the nutrients through their droppings, such animals are able to maintain the greens long after the penguins have left. Such areas also support a higher density and diversity of invertebrates, the majority of which are detritivores. These in turn provide rich feeding for smaller birds. Penguin colonies are not the only sources of such greens, but in many areas they are the most common.

Close to the coastal fringe itself, specialist species that are adapted to the salt laden air tend to dominate. The most widespread of these is tussac grass (*Parodiochloa flabellata*). This species is generally able to grow well away from the coast, but is prevented from doing so by more competitive species. Within about 300 metres of the sea however, tussac grass is adapted to out-compete the more generalist species, and becomes dominant, producing a dense thicket of up to 3 metres in height. Such areas may be comparatively poor in terms of floral diversity, but they hold an abundance of invertebrates, most of which are detritivores. In terms of invertebrate biomass, tussac grass is the most productive terrestrial habitat type of the region, and doubtless holds numerous species unknown to science.

Tussac grass provides important habitat for bird species too, some of which feed on the abundance of invertebrates, and others which use the dense cover as protection for nests. Seabirds such as petrels and shearwaters in particular use offshore tussac islands as breeding grounds.

Penguins do not rely on tussac grass as such, but Magellanic Penguins do have a preference for such habitat when it is available. The deep tussac peat and dense canopy of leaves enables Magellanic Penguins to nest in large numbers at sites that would not otherwise provide suitable habitat for nesting. Many offshore tussac islands around the Falkland Islands and southern Chile would be too rocky, with soils too thin to permit burrowing, were it not for the presence of tussac grass.

The main contribution made to the tussac island ecosystem by penguins, is through the input of nutrients deposited in and around the burrows. Magellanic Penguins are too large and strong to be killed by avian predators, and even their eggs and young are rarely taken from burrows that are so well protected by the dense vegetation. Sea Lions often utilise tussac islands for pupping and as places to haul out, and on rare occasions will lie in wait for Magellanic Penguins as they come and go from their breeding sites.

The tussac island ecosystem supports a few grazing invertebrates, but most tussac islands have no other grazing animals. Tussac grass did not developed in the presence of large grazing animals, and it has low tolerance of being grazed. This has become very apparent where man has allowed uncontrolled grazing of tussac grass by livestock. Most of the belts of tussac grass that once surrounded East and West Falkland have now disappeared as a result of livestock grazing, and such areas are now covered by heath and grass, or have become eroded and rocky.

Northwards along the coasts of South America, the climate becomes warmer, and tussac grass gives way to other coastal vegetation types. Along the Atlantic coast of Patagonia, the climate is comparatively dry, and the vegetation is fairly open. Magellanic Penguins continue to make burrows where the soils are sufficiently deep to do so, but otherwise they will nest above ground in shallow depressions or under bushes. As with tussac islands, guano is deposited around the base of such covering vegetation, raising the level of the nutrients in the soil, but the covering vegetation offers much less protection for the nests, and predation is higher.

By comparison to the drier Atlantic coast of Patagonia, the Pacific coast of southern South America receives high annual rainfall. This gives rise to dense scrub and woodland along the labyrinth of uninhabited islands which border the coastline of southern and central Chile. This region holds numerous seabirds, including Sooty Shearwaters (*Puffinus griseus*), White-chinned Petrels (*Procellaria aequinoctialis*) and Magellanic Penguins, which nest under cover of the dense vegetation. The hundreds of islands and channels which make up this vast area are immensely rich in wildlife, and yet are largely unexplored and uncharted.

Further northwards, along the coast of northern Chile and Peru, the climate becomes very dry, and the guano deposited by seabirds is no longer washed away due to the lack of rain. The guano can accumulate into deposits several metres thick, and at some sites the Humboldt Penguins rely on these deposits to provide a substrate into which they can dig their burrows. The value of such deposits for fertiliser has long been recognised, and in many areas they are excavated by man for use in agriculture. Such deposits have often been scraped away down to the underlying bedrock, leaving the penguins without a suitable surface in which to nest.

Whilst penguins are well adapted to the natural environment in which they live, they are less able to cope with man-made changes to their environment. Agricultural activities have modified the landscape in a number of ways, and these changes have brought about changes for the penguins that rely on such habitat for nesting. The loss of nesting habitat, be it through the excavation of guano or the overgrazing of tussac grass, inevitably restricts the breeding population that a region can support. In general however, penguins are fairly tolerant of human disturbance, and are quite able to live in harmony with man, provided that their feeding and nesting requirements are not compromised.

Ever since these regions were first occupied, penguin eggs have provided a source of food for human settlements, and the practice still continues to a lesser extent in the Falkland Islands. In general it is the Gentoo egg that is preferred, and given the Gentoo's remarkable ability to re-lay, the practice has little impact on the total population, provided that it is not carried out on a commercial scale.

Penguins, seals and whales have thick layers of subcuticular fat which insulate their bodies from the cold waters of the southern ocean. Prior to the availability of petroleum products, this body fat was a highly prized commodity, being used in oil lamps to provide artificial light. Huge numbers of whales, seals and penguins were killed and boiled down to extract this oil. Boats from Britain and Europe visited sites such as the Falklands Islands during the last century, and decimated colonies of penguins and seals. The bodies were thrown into huge metal cauldrons called tripots, and heated up until the body fat melted into an oil that was drained off and stored. Even the fires that heated the tripots were fuelled by the bodies of penguins, which were simply thrown onto the open fires.

The fact that penguin populations were healthy at the beginning of the 20th century, despite such heavy exploitation, bears testimony to the immense productivity of the southern oceans. Penguin populations are generally determined by the availability of food and nesting sites. Although the loss of nesting habitat has undoubtedly had an effect in certain regions, it is generally food availability that controls the overall population size of most penguins around South America and the Falkland Islands. Provided that food availability remains high, then penguins are generally able to tolerate increased levels of mortality and exploitation, but reductions in food availability can destroy penguin populations. This has been clearly documented in Humboldt Penguins in the Pacific Ocean, and Rockhopper and Magellanic Penguins in the Falkland Islands.

Food availability is a delicate balance, and relates not only to total food availability, but also how such food resources are distributed, and how easily they can be found. Healthy adult penguins generally have little difficulty finding sufficient food to meet their own daily needs, but there are occasions when food demands increase dramatically, such as during breeding and prior to moulting.

During the breeding season, one adult must incubate the eggs and young chicks, whilst the partner feeds at sea. Regardless of whether nesting duties change over on a daily basis, or over a longer time-scale, each penguin must nevertheless find two days worth of food for each day spent foraging. Once the chicks hatch, this demand increases still further, since the chicks must rely on food which is surplus to the adults' requirements. Rapidly growing chicks need large quantities of food to maintain their rapidly growing bodies, and unless this food supply is maintained, they will die. Each adult now needs to catch several times its normal daily requirement in order to successfully raise its brood, and yet the range over which the penguins can now forage is restricted to a radius of 30 or 40 km from the nest site.

At large breeding sites, such as Rockhopper colonies, there is considerable competition for food within the feeding grounds close to each colony. Such areas must remain highly productive if the demands of so many penguins are to be met. In general, food is rarely in sufficient abundance to meet the needs of all, and many chicks receive insufficient food and die even without commercial fishing. Food availability is the control that limits the population size of most colonies. If that food is removed, the population that can be supported will obviously decline.

In nests with two chicks, the strongest chick will grab most of the food and grow stronger, whilst the smaller chick grows weaker and dies. Inexperienced adults and adults that are getting old or sick, may have difficulty in catching sufficient food to sustain even one healthy chick. During periods of food shortage, adults can often be seen leaving tiny chicks alone in the nest so that both adults can search for food. This places the chicks in grave danger from predators, but is necessary in order to keep the chicks from starving.

In a natural state of events, the balance of chicks that survive are sufficient to replace the adults that die each year, and the population remains in a steady state. If the population is reduced, due to human exploitation or some natural disaster, then the competition for food will be reduced, allowing more chicks to survive, and hence the population increases until it is once again in balance. This control mechanism is further enhanced through the number of juveniles that survive to breed. It is a time when youngsters must rapidly learn how to feed themselves, whilst competing against experienced adults for food.

If the overall abundance of food is reduced by even a small amount, this balance of chick and juvenile survival will be tilted, and the population will decline. Adult mortality increases slightly, as the very weakest or oldest adults are unable to find sufficient food, perhaps to fatten up for their annual moult. Juvenile mortality increases significantly, as they face greater competition for existing resources from the experienced adult population. Chick production is also reduced considerably, as adults either postpone breeding, or find it more difficult to find the extra food needed to maintain their chicks.

It is through man's ability to alter the marine food chain that he has had his greatest affect on penguin populations. The Humboldt Penguin population was decimated by over-fishing of Peruvian Anchovies along the Pacific coast of Chile and Peru, and Rockhopper and Magellanic penguin populations have been decimated by commercial fishing for squid and fish around the Falkland Islands.

During 2002, Falkland Islands penguins were unable to find sufficient food to build up their body fat reserves prior to their annual moult, and starved to death in their thousands at colonies throughout the Falklands. Rockhopper Penguins were the worst affected, losing around 30% of their Falklands population as a result of this one event.

Gentoo Penguins are able to recover quite quickly from a population decline, as a result of their breeding strategies. During seasons of high food availability, breeding success can exceed 1.5 chicks per nest, and fledglings can return to begin breeding at just two years of age. This has allowed the Falklands' Gentoo population to make a recovery over recent years.

During the austral summer of 1932/33, the Government Naturalist of the Falkland Islands, Mr. A. G. Bennett, undertook a census of Falkland Island penguins, and estimated a Gentoo population of around 116,000 breeding pairs. In 1984 a population study by Dr John Croxall of the British Antarctic Survey reported a similar figure, but by 1995 the population had declined to just 65,000 pairs.

The Gentoo population still remains well below the 116,000 breeding pairs recorded in 1984, but the population has reached a new level that is in balance with the food availability existing under the current fisheries regime.

By comparison to the opportunistic breeding strategy of the Gentoo Penguin, Rockhopper Penguins concentrate on rearing one healthy chick under a wide range of conditions, and therefore display only slight increases in breeding success during years of high food abundance.

The very large Rockhopper breeding colonies create greater competition for food resources amongst members of the same colony. This may well make them more vulnerable to reductions in food availability, and might explain why the Falklands decline of Rockhoppers was so much more severe than that observed for Gentoos. Unlike Gentoos, Rockhopper Penguins are unable to change the location of their breeding sites in response to changes in food availability.

The 1932/33 census conducted by Bennett, recorded a Rockhopper population of 3 million breeding pairs. In 1984 John Croxall and the British Antarctic Survey recorded a population of 2.5 million breeding pairs, but by 1995 the population had crashed to just 297,000 pairs, a decline of 88% in 11 years.

Continued monitoring showed a slight recovery to around 350,000 pairs by the end of the 1990s, but then the massive starvation in 2002 brought that back down to below 300,000 pairs again. Populations now appear to be stable, but it is extremely unlikely that populations will ever return to their former level whilst commercial fishing continues. The population appears to have declined to the point where it is in balance with the level of food available under the current fishing regime. With careful management of commercial fishing, the remaining population of Rockhopper Penguins could perhaps exist in harmony. Unfortunately this is not the case for Magellanic Penguins.

Diet sample studies show that Magellanic Penguins have a 90% reliance on fish taken by the Falkland Islands commercial fishing industry. Magellanic Penguins have declined from 1,300,000 breeding pairs prior to commercial fishing, to just 100,000 pairs in 2020. Despite this 92% decline, populations have not reached equilibrium, and are still declining.

Comparison with populations across the water in Argentina and Chile, where commercial fishing is not permitted, supports the hypothesis that a reduction of prey is leading to poor breeding success in the Falklands. At Cabo Virgenes (Argentina) and Isla Magdalena (Chile), adults are able to find sufficient food for their chicks in about 14 to 18 hours, but around the Falklands they require an average of 35 hours. Chicks are therefore receiving half as much food in the Falklands, and research shows that chick survival is greatly reduced as a result. Magellanic Penguins now rear an average of 0.6 chicks per nest in the Falklands, compared to 1.2 chicks in Argentina and Chile. This huge reduction in breeding success is sufficient to account for the gradual decline in population, with insufficient chicks being reared in the Falklands to replace natural adult mortality.

The timing of Bennett's Falkland Islands census was particularly fortuitous, since it post-dates the end of the killing of penguins for oil, and pre-dates the establishment of a commercial fishing industry. During the

1930s, direct exploitation of penguins was limited to the taking of eggs for human consumption. Even this was generally restricted to those colonies close to settlements, and the overall impact of such a practice on the population as a whole would have been minimal, especially when one considers the huge quantity of eggs taken by natural predators.

Despite the slaughter of so many penguins for oil during the 19th and early 20th Century, penguin populations still remained healthy during Bennett's census of 1932/33. Yet within just a few years of the establishment of the commercial fishing industry, Rockhopper and Magellanic penguin populations collapsed.

Other than through the depletion of food resources by commercial fishing, man has never greatly impacted on the Falklands' penguin populations, not even during the mass killing of penguins for oil. Other species that rely on fish also collapsed. The Southern Sea Lion population now stands at just 1% of its former level. Elephant Seals have also declined by around 90%. Sealions and Elephant Seals both feed primarily on fish and squid taken by commercial fishing.

Out of a total of seven main species of penguin and seal in the Falklands, five compete with the commercial fishing industry for food (Gentoo Penguin, Rockhopper Penguin, Magellanic Penguins, Elephant Seal, Southern Sea Lion), and two do not (King Penguin and Fur Seal). The five species that do compete with commercial fishing all suffered major population declines following the establishment of the Falklands fishing industry. The two Falklands species which do not compete for food with commercial fishing (King Penguin and Fur Seal) have both increased in number over recent years.

The last few years have seen a big increase in the number of wildlife tourists, not just in the Falklands and Galapagos Islands, but throughout South America, and naturally penguins feature highly on the agenda. In actual fact, penguins are highly adaptable to human presence, and this makes them ideally suited to tourism. Provided that tourists remain just a few metres outside the periphery of the nesting area, penguins will readily go about their business without concern. This is especially so for colonies that regularly have visitors, since the penguins readily become accustomed to human presence. Very often penguins will approach tourists in order to get a better look at these strange beings.

The author has carried out numerous studies to investigate differences in breeding success between colonies which receive large numbers of tourists, and those which have no tourism. Perhaps surprisingly, there is no apparent decrease in breeding success for colonies with tourists, provided that people do not enter the nesting area, and a number of sites show slightly higher breeding success as a result of tourism.

The natural predators of penguin eggs and chicks, such as skuas, caracaras, and foxes, are kept at bay by human presence. Penguins close to tourist paths show slightly higher breeding success than penguins without tourists, allowing penguins to raise more chicks in the presence of well-controlled tourism. Only a very small percentage of breeding sites are actually visited by tourists.

A penguin colony is an amazing place. It is never still; always full of hustle and bustle, adults coming and going, calling, squabbling, and dashing about on errands that to our eyes seem completely random. The chicks look so comical too, having bodies that seem out of proportion with their legs. During the early stages of development they are little more than stomachs on legs, with open beaks demanding ever more food to be stuffed inside.

For all their comical mannerisms, penguins are perfectly adapted to the environment in which they live; a half-life between land and water. Of all the animals that live on both land and in the ocean, penguins are perhaps the most successful at adapting to both. They can out-swim most fish, and out-run many a man. They can survive in the coldest climates on earth, and on the equator.

But for all their hardiness, penguins are still very vulnerable. Their success ultimately depends on being able to find sufficiently high concentrations of fish to survive and to raise young. If food resources are respected and protected, penguin populations are able to survive moderate levels of exploitation and disturbance, however when food resources are reduced the inevitable result is the decline of the penguin.

For species that are widespread and numerous, events that impact on the population in one area may not threaten the overall population if other areas remain unaffected. The Southern Rockhopper and Magellanic Penguins, whose populations have crashed in the Falkland Islands, have remained largely unaffected throughout their breeding range in South America.

Species which have a limited distribution, however, are very vulnerable to changes to their ecosystem. The entire world Galapagos Penguin population was hit hard by a single ENSO event of 1982/83, and whilst struggling to recover, it was then hit by oil pollution from a tanker that ran aground in 2001. Similarly the Humboldt Penguin has declined sharply as a result of over-fishing of Peruvian Anchovy stocks during the 1970s, and its population is further threatened by a multitude of man-made changes to its breeding environment.

Given half a chance, penguins are very able to adapt to human disturbance, but we need to be aware of their needs, and of how easily we can disrupt fragile ecosystems. Continued monitoring and research is essential in gauging the health of penguin populations, and for identifying conflicts with human needs at an early stage, so that the consequential damage of our activities can be minimised.

Nevertheless, penguins are far more than a subject for study. They are a valued part of our natural world. They hold a place in the hearts of children, and act as monitors of the health of our southern oceans. They are an important link in the ecosystem of our planet, and so are we. The world is left poorer for the passing of a single species, and yet this power lies in the hands of each and every one of us.

Whilst human populations increase, and our thirst for natural resources continues, then conservation may amount to no more than rearranging the furniture on the *Titanic*. It is all too easy to think that our own individual life styles contribute little, or that we will change when others do, but each grain of sand makes up the beach.

Part 4: Relevant Publications

Article 1.

Bingham M. (2002) The decline of Falklands penguins in the presence of a commercial fishing industry.
Revista Chilena de Historia Natural 75: 805 - 818.

SUMMARY

The Falkland Islands are an important breeding site for three species of penguin, Gentoo (*Pygoscelis papua*), Southern Rockhopper (*Eudyptes c. chrysocome*) and Magellanic penguin (*Spheniscus magellanicus*). The total penguin population for the Falkland Islands has declined by 84% during the 1980s and 1990s. These declines did not occur in coastal South America, so potential causes of decline in the Falklands have been investigated.

The suspected cause of decline is a reduction of fish and squid due to large-scale commercial fishing around the Falklands. Since 1995 Rockhopper and Gentoo populations have ceased declining, and appear to have reached a new equilibrium, albeit at a much lower level than before commercial fishing began. This has been matched by improved chick-rearing success and juvenile survival, however Magellanic penguins continue declining in the Falklands. Diet analysis shows that Magellanic penguins have a greater reliance on squid and fish species being taken commercially.

In 1998 drilling for oil began around the Falklands, despite warnings that environmental protection was inadequate. Within a month the first of three separate oil spills occurred, killing and contaminating hundreds of penguins. The oil rig completed its drilling operations after five months and left the Falklands. Since then no further oil spills have occurred. Oil exploration is due to recommence in the near future, and environmental safeguards have not been improved.

Ecotourism has increased rapidly over recent years in the Falklands, with penguins being the main attraction. Monitoring of the affects of tourism has concentrated on breeding success and population change, and the results indicate no detrimental affects on penguin populations at the current level.

This paper investigates potential causes of penguin decline in the Falkland Islands, drawing comparison with populations in Chile which appear to be healthy. It concludes by calling on the Falkland Islands Government to exclude large-scale commercial fishing close to penguin breeding sites.

INTRODUCTION

The Falkland Islands lie in the south-west Atlantic, 450km north east of the southern tip of South America. The archipelago is made up of over 700 hundred islands, comprising a total land area of over 12,000 sq km. The irregular shape and large number of islands, gives the Falklands a very long coastline in relation to its land area, providing a wide variety of coastal habitats (Figure 1). This varied habitat, combined with the productive waters of the Patagonian shelf, make the Falklands a good place for seabird reproduction and feeding, especially for albatross, cormorants and penguins.

Five species of penguin breed in the Falkland Islands - King penguin (*Aptenodytes patagonicus*, Miller 1778), Gentoo penguin (*Pygoscelis papua*, Forster 1781), Southern Rockhopper penguin (*Eudyptes c.*

chrysocome, Forster 1781), Macaroni penguin (*Eudyptes chrysolophus*, Brandt 1837) and Magellanic penguin (*Spheniscus magellanicus*, Forster 1781). During the 1980s and early 1990s populations of Gentoo, Southern Rockhopper and Magellanic penguins declined dramatically in the Falklands.

A lack of comparative data made it impossible to determine whether such declines were part of a regional trend, or whether they were due to circumstances pertaining to the Falklands. There was also a lack of basic research data with which to determine the extent to which human activities (such as commercial fishing, tourism, oil exploration and removal of eggs for human consumption) were contributing to the decline. Since the late 1980s, penguin populations around the Falklands have been studied in order to address these issues. This paper looks at the evidence of population decline in the Falklands, and investigates the role of human activities, using comparative data from South America.

MATERIALS & METHODS

In the austral summer of 1995/96, an island-wide penguin census of the Falkland Islands was conducted. All species were counted except for the Magellanic penguin, which was not included because of the difficulties of conducting a census on a species that nests in burrows.

For Gentoo and Rockhopper penguins, nest counts were made to determine the number of breeding pairs. Counts were timed to correspond with the end of the egg laying period, thereby ensuring that few pairs were still to lay, and allowing an assessment to be made of the underestimate due to pairs failing, by using failure rates during incubation from other studies.

Gentoo penguins concluded their first egg-laying by the end of October 1995. The 1995/96 census counted 15% of the Gentoo population between 15th and 31st October, and the remainder between 1st November and 1st December. Because Gentoos failing early tend to re-lay, and failure rates during incubation are low (c. 1% per week), the magnitude of any underestimates resulting from differences in survey dates should be well below 5%.

Rockhopper penguins are much more synchronous in terms of egg-laying than Gentoo penguins. Laying was concluded by mid-November 1995, and the 1995/96 census counted 98% of the Rockhopper population between 1st November and 1st December (2% between 2nd and 18th December). Repeated counts of Rockhopper colonies in previous years showed that nest counts drop at a rate of about 3% per week for the first month after egg-laying, as a result of failed nests. It is therefore unlikely that the average underestimate of Rockhopper population exceeded 10%.

For most Rockhopper and all Gentoo breeding sites, the recorder made two separate counts of all occupied nests using a tally counter. The mean of the two counts was taken as the number of breeding pairs. Where these counts differed by more than 10%, a third count was taken to give a mean of three counts. In practice this was rarely necessary, and the spread of results was usually well within plus or minus 5%.

For the very large Rockhopper colonies on Steeple Jason, Grand Jason, Bird Island and Beauchene Island, direct ground counts were not possible. These sites were counted using a total of 60 randomly selected sample plots to determine the range of nesting densities, and the areas of the colonies were determined to enable estimates of total breeding pairs. A minimum of 10% and a maximum of 15% of the total colony area was sampled at each of the sites. These measurements of area and density taken during the site visits were later compared against aerial photographs taken of the colonies. The margin of error for this methodology is greater than for direct counts, but should be within plus or minus 10%.

The breeding cycle of the King penguin is different from that of Gentoos and Rockhoppers, with chicks over-wintering at the colony, and a complete breeding cycle lasting over a year. This tends to result in individual birds having their following breeding cycle out of phase with its predecessor; thus large chicks and eggs both occur in a colony at the same time. This complicates assessment of breeding pairs, so chick counts were taken instead. The estimation of error for chick counts is well below 5%, but will under estimate the number of breeding pairs by about 20% (Lewis Smith & Tallowin, 1979).

Between 1989 and 2002, a total of 40 breeding sites (one King, 21 Gentoo, 8 Rockhopper and 10 Magellanic) were counted annually in the Falklands to determine changes in population size. For King, Gentoo and Rockhopper penguins these counts were conducted as described above. Because Magellanic penguins nest in burrows in the Falklands, nest counts were conducted by examining each burrow within the colony for signs of nest occupation and breeding activity. For difficult burrows the use of a video camera on a long pole was employed to determine the presence of an active nest. Each burrow occupied by a breeding pair was marked with a small spot of paint during the count to prevent double-counting.

Annual chick counts were also made at each of the study sites prior to fledging, in order to determine annual breeding success. Breeding success was determined by conducting nest counts within the colony at the onset of incubation, as described above. Each colony was then revisited just prior to fledging, and all chicks within the colony were counted. Two counts were made using a tally counter, with a third count being made where the first two results differed by more than 10%. Breeding success was taken as the mean number of chicks recorded within the colony divided by the mean number of occupied nests recorded at the start of the season (chicks per breeding pair).

For Magellanic penguins around 250 occupied burrows were also marked with names or numbers, and visited an average of three times per week from October to March, in order to record egg/chick progress and to determine the causes of egg/chick loss. Eggs that failed to hatch were later examined to determine the stage of embryo development, and dead chicks were removed from the burrows for measuring and weighing, and to assess the causes of death where possible. Fledglings were weighed prior to departure from the colony, by suspending birds from a spring balance using a soft cotton loop around the legs.

Some adults were marked in their burrows using red and blue animal marker crayons on long poles, so that each partner could be identified during hourly observations. These markings were placed on the throat where they were easily visible during nest inspections, and where they could not be easily removed during preening. Hourly observations recorded time spent in and away from the burrow for each partner during incubation and chick rearing.

In addition to monitoring overall population trends and breeding success, comparisons were made to determine the effects of human activity in the Falklands. Population trends and breeding success were compared for colonies which are actively promoted by the Falkland Islands Tourist Board as official tourist destinations, and for colonies which are not visited by any tourists, in order to investigate the impacts of tourism. The Falkland Islands Government also permits the removal of Gentoo penguin eggs for human consumption. Unlike most other penguins, Gentoos will readily re-lay after loosing their clutch, leading to claims by farmers that the removal of eggs does not harm the species. Comparisons of population trends and breeding success were made for colonies where eggs are harvested for human consumption, and for colonies from which no eggs are taken, in order to evaluate the impact of egging.

Each year diet samples were taken of Gentoo, Rockhopper and Magellanic penguins using the stomach-flushing technique described in Wilson (1984). Samples were taken during incubation and chick-rearing, from adults returning to the colony after foraging. Samples sizes varied from year to year, but average around 25 individuals per year for each species.

Stomach samples were drained and stored in jars with formaline solution or alcohol, ready for later examination. Once in the laboratory the stomach samples were rinsed with water, drained to remove any excess liquid, and weighed to determine the wet weight of food retrieved. Each sample was then divided up into its appropriate components, which were weighed individually to determine proportional dietary composition by wet weight. Fish otoliths, cephalopod beaks and crustacean carapaces (which are not easily digested) were used to aid species identification, and to estimate proportional composition. These data were then compared with fisheries catch statistics in order to determine the level of overlap between penguin diet and commercial fishing activities (Falkland Islands Government 2001).

From 1998 diet sample analysis in the Falklands was taken over by Dr A. Clausen of Falklands Conservation (Clausen 2000), although the methodology remained unchanged (Wilson 1984).

During the austral summer of 1996/97, a penguin census was conducted in South America, in order to determine whether penguin declines in the Falklands had occurred elsewhere. It had been shown during the 1995/96 census of the Falkland Islands that it requires little extra effort to count all penguin species during the course of such a census. The only exception was the Magellanic penguin. Its widespread, low-density distribution in burrows made it impossible to census with methods employed for surface nesting species. For this reason it was decided that the 1996/97 census would include all South American penguins, except for those of the Genus *Spheniscus.* .

During the 1995/96 Falkland Islands census it had been possible to conduct ground counts of incubating pairs at each of the breeding colonies, because most colonies were relatively accessible. By contrast, many of the South American colonies are remote and inaccessible, and any attempt to conduct ground counts of each and every colony would have been doomed to failure. It was therefore decided from the outset that the census would be conducted by light aircraft, thereby negating the need to get ashore at difficult and remote sites.

The location of all the Falkland Islands breeding sites had been known prior to the commencement of the 1995/96 census, but this was certainly not the case for South America. Although data did exist for a number of known breeding sites around South America (Frere et al. 1993, Venegas 1984, 1991, Woehler 1993), it was likely that other sites existed which had not been previously recorded. This was another reason for favouring an aerial census, since it provided the opportunity to cover large areas of suitable coastline in search of previously unrecorded colonies. This reduced the margin of error that would otherwise have arisen from new sites being overlooked, however the margin of error for aerial counts was higher than for ground counts.

In order to quantify the margin of error likely to be expected from aerial counts, a number of aerial censuses were made of Rockhopper colonies in the Falkland Islands for which the number of breeding pairs was also determined by ground counts. These aerial counts differed by a maximum of 14% from ground counts made of the same colony, giving a total margin of error of +/- 20% for aerial census data.

The 1996/97 aerial census was conducted throughout the known *Eudyptes* breeding ranges of Chile and Tierra del Fuego. The Atlantic coast of mainland Argentina was excluded from the census, since this coastline has been well studied, and does not hold any breeding sites for species covered by the census, except for a very small Rockhopper colony on Isla Pingüino, near Puerto Deseado (Frere et al. 1993). This colony is regularly monitored as part of an ongoing research programme, and population data from their research was used in favour of duplicating results.

Since 1997 the annual monitoring of Magellanic penguins has been extended to include colonies in southern Chile, in order to compare annual population trends, breeding success, foraging behaviour and diet composition between the Falkland Islands and Chile.

RESULTS

The 1995/96 Falkland Islands census recorded 65,000 breeding pairs of Gentoo penguins at 81 breeding sites (Figure 2). This represents a decline of around 45% since the early 1980s (Croxall et al. 1984). A repeat census by Falklands Conservation in 2000/01 (Clausen 2001) shows a population recovery to around 113,000 breeding pairs, equivalent to about 35% of the world population, last estimated at 320,000 breeding pairs (Woehler 1993).

The 1995/96 Falkland Islands census recorded 297,000 breeding pairs of Southern Rockhopper at 36 breeding sites (Figure 2). This represents an 88% decline since the early 1980s (Croxall et al. 1984). A repeat census by Falklands Conservation in 2000/01 (Clausen 2001) recorded a population of 272,000 breeding pairs. The current Falklands population represents about 60% of the world population, with the remaining 40%

located at 15 breeding sites in Chile and Argentina (Bingham & Mejias 1999).

Although an island-wide census has never been conducted for Magellanic penguins, annual counts since 1989/90 indicate that Magellanic penguins have undergone a 76% decline in the Falklands between 1989/90 and 2001/02 (Figure 2). No data exists prior to 1989/90, but since Gentoo and Rockhopper penguins underwent their greatest declines during the 1980s, it is likely that the overall decline of Magellanic penguins is much greater than the 76% recorded. Unlike Gentoo and Rockhopper penguins, Magellanic penguins are still declining.

Gentoo penguins have averaged 0.84 chicks per breeding pair since studies began in 1990/91 (n = 12, S.D.= 0.21). Prior to 1993/94 the average was 0.73 chicks per breeding pair, but between 1993/94 and 1999/2000 the average increased to 0.99 chicks per breeding pair (Figure 3). A Mann-Whitney *U* test showed this difference to be significant at the 5% level. Gentoo populations stopped declining around 1993/94, and by 2000/01 they had recovered to their pre-fisheries level of around 115,000 breeding pairs (Croxall et al. 1984, Bennett 1933). Since then breeding success has slumped to an average of only 0.59 chicks per breeding pair, with the last two seasons data showing the lowest breeding success ever recorded.

Magellanic penguins have averaged 0.71 chicks per breeding pair since recording began in 1989/90 (n = 13, S.D.= 0.25). Prior to 1992/93 the average was 0.43 chicks per breeding pair, but between 1993/94 and 1999/2000 the average increased to 0.92 chicks per breeding pair (Figure 3). A Mann-Whitney *U* test showed this difference to be significant at the 5% level. Despite this improvement in breeding success, Magellanic penguins have continued to decline in the Falkland Islands, and over the last two seasons breeding success has averaged just 0.53 chicks per breeding pair, the lowest level since 1992/93.

Magdalena Island and Seno Otway are the closest major Magellanic penguin colonies to the Falkland Islands with comparable breeding conditions (ie. nesting occurring in burrows as per the Falklands). Monitoring began at these two sites in 1996/97 to provide comparison with the Falklands. Magdalena Island and Seno Otway are situated in areas where large scale commercial fishing does not occur. Commercial fishing did occur around Magdalena Island until a few years ago, since when fishing has been banned in order to protect penguin populations (Radl & Culik 1998). These colonies have shown increases in Magellanic penguin population since studies began in 1996/97, using identical methodology to that which has shown a population decease in the Falklands.

Breeding success for Magellanic penguins has averaged 0.71 chicks per breeding pair in the Falklands (n = 13, S.D.= 0.25) (Figure 3), whilst the two Chilean sites have averaged 1.40 chicks per breeding pair (n = 10, S.D.= 0.08) (Figure 4). A Mann-Whitney *U* test showed these differences to be significant at the 5% level, with the lowest value for Chile being higher than the highest value for the Falklands.

Comparison shows that lower breeding success in the Falklands results from a two fold increase in nest abandonment during the incubation phase, and a two and a half fold increase in chick mortality after successful hatching (Figure 5). This increase in chick mortality in the Falklands was due to increased levels of starvation and malnutrition. Chick mortality during hatching showed no difference between Chile and the Falklands.

Fledgling weights averaged 3.3kg in Chile, but only 2.7kg in the Falklands, differing significantly at the 5% level using a Mann Whitney *U* test. Chicks in the Falklands fledge around 10 days later than in Chile. Mean foraging duration during chick rearing averaged 33.9 hours in the Falklands, and 13.5 hours in Chile, differing significantly at the 5% level using a Mann Whitney *U* test.

Since recording began in 1993/94, Rockhopper breeding success has remained within the range of 0.63 to 0.80 chicks per breeding pair, with an overall average of 0.73 chicks per breeding pair (n = 9, S.D.= 0.05) (Figure 3). A lack of data makes it impossible to determine whether Rockhopper breeding success was lower prior to 1993, during their rapid population decline. However prior to 1995 virtually no juveniles were returning to undertake their annual moult, suggesting low overall recruitment.

In addition to the three main penguin species, the Falkland Islands have small numbers of King and Macaroni penguin. The 1995/96 penguin census recorded 339 King penguin chicks, which allowing for losses during incubation and chick-rearing, and the staggered breeding cycle, gives an estimated Falklands population of around 400 breeding pairs. This is a tiny proportion of the estimated 1,500,000 breeding pairs world-wide (Woehler 1993). The 2000/01 census recorded 275 chicks (Clausen 2001), a reduction of 19% since 1995/96.

There are no Macaroni penguin colonies in the Falklands, but a few Macaroni penguins breed in Rockhopper colonies around the islands. The total population of Macaroni penguins is estimated to be no more than 50 breeding pairs (Bingham & Mejias 1999). Two very small breeding colonies of Gentoo penguins were found in South America, on Staten Island (about 30 breeding pairs) and on Hammer Island, near Ushauia (about 5 breeding pairs). These are the first breeding Gentoos recorded for South America, but other small colonies probably await discovery.

Studies of breeding success in the Falklands showed no harmful effects from tourism or the removal of Gentoo eggs for human consumption (Figure 6). (NOTE: only Gentoo eggs can be legally taken in the Falklands, as they are the only Falklands penguin that can re-lay after loosing the first clutch of eggs.)

Diet sample analysis shows that Gentoo, Rockhopper and Magellanic penguins all rely on species of fish and squid that are currently taken commercially by the Falkland Islands' fishing industry, especially loligo squid (*Loligo gahi*, d'Orbigny 1835) and blue whiting (*Micromesistius australis*, Norman 1937) (Falkland Islands Government 1989, 2001). These species make up a small proportion of the diet of Gentoos (5.9% of observed diet) and Rockhoppers (10.2% of observed diet), but 26.5% of the observed diet of Magellanic penguins (Table 1). Magellanic penguins continue to decline, while Gentoo and Rockhopper penguins appear to have stopped declining.

For all three penguin species, the observed level of competition with commercial fisheries will be an under-estimate. If there were no commercial fishing activity the abundance of loligo squid and blue whiting would be considerably higher. Since penguin diet in the Falklands has only ever been studied under conditions of reduced abundance of commercially harvested species due to commercial fishing, the importance of such species to penguins under natural conditions will be greatly under-estimated.

Further analysis shows that as the decline of Gentoo and Rockhopper penguins bottomed out in the mid 1990s, a gradual change of diet occurred, with less loligo squid being taken. Magellanic penguins have also shown a change in diet away from loligo squid, but Magellanic penguin populations have continued to decline despite this change.

DISCUSSION

The Falkland Islands is an important breeding site for Gentoo, Southern Rockhopper and Magellanic penguins, but over the last 20 years all three have undergone population declines in the Falklands. Despite a recent recovery in the Gentoo penguin population, total penguin populations in the Falklands now total just 16% of that estimated 20 years ago. This decline coincides with the development of a large scale commercial fishing industry around the Falkland Islands over the same time scale.

Southern Rockhopper and Magellanic penguins are only found in the Falkland Islands and southern South America, but population declines appear to have occurred only in the Falkland Islands. Census and monitoring work in Chile indicates that Southern Rockhopper and Magellanic penguin populations in Chile are stable, despite their close proximity to the Falklands.

Rockhopper penguins do not change the location of their breeding sites, so prolonged occupation kills off grasses and other vegetation, leaving bare ground and lichen covered rock. In the Falkland Islands most Rockhopper colonies are now found amidst much larger areas of bare ground, where vegetation has been destroyed by colonies that were once much larger. They appear rather like ponds that have dried out to leave a small puddle at the centre. These visual signs of large-scale decline are supported by census data, which shows the current Rockhopper population in the Falklands to be just 11% of that recorded 20 years ago (Figure 2).

By contrast most colonies in South America occupy the entire area laid bare, and new nesting areas can be found where vegetation has not yet been destroyed. On Staten Island (Isla de los Estados) colonies have expanded at such a rate that large numbers of Rockhoppers are nesting in dense grass which has not yet been killed off by nesting activity. These visual signs suggest that the South American population has remained stable, or in the case of Staten Island, undergone a rapid increase. It is possible that some emigration has occurred from the Falkland Islands to sites on coastal South America, such as Staten Island.

There is no data on Rockhopper breeding success prior to 1993, since when populations in the Falklands appear to have stopped declining, and reached equilibrium. There is however strong observational evidence that recruitment was very low in the Falklands prior to 1995. For both Rockhopper and Magellanic penguins, juveniles and non-breeders return to moult at their breeding site during January and February, a time when colonies are being monitored to conduct chick counts. Virtually no Rockhopper or Magellanic penguin juveniles were observed around the breeding colonies during studies prior to 1995, suggesting very low juvenile survival, despite the fact that colonies had been observed producing fledglings during previous seasons. Since 1995 an increase in juveniles has been observed for Rockhopper penguins, but not for Magellanic penguins. Colonies monitored in Chile have shown healthy numbers of juveniles each year.

Breeding success for Magellanic penguins has been recorded annually since 1989 in the Falkland Islands where large-scale commercial fishing occurs, and since 1996 for two sites in southern Chile, where large-scale commercial fishing is prohibited in order to protect penguins. Breeding success in the Falkland Islands has averaged 0.71 chicks per breeding pair (Figure 3), whilst the average for the two Chilean colonies has been 1.40 chicks per breeding pair (Figure 4). Large variations in breeding success are usually associated with changes in food availability (Boersma et al. 1990), and for the Falklands the main factor influencing breeding success and recruitment is assumed to be local food supply (Putz et al. 2001).

Low breeding success in the Falklands results from greater nest abandonment during egg incubation, and higher chick mortality resulting from starvation and malnutrition (Figure 5). Surviving chicks in the Falkland Islands are of poor body condition and low weight at the time of fledging (average 2.7kg) compared to Chile (average 3.3kg). This suggests that no only do fewer chicks fledge in the Falklands, but that fledglings also have a lower chance of surviving their first year by virtue of being less well nourished. Comparison of juvenile numbers returning to their natal colony to moult support this theory. On Magdalena Island over four thousand juveniles are counted on the beach each year, whilst in the Falkland Islands very few juveniles are ever seen.

Gentoo, Rockhopper and Magellanic penguins all compete directly for loligo squid (*Loligo gahi*) with the Falkland Islands fishing industry (Putz et al. 2001). These penguins also take blue whiting (*Micromesistius australis*) which is the main fish species targeted by the Falkland Islands fishing industry. Dietary overlap for commercially taken species is greatest for Magellanic penguins which are still declining rapidly, less for Rockhopper penguins which have levelled off at around 11% of their pre commercial fishing population, and lowest for Gentoo penguins which have recovered following an initial decline.

Over the last 10 years, the Falklands have experienced dietary changes in all three penguins away from *Loligo gahi*. Putz (2001) suggests that these dietary changes have been forced by reduced abundance of *Loligo gahi*. These changes may be harmful in terms of chick survival, since lobster krill, (*Munida gregaria*, Fabricius 1793), which now makes up one fifth of Magellanic penguin diet in the Falklands, is not easily digested by Magellanic penguin chicks (Thompson 1993). The theory that Magellanic penguins prefer not to take *Munida gregaria* if more suitable prey are available, is supported by diet sample studies in Chile. Magellanic penguins at the two Chilean study sites show a complete lack of *Munida gregaria* in their diet, even though *Munida gregaria* are present in great abundance, forming a major part of the diet of King Cormorants nesting on nearby Marta Island (Radl & Culik 1998).

Not only does the removal of preferred prey force penguins to feed their chicks less favourable species, but it can also lead to greater foraging duration, with chicks receiving less food (Radl & Culik 1998). This increase in foraging duration is evident around the Falklands.

At the two Chilean study sites, where large-scale commercial fishing is no longer permitted, Magellanic penguins average 13.5 hours to return with food for their chicks (Radl & Culik 1998). In the Falkland Islands, foraging trip duration averages 33.9 hours. This huge increase in foraging duration coincides with a 50% reduction in breeding success, higher chick starvation, lower fledging weight, and a substantial reduction in juvenile survival, compared to populations in Chile.

Reproductive success depends on food availability (Crawford & Dyer 1995), and competition for food with commercial fisheries is a recognised cause of population decline in other regions (Brown & Nettleship 1984, Culik & Luna Jorquera 1997, Duffy et al. 1987). Breeding success and fledging weights are recognised bioindicators for monitoring the marine environment and marine food supplies (Cairns 1987, Furness & Camphuysen 1997), and Magellanic penguins suggest that the marine environment around the Falkland Islands may be in poor health.

Prior to 1988 fishing around the Falkland Islands was intensive and totally unregulated, threatening fish and squid stocks (Patterson 1987). No catch data or diet sample data exists for this period, during which huge penguin population declines occurred. Following a mass starvation of penguins in 1986, when many Rockhopper colonies lost over half their adult population (Keymer et al. 2001), it was agreed that commercial fishing around the Falklands needed to be regulated. This regulation was introduced in 1988, since when catch rates have gradually been reduced by controlling the number of boats licensed to fish (Falkland Islands Government 1989, 2001).

For squid, the catch rate per unit effort of fishing vessels is now monitored on a daily basis to determine when the target of 60% biomass has been removed each year. The remaining 40% biomass is deemed by the Falkland Islands Government to be adequate as prey for seabirds and marine mammals, and as breeding stock for the following season. Whilst this may ensure sustainable use of stocks as a financial resource, it seems unreasonable to suppose that 60% of the biomass can be removed prior to the breeding season of seabirds and marine mammals, without having an impact on those species which rely on such prey for successful breeding.

Diet sample analysis shows that there is competition between penguins and commercial fisheries for loligo squid (*Loligo gahi*) (Putz et al. 2001) and potential competition for blue whiting (*Micromesistius* *australis*) (Table 1). Since diet samples have only ever been taken in the presence of commercial fishing activities, the proportion of commercially harvested species found in penguin diet will be greatly reduced. Diet analysis will therefore greatly under-estimate the level of competition between penguins and commercial fisheries.

Any competition for food is likely to be exacerbated by the fact that the commercial fishing season runs until the end of October, when penguins and other seabirds begin breeding. Since stocks are managed by recording the daily decline of catch per unit effort, it stands to reason that penguins will also encounter this decline in catch per unit effort as they enter their breeding phase.

Breeding places great demands on adult penguins to find sufficient food for themselves and their chicks. Each adult must first catch sufficient food for its own needs, and a surplus for its chicks, at a time when its foraging range is greatly reduced by the need to return to the nest. A reduction in food abundance can therefore lead to greater foraging duration, less food being brought back to chicks, and reduced chick survival.

It is probable that the rapid penguin declines observed in the Falklands during the 1980s were a result of uncontrolled commercial fishing. Elephant Seals and Southern Sealions, which also feed on species taken by the commercial fishing industry, also underwent huge population declines in the Falklands during the same period (Galimberti 2000, Strange 1992, Thompson & Duck 1996). As is the case for penguins, these species also occur in South America where no such declines occurred. King Penguins and Fur Seals which feed on prey not commercially harvested, increased in population around the Falklands over the same period.

During the late 1970s and early 1980s, fish and squid stocks were heavily fished without any monitoring or control. In 1986 a lack of food led to mass starvation of adult penguins, and public concern called for controls over commercial fishing. Following the establishment of a regulatory body in 1988, the effects of over-fishing have been greatly mitigated through reduction of fishing effort and control of species taken.

Chick and juvenile survival have shown some signs of improvement, and Gentoo and Rockhopper populations have stopped declining. These populations appear to have reached equilibrium with the current fishing regime, albeit at a much lower level than prior to the 1980s. Magellanic penguins have continued to decline however, and it is likely that their greater dependence on species which are still commercially harvested is a major factor.

Concerns about the removal of Gentoo penguin eggs for human consumption were not borne out by the data, which suggest little effect on breeding success. Unlike most other penguins, Gentoos have the ability to relay within a few days of loosing their clutch. This enables them to rear chicks successfully after losing their first brood. Although egging could hardly be advocated by any conservationist, in the Falklands it is a tradition which is gradually dying out, due to an improved infra-structure that allows people in remote areas to purchase a wider range of food items. Conservationists have taken the view that it is preferable to let the tradition die a natural death, rather than risk a resurgence by threatening people's right to continue the practice.

Tourism is another potential cause for concern. The Falkland Islands are now one of the world's most popular destinations for penguin spotters, and this growing tourist industry is a potential threat to Falklands penguins. The Falkland Islands received around 35,000 visitors during the 2001/2002 season (Fowler 2002).

Over recent years a number of scientific reports have demonstrated that even well-behaved visitors can cause stress and increased heart-rate in penguins and seabirds, but these factors are not necessarily harmful to the bird or its fecundity. Seabirds are subjected to varying levels of stress in their natural environment, so it was important to monitor the effects of tourism in its wider perspective, by conducting long-term studies of population trends and breeding success. Breeding success in particular provides a useful measure of visitor disturbance. Careless visitors have the potential to disturb breeding penguins in a number of ways:

- Incubating birds may be frightened away allowing predators to take eggs or young.
- Raised metabolic rates brought on by stress may lead to greater food requirement.
- Natural behaviour, such as courtship or the feeding of young, may be disrupted.
- Adults could be scared away completely, causing them to abandon eggs or young.
- Severe disturbance could lead to adults or young being killed or injured.
- Birds which live in burrows may be killed if the burrow collapses under human weight.

These potential consequences of disturbance should all lead to reduced breeding success if they are occurring at a significant level, however studies of penguin breeding success in the Falklands and southern

Chile show no harmful effects from tourism so far. Other penguin studies have reached similar conclusions (Cobley & Shears 1999).

Ecotourism undoubtedly has a number of benefits. It provides wildlife with a commercial value, giving support for its protection within the commercial sector. It also educates and entertains the people who see the wildlife, raising awareness and gathering support for wildlife protection within the community as a whole. It is difficult to provide strong argument for wildlife protection unless people can relate to wildlife on a personal level. It is therefore important to promote ecotourism, whilst at the same time ensuring that such tourism does not damage the wildlife resources which people come to see.

There are clearly a number of threats facing penguin populations in the Falkland Islands, but penguin populations appear very robust to disturbance and moderate levels of exploitation on land. Major changes to the landscape brought about by livestock, the removal of eggs for food, and exploitation as a resource for tourism, all appear to have had low impact on penguin populations in the Falklands. Marine pollution around the Falklands has so far been limited to a spate of oil spills that occurred during drilling operations in 1998, and high levels of cadmium common to the Antarctic region in general, that may be due to natural factors (Keymer et al. 2001). The only major predators of penguins, Southern Sealions, have suffered a 97% decline in the Falklands (Thompson & Duck 1996) making them an unlikely cause of penguin decline.

Even in a healthy population, starvation is the main cause of chick mortality for Magellanic penguins (Scolaro 1990, Boersma footnote 1), and in the Falkland Islands low breeding success, high chick mortality, low fledging weight and low recruitment are largely due to low food supply (Putz et al. 2001). On at least one occasion this low food supply has also led to mass starvation of adult penguins (Keymer et al. 2001).

Whilst it is unrealistic to expect the Falkland Islands Government to halt commercial fishing activity, which is a major source of revenue to the islands, minor changes could be adopted which would mitigate the effects of commercial fishing on penguin populations, without greatly effecting revenue. At present commercial fishing vessels are permitted to fish within 3 miles (5km) of the coastline, even where penguin breeding sites are located. It was proposed at the Spheniscus Penguin Conservation Workshop (September 2000, Chile) that fishing vessels in the Falkland Islands should be excluded from within 30 miles (48km) of penguin breeding sites during the breeding season. Such measures would protect feeding areas within the penguins' daily foraging range, whilst reducing the total area available to fishing vessels by just 4%.

Satellite tracking has shown that around the Falkland Islands, Magellanic penguins have a mean foraging range of about 16km during incubation, and 7km during chick rearing, with a maximum distance of 39km being recorded during chick rearing. Gentoo penguins have a mean foraging range of 6km, with a maximum of less than 25km being recorded (Boersma et al. 2001). These foraging distances lie well within the 30 mile (48km) exclusion zone requested at the Spheniscus Penguin Conservation Workshop. Rockhopper penguins were recorded foraging outside the requested exclusion zone, with short foraging trips averaging less than 6km, being supplemented by long distance foraging trips of well over 100km. Even so Rockhoppers made more use of inshore waters during the critical chick-rearing stage (Boersma et al. 2001).

Magellanic penguins fitted with time-depth recorders at the two Chilean study sites showed similar results, with foraging beginning at around 7km from the breeding site. Mean foraging range was 25km, and maximum foraging ranges for the two sites were 33km (Seno Otway) and 47km (Magdalena Island) (Radl & Culik 1998).

Inshore fishing around the Falklands has a negative impact on Gentoo, Rockhopper and Magellanic penguins (Boersma et al. 2001). It is therefore probable that if a fishing exclusion zone were established around penguin breeding sites in the Falkland Islands, as has been done around Magdalena Island in Chile, that this would allow an increase in food availability within the penguins' foraging range. This in turn should lead to a decrease in foraging duration, an increase in food brought back to chicks, and an increase in chick survival and fledging weights, as has been observed since the exclusion of large-scale commercial fishing from around Magdalena Island. The exclusion of fishing would only be required just prior to and during the breeding season, and it might also help protect Falklands penguins from their other major threat, marine pollution.

During 1998 an oil rig was sent to the Falkland Islands to look for oil. During the five months of operation 3 separate oil spills occurred killing hundreds of penguins. It is unlikely that the oil came from the rig itself, which claimed never to have found oil in commercially viable quantities. The oil is presumed to have come from oil rig supply vessels operating in Falkland waters at the time. No further oil spills have occurred since the oil rig and its supply vessels left the Falklands.

In 1995 the United Kingdom, Argentina and the Falkland Islands set aside a Special Area of Co-operation for future oil exploration and development, so there is little doubt that oil exploration around the Falklands will recommence in the near future. Unless environmental protection is greatly improved, it is probable that many more penguins will die in unnecessary oil spills, as happens each year along coastal Argentina.

The Falkland Islands are an internationally important breeding site for penguins, and it is vital that the Falkland Islands Government accept their responsibility to protect this natural resource. Rockhopper penguins now number just 11% of the population recorded in the Falklands 18 years ago, and they are now classified as Vulnerable under IUCN guidelines. Magellanic penguins have undergone a similar magnitude of decline, and are still declining. Sealions and Elephant seals have also undergone major declines since the establishment of a commercial fishing industry in the Falklands.

It is very difficult to prove the link between the decline of these species, and the establishment of large-scale commercial fishing around the Falklands, just as it is difficult to prove links between smoking and individual cases of heart disease or lung cancer. However, many take the view that for non-target species, and especially protected species such as penguins, that the burden of proof for no harm lies with the exploiter (Boersma et al. 2001).

On a per capita basis, the Falklands is one of the wealthiest places on earth, with an annual government income of over US$30,000 for every person living in the islands. As such there is no reason why financial interests should outweigh the need for adequate protection of Falklands wildlife. If a relatively poor country such as Chile can protect the waters around important penguin breeding sites such as Magdalena Island, then there is no reason why the Falkland Islands cannot offer similar concessions in the name of wildlife conservation.

In 2002, the IUCN published its Spheniscus Penguin Conservation Workshop Report (Luna et al. 2002). This report summarises the recommendations of 43 of the world's leading penguin researchers and conservationists, brought together in September 2000 for the 4th International Penguin Conference and Spheniscus Penguin Conservation Workshop, to discuss penguin conservation measures. The report states:

"Recommend that there be no inshore fisheries (within 30 miles of the coast) in the Falklands. Restrict industrial fishing from areas of known concentrated penguin use at sea (including wintering and foraging areas for fledglings). Argentina and the Falklands should establish an integrated series of marine reserves and zones, subject to adaptive management based on continuing research and monitoring, to benefit all species (fish, seabirds, marine mammals)."

The Environmental Research Unit has requested the Falkland Islands Government to adopt the measures recommended in the IUCN report.

Article 2.

Bingham M (2020) "Magellanic penguin monitoring results for Magdalena island (Chile) and Cabo Virgenes (Argentina): 2000 - 2019".
Anales del Instituto de la Patagonia, Vol. 48(1):27-35

SUMMARY

Magellanic penguins (*Spheniscus magellanicus*) are found only in South America, with breeding populations in Chile, Argentina and the Falklands (Malvinas). On Magdalena Island an initial increase in population (59,000 pairs in 2000/01 to 63,000 pairs in 2008/2009) was followed by a population decline (to 43,000 pairs in 2018/19) following a severe drought during 2009 that has left much of the island less suitable for nesting in burrows. The nearby colony situated in Argentina between the lighthouses of Cabo Vírgenes and Punta Dungeness has increased in population from 122,000 pairs in 2008/09 to 146,000 pairs in 2018/19. It is likely that this increase is a result of penguins leaving Magdalena Island. Penguins nesting alongside the tourist path showed a reduction in predation and an increase in breeding success.

INTRODUCTION

Magellanic penguins (*Spheniscus magellanicus*) are found only in southern South America, with breeding populations in Chile, Argentina and the Falklands (Malvinas). Population studies estimate that the world population of Magellanic penguins is between 1.3 and 1.7 million breeding pairs, with approximately 700,000 pairs in Chile, 900,000 pairs in Argentina and 100,000 pairs in the Falklands (Falabella & Campagna (Eds) 2019, Bingham & Herrmann 2009).

Population studies in the Falklands have shown a 92% decline in Magellanic penguins between 1990/91 and 2018/19 (Falabella & Campagna (Eds) 2019, Bingham 2002, Ellis *et al.* 1996). Removal of fish and squid by the Falklands commercial fishing industry established in 1988 is the principal cause of the Falklands decline, making it difficult for adults to find sufficient food for their chicks, causing high chick mortality, which in turn has led to a lack of recruitment to replace penguins dying from old age. The evidence and mechanism of this decline is outlined in detail in Bingham 2002.

Population studies at the Provincial Reserve Cabo Vírgenes (Argentina) indicate a population of 146,000 reproductive pairs in 2018/19 (Fig 1). Cabo Virgenes is open to the public but visitor numbers are low and there are no tour operators visiting the colony. The nearest town of Rio Gallegos is small and has little tourism, so visitors to the colony are mostly local. Access to the colony is by vehicle along a severely degraded dirt track that is 115 kilometres long, and more suited to off-road vehicles than cars, so visitor numbers are low, averaging about 30 per week during 2019.

One of the largest and most important breeding sites for Magellanic penguins in Chile is located on Magdalena Island in the Straits of Magellan (Fig 1). In 1966 the island was declared a Natural Monument due to its importance as a breeding site for the species, and is managed by CONAF (Corporación Nacional Forestal). Magdalena Island is a popular tourist destination, with an average of 2,500 tourists visiting the island each week during 2018. The tourists arrive by boat in groups of up to several hundred at a time, and follow a set path around the island. Tourists are allowed just one hour ashore by the tour operators, and are accompanied by professional guides. Penguins have an average of two or three visits per day during which people are walking along the path, with a complete absence of tourists between these visits. Hundreds of people in Punta Arenas are directly and indirectly employed by tourism on Magdalena Island.

The aim of this study is to monitor the effects of tourism on the reproduction and survival of penguins at both Magdalena Island and Cabo Virgenes, and to ensure the sustainable use of these reserves as a tourist resource. The study also aims to monitor population trends at these locations and to identify any other problems that may impact on the penguins.

MATERIALS AND METHODS

Because Magellanic penguins live below ground in burrows, and over such a large area, direct nest counts are not possible. Many burrows are unoccupied, or are occupied by non-breeding single adults, so to assume that all burrows contain nests would greatly over-estimate the population size. To count breeding pairs it is necessary to look inside each burrow to confirm the presence of eggs shortly after laying. For Magellanic penguins it is necessary to establish fixed study plots to obtain long-term population data (Hiscock 1993, Bingham 2004, Bingham and Herrmann 2009).

In December 1998, studies began on Magdalena Island to determine the number of plots required for an island with such a varied terrain and soil type. Habitat maps were prepared, along with a population census of all bird species found on the island (Bingham & Herrmann 2009).

With funding from the British government, seven fixed study-plots were established on Magdalena Island in 1999 to estimate penguin population trends, six plots of 50 metres by 50 metres, and one plot of 30 metres by 100 metres. Every single burrow within these plots was examined each year in late October to determine the number of occupied nests, and this was used to estimate the average breeding density in nests per square metre. The nesting area was also mapped out by GPS, and multiplying the breeding area of the island in square metres, by the average number of nests per square metre, an estimate of the island's population size was obtained.

The greatest margin of error in determining population size using this method is in the assumption that breeding density recorded in the plots is representative of the entire island, but by using permanent study plots year after year, this margin for error is eliminated when looking for *changes* in population size. Even minor changes in breeding density, and hence population size and trends, can be measured with accuracy using permanent study plots, even though a greater margin of error is implied when extending this to defining an actual population size in any particular year (Hiscock 1993).

In addition to studying population changes, in late October, shortly after egg-laying, around 20 occupied nests in each plot were marked, and these nests were visited regularly throughout the season, to determine what proportion of eggs hatch, how many chicks survive to leave the nest, the major causes of egg and chick loss, and chick weight. In addition to the seven study plots, occupied nests alongside the tourist path were also marked and studied, to look for differences in breeding success and chick survival rates resulting from the presence of large numbers of tourists.

The same methodology was employed to study Magellanic penguin populations at Cabo Vírgenes since 2003 (Fig 1). Unlike Magdalena Island, Cabo Vírgenes has dense thorn bushes, and the penguins nest above ground underneath the bushes instead of making burrows. Five fixed plots of 50 metres by 50 metres were used at Cabo Vírgenes where the terrain is much more uniform and there is much less variation in nesting density. Nests alongside the tourist path were also marked and studied to look for differences caused by the presence of visitors.

RESULTS

Magdalena Island colony

Seven fixed study-plots were established on Magdalena Island to estimate penguin population trends. These plots indicated populations of 59,000 breeding pairs in 2000/01, 63,000 pairs in 2008/09, and 43,000 pairs in 2018/19 (Table 1).

Magellanic penguins make their nests in burrows on Magdalena Island. Prior to the drought of 2009 penguins nested over almost the entire island, so population increases could not occur as a result of increases in nesting area, only through increases in nesting density, which is limited for penguins that nest in burrows. The island had short grass with deep roots that stabilised the soil enough to support burrows over most of the island. In 2009 and 2010 the island suffered a severe drought that killed off all the vegetation leaving just bare soil. Without vegetation, the wind caused loose soil to be blown across the island (Fig 2), covering and burying burrows, eggs and chicks (Fig 3). This caused very low breeding success, and reduced the available nesting area of the island. The vegetation is now recovering over much of the island, however despite the return of vegetation, many areas still have soil below the surface that is too sandy and unstable to support the construction of burrows, reducing both the available nesting area and the nesting density of the colony.

During 2018/19 a comparison of the fixed plots indicated large population changes since 2008/09. Five of the seven plots showed a decline in the number of occupied nests, ranging from -20% to -60% (Table 1). However an increase of 10 to 20% in the number of occupied nests was observed in two plots (Table 1). The majority of the decline on Magdalena has occurred in the flat valleys, with the hills showing a slight increase in population.

Plots 1, 4 and 5 are all very similar except for their location. They are all located in flat valleys where the worst of the drought occurred. The loss of almost all the vegetation on the island during the 2009-10 drought caused the wind to lift loose soil and deposit it in these valleys and plains, filling up the burrows, covering the nests, and causing the loss of many burrows. These areas are now covered with fine dusty soil underneath a shallow layer of new vegetation, with a labyrinth of voids below the surface because of the abandoned burrows that were buried.

These areas are no longer very suitable for building new burrows because the burrows collapse too easily. These three plots have registered the highest population decreases on the island. Plots 1 and 5 are linked by the large valley located between the lighthouse and the jetty, while Plot 4 is located on the opposite side of the island where tourists never visit. The plots were chosen to observe differences caused by the presence and absence of tourism in these types of flat terrain.

Plots 2 and 3 are also very similar to each other. Despite being flat these areas have firmer soil and better vegetation, making them more suitable for burrows. Plot 2 is exposed to low presence of tourists while Plot 3 has zero contact with tourism. The decrease in penguins is much lower in both these areas.

Plots 6 and 7 are both on top of hills and both are very similar in terrain, slope and aspect. They are on opposite sides of the island. Plot 6 has zero contact with tourism, while Plot 7 has tourists crossing between the plot and its access to the sea. However both plots have registered an increase in population.

During 2018/19 the mean breeding success on Magdalena Island was 0.74 chicks per nest (range = 0.34 to 1.60), which indicates that 37% of all eggs laid survived to produce a juvenile that left the nest successfully (Table 3). Compared to that figure for the island as a whole, nests placed within two meters of the tourist path had a breeding success of 1.18 chicks per nest, which indicates that 59% of eggs placed very close to tourists survived. Nests within 2 metres of the tourists were 50% more successful than nests situated well away from tourists (Table 3).

This breeding success of 1.18 chicks per nest observed near to the tourist path is not only high for 2018/19, it is also high compared to any year for Magdalena in general. Excluding the tourist path, Magdalena Island has not had breeding success of 1.18 in any plot since 2007/08 which was before the drought (Table 3).

Plot 1 is directly located below the lighthouse and is the plot with the highest presence of tourists compared to any other plot on the island. Despite suffering a reduction in nesting density since the drought, during 2018/19 the penguins remaining in Plot 1 had the highest breeding success on the entire island by far. Plot 1 was 60% more successful than any other plot on the island, with an average of 1.6 chicks per nest. A breeding success of 1.6 chicks per nest is exceptional, so exceptional that in 20 years of studies on Magdalena Island only penguins nesting alongside the tourist path have ever registered such a high level of breeding success.

During 2018/19 the breeding success in Plot 1 was more than double the average for the entire island, and raised more chicks per nest than any other plot during the 20 year study period. By comparison, the plots located in areas with zero contact with tourists had the lowest breeding success (0.5 chicks per nest or less).

Cabo Virgenes colony

The Magellanic penguin population at Cabo Vírgenes has increased by 20% during the last 10 years, from 122,000 pairs in 2008/09 to 146,000 pairs in 2018/19. With very few tourists visiting the colony there is no significant difference in breeding success between penguins alongside the tourist path and penguins well away from tourists. The colony at Cabo Virgenes appears to be in good health.

DISCUSSION

Magellanic penguins are only found in Argentina, Chile and the Falklands. Population studies are being carried out in all three countries using the same methodology of fixed study plots.

Small colonies of Magellanic penguins can be counted nest by nest, but a direct count is impossible for large colonies such as Cabo Virgenes and Magdalena Island. In such cases it is necessary to calculate the size of the population by plotting the total area of the colony, and multiplying this area by the density of nests per square meter determined by study plots.

According to the criterion given above and the errors inherent in the use of an average nesting density instead of direct counts, the population totals obtained using the aforementioned methodology have a margin of error of plus or minus 20%. There are several methods available to obtain a single population estimate of Magellanic penguins, but only direct counts of every nest can reduce this margin of error. If the objective is to monitor population changes, or compare two or more censuses separated by time, then fixed plots is the only method available for large colonies. Fixed plots allow the precision of direct counts in small areas within the colony.

The use of fixed plots has a margin of error comparable with any other methodology when estimating population size, but with the advantage that using fixed plots eliminates the margin of error when estimating *changes* in population. Even small population changes can be detected using fixed plots. Other methods of estimating Magellanic penguin populations re-introduce the margin of error with each new count, eliminating any possibility of detecting changes smaller than the combined margin of error of any two counts.

To explain this in layman's terms, imagine throwing grains of rice onto a large table. Time does not allow each grain to be counted, so instead small squares (study plots) placed randomly across the table can estimate the amount of grains on the table. The estimate will obviously have a large margin of error because it assumes that the density in the squares is representative of the whole table. If the squares are fixed the same result will be recorded each time that the count is repeated. If someone later threw some additional grains onto the table, some additional grains would fall into the squares and the increase would be detected.

If the squares were not fixed, or if other methodology was employed such as transects running across the table at random, the count will be different each time it is repeated, even if the grains on the table have not changed. If the methodology gives different results each time it is repeated, then it is clearly impossible to use such a method to detect small changes.

Long-term population studies using fixed plots began in the Falklands in 1989 (Bingham 2002), on Magdalena Island in 1998, and at Cabo Virgenes in 2003.

The decline of penguins on Magdalena Island is worrying at a local level, but does not indicate a decline at a regional level. At a regional level Magellanic penguins have shown a very slight and statistically insignificant increase over recent years. The increase of 24,000 pairs at Cabo Vírgenes is greater than the loss observed on Magdalena Island during the same period, and it is likely that Cabo Virgenes has benefited from an influx of penguins coming from Magdalena Island. Adding together both colonies gives a population of 185,000 pairs during 2008/09 and 189,000 pairs in 2018/19, an increase of 4,000 pairs over the last 10 years, so the regional population as a whole is healthy and stable.

At Cabo Virgenes the soil is not suitable for burrows, but the area is covered by thorn bushes which the penguins use as protection instead of burrows. There are no bushes at all on Magdalena Island, so without soil suitable for burrows the penguins are left exposed to predators and the weather, forcing them to look elsewhere to breed.

Magdalena Island and Cabo Virgenes are both located in maritime areas that are protected from large-scale commercial fishing by no-fishing zones. Penguins at these sites can usually find plenty of food to feed their chicks, with the exception of during climatic events such as El Niño and La Niña. Penguin populations are tolerant of many problems if food remains abundant.

Magellanic penguin populations on the Falklands have declined by 92% from 1,300,000 pairs in 1990 (Ellis *et al.* (Eds) 1996) to about 100,000 pairs in 2018 (Falabella & Campagna (Eds.) 2019). This decline is due to competition for food resources with the commercial fishing industry (Bingham 2002). In September 2000 the participants of the Spheniscus Penguin Conservation Workshop held at La Serena (Chile) signed a petition calling on the Falkland Islands Government to establish no-fishing zones around penguin colonies, but that protection has still not been provided, and the penguin population continues to decline (Luna *et al* 2002 (Eds.), Bingham 2002, Falabella & Campagna (Eds) 2019).

Penguins on Magdalena Island have declined for different reasons. Current data indicate that tourism is not the cause of the decline, and even has a minor role in improving breeding success for a few hundred penguins nesting alongside the tourist path.

The data indicate that penguins nesting in the presence of tourists have higher breeding success than other penguins on the island. During 2018/19 penguins most exposed to tourism had a 50% higher breeding success than the rest of the island. The same was recorded during 2005/06 and 2008/09. In 2009/10 and 2012/13 the penguins closest to tourists recorded a 30% higher breeding success, and on many other occasions the penguins most exposed to tourism recorded superior breeding success of less than 30% higher (Table 2).

The main predator of penguin chicks on Magdalena Island is the Skua (*Stercorarius chilensis*). The skua is very shy and avoids areas frequented by tourists. A reduction in the abundance of the skua decreases the mortality of chicks and increases the breeding success of the penguins. The data for Magdalena Island indicate that penguins raise more chicks and suffer less mortality of eggs and chicks in the presence of tourists, because the presence of tourists reduces the level of predation by skuas.

One of the main threats to Magdalena Island is the reduction of rainfall necessary to maintain vegetation in order to stabilise the soil so that penguins can dig burrows. The drought that occurred on Magdalena Island in 2009 seems to have been an unusual phenomenon. Before the drought the vegetation mostly comprised of grass species, but following the drought the re-colonisation has largely begun with small ground-hugging flowering plants. If the drought was a cyclic event occurring every 20 years for example, then major changes in vegetation composition would seem unlikely. The change in vegetation indicates that the drought was an unusual event and a link to climate change is a strong possibility.

Even though the vegetation has started to return on much of Magdalena Island, in many areas the number of penguins has continued to decline. The new vegetation has not established the deep roots that the original vegetation had, and the soil underneath is still sandy and collapses easily when penguins try to make burrows. The low-lying valleys are the most seriously affected because these are the areas where dust storms following the drought deposited thick layers of dry dusty soil which collapses too easily to support burrows. Until such time as the vegetation can stabilise these areas the penguin population on Magdalena Island is likely to continue declining.

Article 3.

Bingham (2004) **Seabird Monitoring Instruction Manual**
Sponsored by The Darwin Initiative, Department of the Environment, Food and Rural Affairs, UK

CONTENTS

1. INTRODUCTION

Magellanic penguins (*Spheniscus magellanicus*) are only found around southern South America, with breeding populations in Chile, Argentina and the Falkland Islands. Best guess estimates put the current world population of Magellanic penguins at around 1.5 million breeding pairs, with approximately 700,000 pairs in Chile, 650,000 pairs in Argentina and 150,000 pairs in the Falkland Islands (Bingham 1998, Bingham & Mejias 1999, Gandini *et al.* 1998).

Population studies in the Falkland Islands conducted by Dr Mike Bingham have revealed an 80% decline in Magellanic penguins between 1990/91 and 2002/03. The removal of fish and squid by large-scale commercial fishing vessels appears to be the cause of the Falklands decline, with high rates of chick and juvenile mortality from starvation leading to a lack of recruitment (Bingham 2002, Boersma 1997).

Population studies conducted in Argentina show evidence of decline at some colonies, but not all (Boersma 1997). Declines in Argentina appear to be largely the result of high adult and juvenile mortality caused by oil pollution. An estimated 40,000 Magellanic penguins are killed by oil pollution every year along the coast of Argentina, representing the main cause of adult mortality (Gandini *et al.* 1994).

No population studies have yet been carried out on Magellanic penguins in Chile, even though Chile holds around half the world's population. The reason for this is lack of financial resources, which has not only prevented the establishment of a long-term monitoring programme, but also inhibited training of local personnel in seabird monitoring techniques.

One of Chile's largest and most important Magellanic penguin breeding sites is situated on Magdalena Island in the Straits of Magellan. Provisional examination suggests that Magellanic penguins are not declining on Magdalena Island, despite its close proximity to the Falklands (Bingham 2002, Bingham & Mejias 1999), but a long-term monitoring programme needs to be established in order to accurately determine population trends.

The island has been designated a national nature reserve because of its importance as a Magellanic penguin breeding site, and it is managed by the government agency Corporación Nacional Forestal (CONAF). The island is a popular tourist destination, so it is important to monitor the effects of tourism on penguin survival and breeding success, in order to ensure sustainable use of the reserve as a tourist resource. Magdalena Island holds a population of around 60,000 breeding pairs of Magellanic penguin, making it an ideal site at which to establish Chile's first long-term penguin monitoring programme.

2. BASELINE SURVEY

In order to correctly interpret the findings of any long-term monitoring programme on Magdalena Island, it was essential to conduct an Environmental Baseline Survey of the island. An Environmental Baseline Survey aims to provide the best practicable assessment of the abundance and distribution of birds and mammals, and to map out the vegetation and habitat types which support them. This provides baseline data with which to assess future changes in any component of the island's ecosystem.

2A. HABITAT

The first step of a conventional baseline survey is to identify and map out the key vegetation/habitat types found within the study area (Hiscock 1993). Initial studies undertaken by Dr Bingham identified the key vegetation/habitat types occurring in the region, including those which are not found on Magdalena itself (Appendices 1 & 2).

A survey of Magdalena Island was then conducted to map out the location and area of each vegetation/habitat type present on the island. This was performed by walking the entire coastline of the island, once along the littoral zone, and once along the adjacent terrestrial zone. The island was also repeatedly traversed in order to ensure that the interior was mapped out correctly according to the vegetation/habitat types present.

The littoral and terrestrial vegetation/habitat types were mapped out on field maps during the survey, and later copied onto the final survey map (Appendix 3). This method is consistent with MNCR/NCC Phase 1 Survey methodology (Nature Conservancy Council CSD Report No.1072 / Marine Nature Conservation Review Occasional Report MNCR/OR/05). The results will allow future changes in vegetation and habitat to be recorded, in order to observe potential links between changes in fauna and their associated habitat.

2B. FAUNA

A baseline survey of all birds and mammals present on the island was also recorded. Birds and mammals which breed in colonies can be accurately recorded by counting the number of breeding pairs in each colony, and mapping the colony locations. Species which breed individually require different techniques, depending on whether they are coastal birds or inland birds. Magellanic penguins are loosely colonial, breeding in burrows over a large area. Small Magellanic penguin colonies can be counted as per colonial birds, but larger colonies, such as found on Magdalena Island, require measurements of nesting density and area to determine total population size.

3. POPULATION CENSUS

3A. COLONIAL BIRDS & MAMMALS

During an initial survey of the study area, all breeding colonies of birds and mammals were located and recorded on the map using a letter code (Appendix 4). These colonies were then visited at the appropriate stage of the breeding cycle to record the number of breeding pairs within each colony.

Counts are generally expressed in terms of breeding pairs, since this is the only meaningful figure for measuring population size. The number of individuals present within a colony will change during the course of the day, as individuals come and go in order to feed. The number of breeding pairs provides a constant measure of colony size regardless of daily changes.

For bird colonies, population counts are taken at the end of the egg-laying period, when incubation of the eggs has just begun. Counts are made of occupied nests only, which equates to the number of breeding pairs. Only incubating birds that are lying or sitting on nests are counted. Birds which are not on nests are ignored, since they are either non-breeders, or have partners nearby that are on nests. If two birds occupy the same nest only one is counted.

By conducting counts at the end of the egg-laying period, under-estimates of population resulting from abandoned or failed nests are kept to a minimum. Counts are recorded using tally-counters, with three nest counts being taken at each colony. The result is the mean of the three counts, whilst the spread of results gives an indication of the margin of error. For small discrete colonies the margin of error can be well below plus or minus 5%, but a margin of error of plus or minus 10% is usually allowed for counts of this type.

The number of breeding pairs within each colony is entered on the map, along with the letter code indicating the species, and an arrow pointing to the exact location of the colony (Appendix 5 and 6).

The only colonial mammals likely to be encountered are pinipeds (seals & sealions). Pinipeds do not have nests, and dominant males often mate with several females, so breeding females are the nearest equivalent to breeding pairs. Since it is not possible to be certain which females have mated, population counts rely on counting pups. This is not ideal, since it only records successful births, but it is the internationally accepted method of determining population size for pinipeds.

Counts are made upon completion of pup births, although some under-estimation is inevitable due to pup loses prior to counting, or late births. Nevertheless with careful timing of the census the margin for error should be within plus or minus 10%. Counts are recorded on the map as per colonial birds.

On Magdalena Island, gulls (Appendix 5) and cormorants (Appendix 6) were the only colonial birds recorded (excluding Magellanic penguins which are semi-colonial and covered separately). No pinipeds were recorded breeding on Magdalena Island.

3B. NON-COLONIAL BIRDS

SHOREBIRDS

Shorebirds, such as oystercatchers, marine ducks and marine geese, nest above the high water mark and patrol a territory that includes a section of beach. Because their breeding territories are restricted to the coastal strip, population size can be determined by walking the coastline. This is aided by the fact that such species are territorial and conspicuous, with the male usually holding a prominent position overlooking his territory.

During the incubation phase at least one bird from each pair (usually the female) will be sitting on eggs and well hidden from sight, increasing the likelihood of missing the pair if the male is resting. Once the chicks have hatched, they generally leave the nest and forage along the littoral and sub-littoral zones under the supervision of the adults, making the pair very visible and easy to count. Shorebird census work is therefore best conducted after the chicks have hatched, although the timing of the census is not as critical as for colonial birds.

Pairs that fail to breed will remain as a pair within their territory where they can still be visible for counting, so population size will not be underestimated as a result of failed breeders, as would be the case for colonial birds. Margins of error associated with shorebird counts are usually very low, although some error may arise when determining the breeding status of single birds encountered along the shore.

Counts are made of breeding pairs rather than individuals, but when counting shorebirds it is common to see only one member of the pair. A male that is prominently positioned, or which calls and shows alarm when approached, will probably have a female close by and should be counted. Lone females, or males that leave the area when approached, are probably non-breeders and should not be counted. A repeat census two or three weeks later will help to determine the status of lone birds, since breeding pairs will remain in the same section of coast, even if they fail to breed successfully. Shorebird populations can usually be recorded to within a margin of error of plus or minus 10%.

Breeding pairs of shorebirds are recorded on the map in the exact location at which they were recorded, using the appropriate letter code. Where more than one pair occurs too close together to mark individually on the map, they should be marked together, with the number of pairs written before the letter code, as per colonial birds.

INLAND BIRDS HOLDING TERRITORY

Conspicuous birds that hold large territories, such as raptors, can be assessed by recording their individual breeding territories. Breeding pairs patrol their own territories in search of food, making them easy to record, and with sufficient observation the actual nesting sites can usually be determined for each breeding pair. The location of each nest site should be recorded on the map using the appropriate letter code. The best time to record birds holding territory is during the chick rearing stage, when foraging activity is greatest. Accuracy is usually well within plus or minus 10%, unless specific problems in determining territorial status are encountered.

Where territories are smaller, and nest sites harder to find, numerous daily records may be necessary to determine territories. The study area should be walked twice a day, recording all bird sightings on a map, using a separate sheet for each visit. After three or four weeks the daily sightings are transferred onto one common map, with a separate map for each species. With three or four weeks of observations overlaid onto one map, territories will show up as clusters of sightings, allowing the size and number of territories to be determined, even if the actual nest sites cannot be found. The location of each territory (breeding pair) can then be marked on the survey map using the appropriate letter code. Accuracy is dependent on species type and number of recordings, but can usually be estimated from the clarity of the clusters observed.

INLAND BIRDS NOT HOLDING TERRITORY

For inland birds which do not nest in colonies, and for which territories cannot be determined, census work must rely on rough estimates of density using transect counts.

The study area is crossed a number of times along set lines (transects) so that all areas and habitat types are represented. All birds observed within a set distance from the transect line are recorded in their appropriate position on the map. This distance from the transect line is called the Effective Transect Width (ETW) and is determined by species and habitat type. The ETW is the distance at which birds can be reliably sighted whilst walking the transect.

For dense habitat cover, such as woodland, a narrow ETW is required due to the difficulty of spotting birds. For open habitat, such as that found on Magdalena Island, a much wider ETW is possible because birds can be reliably sighted at a greater distance. For passerines in open habitat the ETW is set at 25 metres, so that all birds observed within 25 metres each side of the line being walked (transect) are recorded. Birds observed outside the ETW are ignored. For larger birds, such as geese, the ETW can be set at 100 metres.

The total distance walked (transect length) is recorded, and multiplied by the ETW to give the total area surveyed for each species (this will vary according to the ETW used for each species). The density is the number of individuals or pairs recorded within the survey area.

Ideally only breeding pairs should be recorded, and for geese this should be possible if sufficient time is taken, because pairs generally remain together or close by during the chick rearing period. For passerines however, it is generally impossible to determine breeding status of individual birds, and pairs are often not seen together. For this reason all birds are recorded, and the number of individuals is divided by two to give a figure for breeding pairs. This can greatly over-estimate the breeding population due to non-breeders, or under-estimate the population due to birds hidden from sight, during incubation for example.

There is no preferred time for a census of passerines, provided that it is conducted during the main breeding season, because passerines begin nesting early and often have multiple broods. Because of the nature of the census, and the difficulty in determining breeding status, the margin of error for passerines is likely to exceed plus or minus 50%. It is generally only of use in determining relative abundance.

3C. BURROWING PENGUINS

Penguins which live above ground, such as Rockhopper and Macaroni penguins, are treated in the same way as other colonial birds, as described above under section 3A. Magellanic penguins also live in loose colonies, but their nests are hidden from sight below ground in burrows, making them impossible to count in the same manner. Because the nests are in burrows, it is not possible to see how many nests are in a given area. Many burrows are unoccupied, and to assume that all burrows contain nests would greatly over-estimate the population size.

Small Magellanic penguin colonies can be counted by looking into each burrow with the aid of a flashlight to determine which burrows contain incubating birds on nests. Counts should be made immediately after the completion of egg-laying, whilst adults are incubating the eggs. The total number of occupied burrows in the colony is recorded with the aid of a tally-counter, and a spot of bright spray paint is put in front of each burrow in order to prevent double-counting or missing burrows (the paint disappears within a few days).

Burrows containing eggs but no adult are still counted as occupied nests. Because Magellanic penguins live in burrows egg losses are low, and abandoned eggs usually remain in the burrow for many days. Under-estimation due to breeding failure is therefore usually low, and the margin of error should be well within plus or minus 10% for this type of census.

The only drawback to this methodology is that it is very time consuming, and therefore impractical for very large colonies. In such cases it is necessary to calculate the population size by mapping out the total area of the colony, and multiplying this area by the density of occupied burrows (nests/pairs) determined from study plots.

A number of study plots should be selected at random from areas within the main colony. Study plots should not cross the periphery of the colony since any area outside the colony would reduce the plot count and give a lower density reading. Plot size is determined by nesting density. For areas of moderate to high nesting density (0.05 to 0.1 nests per sq.m) the suggested plot size is 50m x 50m. For areas of nesting density below about 0.025 nests per sq.m. a plot size of 100m x 100m is recommended.

Once the study plots have been marked out, the number of occupied burrows (nests/pairs) within each study plot is counted using the methodology described above for small colonies. This gives the number of nests within a known area, allowing the mean nesting density to be calculated as nests per square metre.

The total area of ground occupied by the penguin colony is then mapped out, and the area of the colony calculated from the map using a dot matrix overlay. (A dot matrix overlay is a clear acetate sheet with squares and dots used to accurately determine area from a map). The area of the colony in square metres is multiplied by the mean nesting density (nests per square metre) to give the estimated population total.

If during the above procedure it is discovered that nesting density varies by more than 25% (eg. 0.10 nests per sq.m. to 0.075 nests per sq.m.), and that the areas that lie outside this range cover greater than 10% of the total colony area, then the colony must be mapped out in greater detail according to density variation.

The colony should be mapped out to show sectors of high and low density (Appendix 8) (or high, medium and low density if the level of variation warrants it - Appendices 7 & 9). The total area covered by each density is calculated from the map using a dot matrix overlay. A number of study plots in each sector determine the mean nesting density for each sector, and this nesting density is multiplied by the appropriate area to give a separate population total for each.

EXAMPLE:
High Density: Area = 492,090 sq.m Mean Density = 0.098 nests/sq.m.
TOTAL = 48,225 breeding pairs (occupied nests)
Medium Density: Area = 115,223 sq.m Mean Density = 0.077 nests/sq.m.
TOTAL = 8,872 breeding pairs (occupied nests)
Low Density: Area = 39,054 sq.m Mean Density = 0.050 nests/sq.m.
TOTAL = 1,953 breeding pairs (occupied nests)
TOTAL FOR COLONY = 59,050 breeding pairs

Given the criteria above, and the inherent inaccuracies of using mean density instead of direct counts, population totals obtained using the above methodology should allow for a margin of error of plus or minus 20%. Clearly direct counts as described for small colonies is preferable, but for very large colonies it is usually impractical.

4. PENGUIN MONITORING

The Baseline Survey and Population Census work described under Sections 2 and 3 above provide the basis upon which a penguin monitoring programme can be built. Such ground work is essential for the correct interpretation of any changes observed during long-term monitoring. The population census work carried out under Section 3C, when repeated annually, provides the first step of the monitoring programme.

4A. POPULATION TRENDS

One of the most important parameters of any monitoring programme is the study of population trends. Population trends indicate the overall health of a colony or population. A declining population may well indicate problems which need to be identified and rectified in order to protect the population, whilst increasing populations suggest a thriving population, even if some conflict with human activity is occurring.

In order to identify population trends it is necessary to record the population size at regular intervals, preferably every year if other factors such as breeding success or food abundance are to be recorded and related to population change. The method of recording population size each year is described under Section 3, and it is essential to ensure that the census is conducted in an identical manner each year if observed changes are to be valid. Any deviations from the stated methodology, which may be necessary because of local conditions, must be recorded in detail so that future census work can be conducted in a compatible manner.

The same permanent study plots must be used each year for determining changes in penguin population. If permanent study plots reveal annual increases or decreases in all sectors of the colony, then these observed changes can be assumed to be fairly reliable, since they are not subject to the 20% margin of error associated with turning study plot counts into population totals. Changing study plots is not recommended, since it reintroduces the 20% margin of error for each season's data, making small population changes impossible to detect.

Annual changes in area must also be considered when determining overall population change.

4B. ANNUAL BREEDING SUCCESS

Annual breeding success is the mean number of chicks reared to the point of fledging per breeding pair each year. For penguins, fledging is taken as the point at which chicks shed their mesoptile plumage and grow water-proof plumage ready to take to sea.

For penguins which breed on the surface in colonies, the number of breeding pairs within the colony is counted using methodology described in section 3A. The colony is then revisited later in the season, just prior to the chicks fledging and leaving the colony. The total number of chicks within the colony is counted, with the mean of three counts being taken as the result.

The number of chicks surviving to the point of fledging is divided by the number of breeding pairs (nests) recorded in the colony at the beginning of the breeding season. This figure is the breeding success or productivity, expressed as chicks per breeding pair. This figure may also be expressed as a percentage, where 100% is equal to 1 chick per breeding pair (nest). Provided that chicks have not already begun leaving the colony at the time of the count, productivity will be slightly over-estimated as a result of some chicks which are not at the point of fledging, and which may still die prior to fledging. However surface-breeding species are fairly uniform in development, and chick losses reduce as chicks mature, so the margin of error should be within plus or minus 10%.

It is important not to mistake juveniles, (which return to their natal colony to moult at this time of year) with moulting chicks, or an artificially high breeding success will be recorded. Careful observation of plumage will differentiate between moulting chicks and juveniles from previous seasons.

For penguins that live in burrows, such as Magellanic penguins, there are two possible ways of recording breeding success. The number of chicks surviving to fledge can be estimated from a second visit as for surface-breeding species, with the total number of chicks in any given colony or plot being divided by the number of occupied nests. However penguins living in burrows are much less uniform in development, especially when food is short, and this method can greatly over-estimate breeding success for Magellanic penguins.

Studies in the Falkland Islands have shown that chicks which receive less food take much longer to develop, causing chicks to become abandoned by the adult whilst still dependent on the adults for food, leading to high chick mortality just prior to fledging. These late developing chicks, most of which die, would be counted as successfully fledging according to the above methodology, greatly over-estimating breeding success. A much better methodology is therefore to make regular observations of egg and chick development throughout the season, right up until the point that each chick either leaves the nest to fledge or dies.

When the study plots are counted at the beginning of the breeding season, twenty occupied burrows in each plot are marked with small sticks bearing names or numbers to identify individual nests. These nests are visited on a regular basis until the chicks change their mesoptile plumage into water-proof plumage and leave the nest. Chicks disappearing prior to shedding their mesoptile plumage are presumed to have died. Chicks disappearing afterwards are presumed to have fledged (see Appendix 10).

The number of chicks fledging is divided by the number of marked burrows being observed in each study plot. This figure is the breeding success or productivity, expressed as chicks per breeding pair.

This method not only allows for accurate measurement of breeding success, but also the timing and causes of breeding failure. Abandoned eggs are opened to determine the stage of development, after it is certain that the eggs have been completely abandoned for at least two weeks. Dead chicks are removed for weighing and examination to determine causes of death. Hatching dates, development duration, and the proportion of breeding failures that result from egg losses and chick mortality can be determined.

4C. DIET AND FORAGING OBSERVATIONS

Diet and foraging behaviour are important aspects of seabird monitoring, especially when commercial fishing activities operate in the region. However many aspects of foraging behaviour are difficult to observe, except as part of a separate research programme. For a site-specific monitoring programme, observations of foraging behaviour and diet will inevitably be limited. One such limitation is the time of year during which foraging behaviour and diet can be observed.

When adults are not breeding they are not restricted to the locality of their breeding site, and are therefore difficult to observe as part of a site-specific monitoring programme. However this freedom to forage wherever food resources are most abundant means that adults find it comparatively easy to locate sufficient food, even when prey is scarce, and starvation during the winter migration is not usually a major mortality factor for adult Magellanic penguins.

During the breeding phase adults are not free to forage wherever food resources are most abundant, because their foraging range is restricted by the need to return regularly to their nest. In addition, each adult is only able to spend half the time foraging for food when brooding eggs or small chicks, as nesting duties are shared between the two parents. Chicks are totally dependent on food caught over and above what the adults require for their own metabolic needs. If adults only catch sufficient food to meet their own metabolic needs, the chicks will starve.

The usual method of determining prey composition is by stomach flushing adults returning from foraging trips. The best place to catch adults is between the beach and their nest site. Catching adults too close to the water will allow them to escape back into the sea, whilst catching within the confines of the colony leads to excessive disturbance. It is important to ensure that only birds returning from foraging trips are caught.

Once the adult is caught, a small plastic tube (such as used in hospital for stomach-flushing infants) is passed carefully into the penguin's stomach through the open beak, taking care not to enter the wind-pipe by mistake. It is important not to apply too much pressure in order to avoid injury. Sea water is then poured into the stomach using a funnel attached to the other end of the tube. (Pump mechanisms are not recommended since it is important not to create excess pressure in the stomach). The tube is then removed, and the penguin is inverted over a bucket, so that the water in the stomach flushes out into the bucket with the stomach contents. This is repeated two or three times, until little food remains.

During the chick rearing stage it is possible to record not only prey composition, but also the quantity of food being brought back to chicks. It is therefore important to ensure that the stomach is flushed until the water is mostly free of remaining food. This may require 4 or 5 flushes. Outside of the chick-rearing phase measurements of food quantity have little significance, and it is not necessary to flush out all the stomach contents in order to determine prey composition. It is therefore better to release the bird after the majority of food appears to have been flushed.

Prior to release, the bird should be weighed, and marked with an animal-marking crayon to ensure that the same bird is not caught a second time. The stomach samples are drained and stored in jars with formaline solution or alcohol, ready for later examination. The jars should be carefully marked with date, species and location.

In the laboratory the stomach samples should be rinsed with water, and then drained and padded with cloth to remove any excess liquid. They are then weighed to determine the quantity of food retrieved (wet weight). Each sample is then divided up into its appropriate components, which are weighed individually to determine proportional dietary composition by wet weight. Fish otoliths, cephalopod beaks and crustacean carapaces (which are not easily digested) can be used to aid species identification, and to estimate proportional composition.

The number of diet samples taken, and the period of time over which samples are taken, is a balance between the need for new data and the well-being of the birds. Whilst stomach-flushing does not cause long-term harm when carried out carefully, it is very stressful, and has the potential to be fatal if the procedure goes wrong. It is therefore important to limit such an invasive and risky procedure to the minimum.

Diet composition can also be evaluated from food dropped when adults feed chicks, and from analysis of faeces, which may contain fish otoliths, cephalopod beaks and crustacean carapaces.

For Magdalena Island, diet composition is well known from previous studies, and from ongoing collection of faeces and food scraps spilt when adults feed chicks. Stomach-flushing is therefore not considered necessary under the present monitoring regime.

Foraging duration during chick-rearing can also be recorded by marking adults in burrows that are incubating or feeding chicks. Adults in burrows can be easily marked using animal-marking crayons attached to the end of a stick which is passed down into the burrow. Each penguin should be marked around the neck and throat area where it cannot preen. Although animal-marking crayon can last several days at sea, it is important to re-apply the marking whenever it begins to fade. By marking each member of the breeding pair with a different colour, and observing the times that each penguin leaves and returns on foraging trips, it is possible to record foraging duration.

These observations are particularly important during the chick-rearing phase, when the time taken collecting food for chicks has a significant impact on chick survival. Such observations can be combined with observations of chick mortality described under section 4B.

Where financial resources permit, satellite transmitters, time-log recorders and dive-depth recorders can provide useful information on where birds forage on a daily basis, how deep they dive, how long they spend during each dive, and where they forage during the non-breeding season.

4D. ADULT & JUVENILE MORTALITY

Assuming that a colony or population is not subject to significant emigration or immigration, then population trends are a function of adult mortality, breeding success and juvenile survival. The previous sections deal with monitoring population trends and breeding success, which leaves two unknown factors in the equation: adult mortality and juvenile survival.

In a fairly self-contained population, such as the penguin population on Magdalena Island, adult mortality can be estimated by tagging large numbers of adults to see how many fail to return each year. Unfortunately because penguins have short, stubby legs, and travel through the medium of water rather than air, they cannot be ringed around the leg as for most birds. Despite extensive development, current penguin tags still cause considerable drag, reducing the penguin's ability to forage and escape predators. Existing tags also cause abrasions on the flipper, which can lead to infection. These side-effects not only cause stress to the birds, but increase mortality, which is the very factor which needs to be measured.

Juvenile survival can also be monitored through the use of tags, but the same problem exists as described above for adults. Fortunately tagging is not the only method available for estimating juvenile survival. After fledging and leaving the colony, most surviving juveniles return to their natal colony to moult each year until they are ready to breed. A rough estimate of juvenile survival can therefore be achieved by counting juveniles returning to moult each year.

Moulting juveniles are found along the beaches adjacent to the colony from January through to March. To a casual observer they can be mistaken for moulting chicks, but juveniles are easily distinguished from chicks and adults by their plumage, even during their moult. The plumage of juveniles is generally much paler than adults, but the most striking feature is the cheek area below the eye and bill, which is black in adults, but very pale in juveniles. Juveniles also lack the extensive area of pink skin above the eye and bill which is found on all adults. Juveniles differ from chicks in the facial plumage, which when huddled together is often all an observer can see.

It is worth spending time familiarising oneself with the difference in plumage between juveniles and adults / chicks before commencing the juvenile count. (NOTE: Newly moulted chicks, which have slightly different plumage, are not counted as juveniles. Juveniles must be at least one year old. Care must be taken not to mistake moulted chicks for juveniles)

Counting juveniles along the beach can be difficult and unreliable where several colonies are scattered along a long length of coastline, but for a discreet island population such as the one found on Magdalena Island, it can provide valuable data.

The number of juveniles present around the coast is counted each week from end of January to end of February. These timings may differ for other locations, or for acceptional years, but the correct timing can be established from the spread of results. Counts will initially increase as a result of the daily arrival of new juveniles coming ashore to moult. Eventually a peak will be reached, and the counts will drop as juveniles begin to leave following completion of their moult. The peak figure is divided by the total number of surviving chicks estimated for the previous year, to give juveniles (year Y) per surviving chick (year Y-1).

The resulting figure is not a direct measure of the previous season's cohort, since juveniles counted do not comprise solely of chicks from the previous year. The results can initially be used only to estimate juvenile survival over the previous two or three year period, however after several years of data, statistical analysis can be employed to reveal annual changes in juvenile survival.

Despite the limitations, long-term counting of juveniles can provide invaluable data which can be used to identify years of high or low juvenile survival. Seasonal changes in juvenile survival may correspond with other observations, such as variations in breeding success, changes in prey composition, oil spills or El Niño years. Such observations can also be used to identify colonies with low juvenile survival, or to show whether years of population decline correspond to periods of low juvenile survival, helping to identify or eliminate potential causes of concern.

4E. COMPARING COLONIES

Penguin monitoring techniques described above are used to monitor the health of a particular colony or population, but they can also be used to investigate or monitor external factors which may impact certain colonies or areas within a colony. On Magdalena Island tourism is a potential cause of concern, and it is important to monitor the effects of tourism in order to ensure sustainable use of the island as a tourist resource.

Human presence in the form of tourism has the potential to disturb breeding birds in a number of ways:

- Incubating birds may be frightened away allowing predators to take eggs or young.
- Raised metabolic rates brought on by stress may lead to greater food requirement.
- Natural behaviour, such as courtship or the feeding of young, may be disrupted.
- Adults could be scared away completely, causing them to abandon eggs or young.
- Severe disturbance could lead to adults or young being killed or injured.
- Birds living in burrows may be killed if the burrow collapses under human weight.

To identify the level of disturbance, monitoring is carried out in areas that are subjected to tourism, and in control sites which are well away from tourists. Significant levels of disturbance within the study site would be evident from reduced breeding success. There may also be observed changes in predation, or the causes of egg and chick mortality. Over a longer time-scale, continued disturbance may lead to a reduction in population size.

On Magdalena Island tourists are only permitted to walk within a controlled area. Penguin burrows adjacent to this area are monitored to determine nesting density, breeding success, egg loss rates, chick mortality rates, predation and the causes of egg and chick mortality. Similar studies are conducted in other parts of the island, well away from where tourists are permitted to walk, in order to monitor any changes that may result from tourism.

Where other human activities occurring away from the breeding site are under examination, such as the impacts of commercial fishing or oil pollution, the principals are the same. Comparisons are made of study areas within the zone of human impact (eg. area that is fished or area of pollution), and control areas that are outside the zone of impact. Studies into the effects of commercial fishing or oil pollution should look for reductions in population size, breeding success, and juvenile and adult survival. Studies into the effects of commercial fishing should also look for increases in foraging range and duration, and changes in dietary composition, all of which effect chick survival.

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7. APPENDICES

APPENDIX 1: TERRESTRIAL HABITAT TYPES

GRASS HEATH is dominated by long, rough grasses. On well drained sites these may adopt a tussock growth form, but on poorly drained plains they usually take on a more lax form. Where present Grass Heath supports many flowering plants, invertebrates and birds, but there was no Grass Heath recorded on Magdalena Island.

DWARF SHRUB HEATH is dominated by low growing shrubs, and is usually found on exposed, dry areas, such as hard peat overlying rocky ridges. Where present Dwarf Shrub Heath provides shelter for invertebrates, flowering plants and birds, but there was no Dwarf Shrub Heath recorded on Magdalena Island.

FELDMARK is dominated by cushion plants, often in association with ferns, dwarf shrubs and coarse grasses. It tends to be found on higher hills and exposed ridges, where the combination of thin shaley soils and exposure to wind exclude faster growing species that are less adapted to desiccation and nutrient deficiency. Where present Feldmark can provide habitat for a few specialist invertebrates and birds, but the harsh conditions and open nature excludes a diversity of species. There was no Feldmark recorded on Magdalena Island.

ROCKY OUTCROP occurs where thin soils and underlying geology result in exposed bedrock or surface stones. Where present such habitat can provide crevices for nesting birds and specialist plants, and surfaces for colonisation by lichens. There was no Rocky Outcrop recorded on Magdalena Island.

FEN is an area of tall freshwater vegetation surrounding ponds, lakes or streams. Where present Fen can provide important cover for nesting birds and invertebrates, but there was no Fen recorded on Magdalena Island.

BOG is a variable habitat comprising wet swampy areas, but there was no Bog recorded on Magdalena Island.

WOODLAND is a variable habitat comprised of trees, which needs to be further categorised according to species composition. Where present it can support a wide variety of mammals, birds, invertebrates and flora, but there was no Woodland recorded on Magdalena Island.

SAND DUNES are areas of loose or vegetated sand which form behind the littoral zone. The consolidating vegetation comprises drought and salt tolerant species able to survive in the harsh conditions. Where present Sand Dunes can provide cover for nesting birds and specialist invertebrate species, but there were no Sand Dunes recorded on Magdalena Island.

ERODED AREAS featuring exposed soil, as opposed to bedrock, caused by overgrazing, burning, physical disturbance or climatic conditions. The low-lying plains of Magdalena Island hold many eroded areas that are too small in area to be mapped. These result from a combination of low rainfall, desiccating salt-laden winds, sandy soils, and disturbance by penguins, which together prevent the establishment of vegetation. These eroded areas give rise to dust storms during strong winds. Low-lying cliffs around the island also feature eroded areas that result from land-slip and coastal erosion.

SETTLEMENTS are areas of housing or human development. Where present such areas often provide niches for specialist plants and animals, some of which are dependent on human habitation (eg. rats and mice). The only area of settlement on Isla Magdalena is the lighthouse.

GREENS are characterised by a short turf of fine grasses and flowering plants, as opposed to the tall grasses of Grass Heath. The terrestrial habitat of Magdalena Island comprises almost entirely of short grasses, mixed with drought-tolerant flowering plants and eroded areas. This is the result of low rainfall, desiccating salt-laden winds, sandy soils, and thousands of penguins that trample the ground and nutrify the soil through the deposition of guano. These Greens attract grazing geese, but a lack of natural fresh water on the island keeps the breeding population of geese low.

PASTURE is very similar to Greens, except that the grass is kept short by livestock rather than natural factors. There was no Pasture recorded on Magdalena Island.

PONDS & STREAMS There were no Ponds or Streams recorded on Magdalena Island.

APPENDIX 2: LITTORAL HABITAT TYPES

Littoral Habitats are divided into physical features and biological features.

a) Physical features:

BOULDER SHORE has stones with an average diameter of more than 300mm. Boulders provide cover for marine invertebrates avoiding desiccation at low tide, and attract feeding birds such as oystercatchers and black-crowned night herons. Boulder Shore is usually subjected to high energy waves, and does not offer safe nesting sites for birds, or suitable habitat for plants, except at the very upper reaches of the shore. There was no Boulder Shore recorded on Magdalena Island.

STONY SHORE has stones with an average diameter of between 2mm and 300mm. The shifting nature of beach stones provides a poor substrate for plants to gain a foothold, and little cover for fauna. Birds such as oystercatchers and gulls may nest on the upper reaches, but most other birds prefer sites which offer more seclusion. Stony Shore is found around the entire coast of Magdalena Island, and it is used by hundreds of gulls which nest above the high water line.

SANDY SHORE has visible grains with an average diameter of less than 2mm. Where present Sandy Shore can provide important feeding and nesting areas for waders. There was no Sandy Shore recorded on Magdalena Island.

MUDDY SHORE has soft sediment made up of grains which are too small to be visible with the naked eye. Such sediments provide rich feeding areas for waders because of the invertebrates living in the mud. Low-energy, estuarine environments are usually covered during spring tides, precluding nesting or the establishment of terrestrial vegetation. There was no Muddy Shore recorded on Magdalena Island.

ROCKY SHORE is made up of exposed bedrock which provides secure attachment for marine invertebrates such as mussels and limpets, and for marine algaes which in turn support other marine creatures. Rockpools also tend to be numerous at low tide, trapping small fish and marine creatures. This wealth of marine life provides rich feeding for birds such as oystercatchers, black-crowned night herons and gulls. The high energy waves prevent nesting, or the establishment of terrestrial plants, except in the upper reaches. There was no Rocky Shore recorded on Magdalena Island.

CLIFFS are steep inclines of underlying rock that exceed 8m in height, and there are several areas of cliff around Magdalena Island. Cliffs provide unsuitable feeding or nesting areas, except for a few seabirds such as gulls and rock shags. Cliffs around Magdalena Island are made up of soft sedimentary rock, which Magellanic penguins use for burrows wherever they can reach. These soft sedimentary rocks are subject to coastal erosion and landslip, which prevents the establishment of cliff flora.

b) Biological features:

GREEN ALGAE is where significant amounts of green algae (*Ulva sp.*) is found. Sea lettuce tends to grow around the mean tide level, where it provides a valuable food resource for shorebirds such as kelp geese. Although some green alga is present, no significant areas were recorded around Magdalena Island.

KELP BEDS are areas where kelps, such as giant kelp (*Macrocystis pyrifera*) and tree kelp (*Lessonia sp.*) can be found in the sub-littoral zone. Kelp beds provide an important ecological niche supporting small fish and invertebrates, making them important feeding areas for seabirds such as cormorants. Kelp beds were recorded around the entire coast of Magdalena Island.

MUSSEL BEDS are areas where large numbers of mussels are present. Mussel beds provide an important food resource for birds such as oystercatchers and gulls, especially during the winter when other food is scarce. One significant area of mussels was found along the northern coast of Magdalena Island.

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GLOSSARY

ALLOPREENING: the process whereby one bird preens another bird's plumage.
ANAEROBIC: in the absence of oxygen.
BIOLUMINOUS: describes living tissue which emits light.
BIOMASS: total weight of organic material.
CULMINICORN: side of the upper beak.
DECAPOD: crustacean with ten thoracic legs such as shrimps, lobsters, crayfish and crabs.
ECTOSKELETON: hard outer skin of invertebrates.
EGGING: local term for the taking of eggs for human consumption.
ENSO: abbreviation for El Niño Southern Oscillation. Refers to the process whereby cool nutrient rich waters which flow northwards along the coast of Chile and Peru, become displaced by warmer nutrient poor waters flowing from the central Pacific. This loss of nutrients is characterised by a slowing down of primary production by phytoplankton, which in turn leads to changes in the entire marine food chain.
FURCULA: one-piece collar bone found in birds.
MANDIBULAR PLATE: coloured patch running from the lower beak to the cheek.
MESOPTILE PLUMAGE: thick downy plumage of chicks.
PROTOPTILE PLUMAGE: very sparse plumage of very young chicks.
OCCIPITAL CREST: crest of erect feathers found around the head of certain penguins.
ORCA: killer whale
PINIPEDS: sea lions, seals and walruses.
UROPYGIAL GLAND: gland at the base of the tail that produces wax for waterproofing plumage.

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