AUSTRALIAN NATURAL HISTORY SERIES

ALBATROSSES

TERENCE LINDSEY

ALBATROSSES

If I were reincarnated, I’d choose to come back as an albatross.

Frans Lanting, 1993

I now belong to a higher cult of mortals, for I have seen the albatross!

Robert Cushman Murphy, 1911

This book is dedicated to my beloved daughter Claire

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TERENCE LINDSEY

Principal Photographer Rod Morris

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Front cover
Black-browed albatross (population impavida), off Campbell Island, New Zealand.
Photo: Ann Lindsey

Back cover
A pair of royal albatrosses on the Chathams, east of New Zealand.

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ACKNOWLEDGEMENTS

I haven't, you understand, actually counted them, but I guess there must be something close to 10 000 pages of technical material devoted solely to albatrosses archived in the world's primary ornithological literature spanning the last century or two. Several hundred research papers have been directly accessed in the compilation of the text that follows alone. Since a typical modern research report runs to a dozen pages or so, that's around 5000 pages to start with. And there is at least as much material again that is, for one reason or another (taxonomic debate, detailed plumage description, superseded research, and so on) less directly relevant – although nearly all of it has been read, re-read, or at least scanned in the preparation of this text.

Yet, despite this mountain of material, so far as I am aware, works that seek to convey the essence of one of the most magnificent of all birds, and its place in its world, to any wider audience beyond the arena of the seabird enthusiast, whether amateur or professional, are nearly non-existent. This book is a modest attempt to plug that gap.

In having a go at it, I have leaned heavily on a number of standard specialist sources and classic works on seabirds. To list all risks having this acknowledgement run on for pages, but a few of the more prominent must be mentioned. For decades the single most authoritative source on albatrosses was Robert Cushman Murphy's two-volume Oceanic birds of South America, published by the American Museum of Natural History in New York in 1936, and still a classic in its field. Today, the most authoritative single source is undoubtedly W.L.N. Tickell's Albatrosses, published by Pica Press in 2000. It is nearly impossible to find anything written about albatrosses before the close of the twentieth century that isn't reviewed by Tickell. Also relevant is Dr Rosemary Gales' admirably concise summary of basic albatross biology in Co-operative mechanisms for the conservation of albatross, published by the Australian Antarctic Foundation in 1993. A further important event in the documentation of albatross biology occurred in 1998 with the publication by Surrey Beattie & Sons in Sydney of Albatross biology and conservation, bringing together reports on just over a score of current research projects under the general editorship of Drs Graham Robertson and Rosemary Gales. As well, much peripheral material on the world of the albatross in these pages is drawn from The biology of the Southern Ocean, by George A. Knox, published by Cambridge University

Press in 1994. What might be termed the passive support of all of the researchers involved in these works, and others unspecified, is here fully and gratefully acknowledged.

In the original planning stages of this book, I almost immediately dismissed the notion of incorporating the kind of information here summarised in tables at the end of the book (pages 114 to 117). This book is not intended as a reference, but more directly to the point, any preconception that the various albatross populations of the world must surely by now have been thoroughly weighed, measured and counted, and the results published, is entirely unfounded. Some have, but comparable data for many others is based on a mere handful of specimens. To pluck an instance at random, published data on the weight of mollymawk eggs is almost non-existent – yet the weight of a bird's egg carries far more significance than the ordinary non-zoologist might at first realise. In a few cases, estimates based on closely related populations are the only data available. However, I ultimately came to the view that leaving the general reader with absolutely no idea at all of 'how big' and 'how many' would be completely untenable, so the tables were reluctantly inserted. The material included here was compiled from several score of published sources, mostly original but also leaning heavily on such standard references as Volume 1 of the Handbook of Australian, New Zealand and Antarctic birds, coordinated by S. Marchant and P.J. Higgins and published by Oxford University Press in 1990 (and known almost universally among bird enthusiasts simply as HANZAB).

Some population estimates were extracted from BirdLife International's website at www.birdlife.org. If even physical dimensions of albatrosses present nearly insuperable difficulties in terms of scrappy uneven data with enormous gaps, in many ways the situation with regard to population estimates is even worse. On the one hand, for example, the US Fish and Wildlife Service has several times in recent years succeeded in coordinating sufficient volunteer labour to complete nearly perfect censuses of Laysan and black-footed albatross nests at their Hawaiian breeding colonies – but on the other hand there are still several substantial mollymawk colonies in the Southern Ocean that have never been satisfactorily surveyed even once. The situation is rapidly improving as scores of researchers continue working on nearly all of the world's albatross populations, but the logistical difficulties are usually formidable and sometimes utterly daunting.

In brief, the tables offer no pretence whatever of any level of statistical rigour. I constructed them by plodding methodically through, item by item, and tussling with the assembled published dataset until I arrived at a single number that seemed to me most plausibly and most nearly to encapsulate the dimensions of a 'typical' representative of the population. Their only purpose is to convey to the general reader a 'first approximation' of an overall impression of basic life history data relating each species to the others. Anyone seeking currency, precision or complete accuracy is urged to go to any of the standard technical texts.

Dr Jennifer Spencer and Dr Walter Boles read the manuscript, and I – and the text – have benefited much from their conversations, comments and general moral support. Walter facilitated my access to the resources of the Australian Museum in Sydney. Jennifer was also especially helpful in producing copies of a number of research papers that had eluded my own retrieval mechanisms. I hope errors are few, but any that do remain are entirely my own. My friend Rod Morris in New Zealand contributed most of the photographs (all are by him unless specifically credited elsewhere). Ann Lindsey and Claire Lindsey helped with several practical matters. To all I extend my thanks.

1

MYTH AND LEGEND

Almost everyone who has ever written anything about albatrosses has waxed lyrical at some point in his or her discourse, especially when dealing with the prince of them all, the wandering albatross. There is something about this enormous bird, roaming as it does forever alone over the vast empty spaces between the continents like some sort of avian Flying Dutchman, that conjures up all sorts of romantic and dramatic images in the human observer. It's a failing I'm prone to myself, and it seems to make sense just to roll with it and get it out of the way right upfront.

I have watched peregrine mothers teaching their young to hunt, and it is indeed a spectacular sight. I have watched golden eagles soaring in Alaskan mountain wildernesses so preposterously wild and grand it brought tears to the eyes. I have watched the blue bird of paradise in full courtship display in Papuan mid-mountain oak forests – it is truly jaw-dropping. As a boy I've seen snow geese surging north in spring over the Canadian prairie in flocks tens of thousands strong, overhead a shattering thunder of wings, their more distant squadrons like smoke on the horizon. But I have also watched wanderers storming along in a Force 7 gale in the depths of the Southern Ocean, and I have to say I find it impossible to imagine that anything could be more impressive, while still

Albatrosses

clad in feathers. The wanderer is the ultimate seabird, the ultimate flying machine. He owns the wind. He is the Storm-Rider. It is not easy to be entirely unmoved by a wanderer.

The thing is, it's not all myth and legend and over-dramatic froth. The wandering albatross is an extraordinary bird by any objective standard. It is the largest living thing in the air. It has the lowest 'cost of flight' of any flying animal. Its reproductive cycle is longer than that of any other bird. It is the most mobile creature on the planet: nothing else can move so far so fast. Thanks to numerous television wildlife documentaries, many of us are aware that the cheetah on the plains of Africa went through an 'evolutionary bottleneck' some thousands of years ago and in consequence has a vastly impoverished gene pool – but the wanderer has the smallest gene pool yet found in any vertebrate animal. It is even of interest to mathematicians because in its searches for food it exhibits the only example of an abstruse theoretical concept called a Lévy path yet found in any living system (no, we won't go there). And the bird is of special interest to zoologists because in its lifestyle it crowds the outer limits of what it's possible for an animal to do.

This book is about albatrosses rather than any particular species of albatross. Throughout the exploration of the bird and its world that follows, the focus is on those things that make the albatross unique rather than the things that merely distinguish one species of albatross from another. The wanderer gets mentioned perhaps more frequently than any of the others. I have no difficulty confessing that the wanderer happens to seize my own imagination more vividly than any of the others, but there's more to it than that. The wanderer is undeniably the flagship of the albatross fleet, in the sense that in nearly everything an albatross does that makes it an albatross the wanderer goes just that one step further.

Late last century two things affecting albatrosses occurred. The 1980s saw a catastrophic population collapse when albatrosses came in contact with something new brought in by the world's fishing fleets (explored in Chapter 8). A decade or so later technology made it possible for detection devices to be strapped to albatrosses and for them to be spied on from satellites. Both events, separately and in combination, provoked a surge of research interest in albatrosses, and both – for a variety of reasons – impinged most heavily on the wanderer. Several albatross species, notably the Laysan albatross in Hawaii and the royal albatross in New Zealand, have been intensely studied at their nests for five decades or more, but since around 2000 we now know a huge amount more about all the other aspects of their lives at sea. This is especially so in the wanderer's case. Overall it could be argued that the wanderer is now better known, across all aspects of its biology, than any other albatross, so it seems to make sense to let it serve as spokesman, so to speak, for all members of the group. Moreover, the albatrosses constitute an extremely compact group and, to an extent perhaps unusual among birds, almost any interesting statement true of one species could be applied to any of the others, if you are willing to tolerate just a little squeezing and moulding and fuzz around the edges.

There is another relevant consideration. Reduced to baldest possible terms, the world of albatross specialists is currently divided into two camps: those who declare there are 13 species of albatrosses (and their supporters), and those who declare there are 24 species of albatrosses (and their supporters). Albatross taxonomy is complicated – well, not really (as I hope to show), but it's undeniably a confused and fluid situation. As this book is essentially about albatrosses rather than any particular species of albatross, the taxonomic debate is largely irrelevant. This text seeks to go around the issue rather than through it. However, in Chapter 2 we'll tiptoe into the taxonomist's arena and remain just long enough to pick up a general impression of at least the size and shape and flavour of the debate, but for the most part we'll leave it alone. References to particular species in this book are deliberately casual and informal. In those few cases where it really is vital to be absolutely specific I adopt the convention of using only the name (exactly the name) from column four in the table on page 114. But wherever it seems to me possible and appropriate, in these pages wanderers are given special licence to wander on and off the stage as they please.

Albatrosses belong to an order of birds called the Procellariiformes. This assemblage also includes the fulmars, petrels, shearwaters, storm-petrels and diving-petrels, which have in common a number of features otherwise unusual among birds. In this order, for example, are found the only genuinely pelagic birds. Most of the birds we conventionally consider seabirds are in fact birds of the coast, seldom or never leaving sight of land, but the reverse is true of albatrosses and their kin. These birds must come ashore to nest, but otherwise they remain far out at sea, sometimes for years at a time. The group also has the greatest size diversity of any order of birds – that is, the ratio in physical measurements of the largest member to the smallest is greater than in any other group of birds. The largest albatross has a three-metre-plus wingspan, whereas the smallest, a storm-petrel, is little bigger than an ordinary starling. One distinctive – in fact diagnostic – physical feature is the presence of two tubes that sit side by side on the upper bill, close to the base. This feature, which is linked with the dumping of excess salt from the blood, leads to the common name 'tubenose' often used to refer to the group as a whole.

In order to evolve a successful life strategy that exploits the foraging resources of the deep ocean, the tubenoses have had to confront a challenge nearly unique among birds. Indeed, it is not easy to find a truly comparable instance anywhere else in the animal kingdom. In a word, seabirds need to be extremely mobile; they have to travel great distances to gather food that by its very nature is widely scattered across even greater distances. But the real catch emerges when nesting season rolls around. Even the most oceanic of birds must perforce return to land to lay their eggs and rear their chicks. It is unusual for a typical land bird, on the one hand, to need to travel more than a kilometre or two from its nest to find food for its young. But even coastal birds often need to travel tens or scores of kilometres, and those tubenoses that forage over the deep ocean must commute hundreds or even thousands of kilometres from their nests to find food for their young and fetch it safely home. It is this steep escalation in what might be termed 'commuting costs' that is the pivotal factor in understanding the behaviour of seabirds and the way in which they organise their lives. It is not the finding of food, so much as the carrying of it.

All this throws a premium on the development of fast, efficient, effortless flight. Nearly all of the tubenoses have evolved, to a greater or lesser extent, and each in its own particular fashion, behavioural and physical characteristics that in effect respond to the challenge by finding ways of reducing muscular exertion while allowing the wind to do as much of the work as possible.

The albatrosses are those tubenoses that have gone the farthest down this particular evolutionary pathway, having very nearly abandoned powered flight altogether. They have turned themselves, you might almost say, into the ultimate super-efficient high-speed gliding machines.

In the Western world, the albatross was entirely unknown until the earliest Portuguese, Spanish, Dutch and English explorers set off in search of a sea route to the fabled Spice Islands of the East in the fifteenth and sixteenth centuries. The earliest written mention of the bird in English seems to be contained in the Elizabethan privateer Sir Richard Hawkins' account of one such voyage in 1593, where he noted 'certain great fowles as big as swannes, soared about us', adding that their wingspan was 'about two fathoms' (quoted in Markham 1878). These birds were clearly

With their long, super-efficient wings, albatrosses are among the very few birds able to travel far from land and roam the furthest reaches of the world's oceans.

albatrosses, perhaps wanderers. Early mariners had nothing in their traditional bestiaries to guide them in deciding what manner of bird these unknown 'great fowles' might be, and early guesses tended to alight on the pelican (itself an exotic creature at the time) as the new bird's closest relative. Somehow the Arabic word for pelican, transmogrified into Western languages (through Spanish via Moorish influence) as alcatraz, became linked to the bird. By the close of the eighteenth century the bird, its name now anglicised to albatros or albatross, had become firmly established in English language and culture, with its own large body of folklore.

In 1758, the first albatross (the wanderer, as it happens) was formally introduced to Western science when it was named Diomedea exulans by the Swedish taxonomist Carl Linnaeus. The epithet exulans comes from the same ancient Greek word that lives on in modern English as 'exile', meaning homeless or wanderer. The generic name Diomedea was not at first particularly linked with the albatross by Linnaeus, who associated it with several other (unrelated) birds in his concept, but even here the resonances, though fanciful, are intriguingly apt. Linnaeus selected his name from classical Greek legend. One of the prominent figures in Homer's Iliad, Diomedes served with Odysseus and Palamedes as commanders of the Greek army that sailed with Agamemnon to lay siege to Troy and to recover the abducted Helen. According to Greek mythology, Diomedes later offended the goddess Athene, who gave effect to her displeasure by conjuring up a ferocious storm at sea to wreck his fleet. In one version of the legend she turned him and all his drowned men into large white birds; in another version he survived to live out his life in exile at the court of King Danaus.

It is far from clear just how the albatross acquired its profound spiritual connotations in English folklore. For most literate folk the link is epitomised in Samuel Taylor Coleridge's poem The Rime of the Ancient Mariner, a harrowing tale of murder, penance and redemption that quickly became one of the landmarks of English literature after its publication in 1798. In this fantasy, the murder occurs when the Ancient Mariner kills the bird of good omen, the Albatross, the bird 'that makes the breeze to blow', with the result that the vessel is becalmed and the crew all die of thirst. But where did Coleridge get the core idea of the albatross as an omen? Coleridge himself described the work as purely imaginative, although historians later forged an intriguing link by uncovering the fact that one of Coleridge's early schoolmasters was William Wales, who had in his youth sailed as astronomer and meteorologist with Captain James Cook during his second voyage of 1772–1775. At the time, exploration of the Southern Ocean was in its infancy, the exploits of the early mariners had seized the public imagination and popular accounts of their voyages were on the best-seller lists of the day. Even so, it seems remarkable that the symbol of the Southern Ocean, the albatross, had, within a few decades, so quickly established a place in the superstitions of the ordinary seaman. This association continued at least well into the nineteenth century: in the maritime folklore at the time of the Tall Ships (the clippers racing from China to home ports in England with their precious cargoes of tea) one of the myths that crops up frequently is that old sailors who die at sea are reborn as albatrosses.

Two characteristics above all others quickly captured the public imagination: the albatross's great size, and its ability to cover enormous distances with seeming effortlessness.

Albatrosses spend nearly their entire lives on the wing. There is something compelling, almost hypnotic, about loafing against the rail of a vessel at sea watching an albatross wheeling and soaring in the ship's wake as it follows the vessel for hour after hour, something akin to staring into the embers of a dying campfire. Generations of early mariners had similar experiences – but even the earliest of them sometimes noticed, or thought they noticed, something else again. It often seemed to them that they were staring at the same individual bird, so doggedly trailing the vessel for hour after hour. Some even noted the experience of coming up on deck the morning following such an observation, to be greeted by the sight of what they became intuitively convinced was exactly the same individual, still escorting the vessel. Sometimes an idiosyncratic feature of the bird – a missing wing feather or some such detail – served to strengthen the impression. Occasionally the intuition could be reinforced with a little more rigour. Sometimes it was possible to catch the albatross with a baited hook and line, to be hauled ignominiously aboard, marked in some way (a quick daub or two from a bucket of tar was often the most convenient method in the days of wooden sailing vessels, when such artefacts were nearly ubiquitous), then released. Often enough, the exercise proved sufficient to confirm that it was indeed the same bird following along, day after day, sometimes for a week or more.

In his monumental thesis on the oceanic birds of South America, Robert Cushman Murphy relates an incident that conveys the essential point so vividly that it has been retold many times since, and bears retelling here. The archives of Brown University Museum in America hold a manuscript that reads:

> Dec. 8th, 1847. Ship ‘Euphrates,’ Edwards, 16 months out, 2300 barrels of oil, 150 of it sperm. I have not seen a whale for 4 months. Lat. 43°S., long. 148°40′W. Thick fog, with rain. (Quoted in Murphy 1936)

This terse message was found in a small container tied to the neck of a wandering albatross shot off the coast of Chile at 45°50′S, 78°27′W on 20 December 1847. Conceding the accuracy and precision of the stated dates and locations, the bird had thus flown, point-to-point, 5837 kilometres in 12 days.

This extraordinary mobility, the astonishing ability to cover enormous distances in a matter of days, very soon became firmly established as one of the key elements in Western folklore surrounding the albatross, and in particular the wanderer. Folklore, in this particular case, that was founded firmly in fact, although that was not to be finally and unequivocally demonstrated until the deployment of advanced satellite technology late in the twentieth century.

The albatross is indeed the largest of all flying creatures, but only if wingspan is deemed the decisive criterion. If the judgement is to be decided by mass or weight, then several among the various species of swans, cranes or pelicans have legitimate claims that need to be evaluated. A mature male wandering albatross may weigh as much as 11 or 12 kilograms, seldom more. On the other hand, in northern Europe it should not be too difficult to find a mute swan of comparable age and gender that matched such a bird in weight, and some have been recorded at two or even three kilograms heavier still. Similarly, recorded weights for the Dalmatian pelican range up to 13 kilograms. There are several other possible contenders in this general class of super-heavyweights among birds.

When it comes to wingspan the picture is much clearer, though not entirely so. A mature male wanderer has a wingspan comfortably in excess of three metres. Nothing else even comes close. Except another albatross, that is. The fact is, the two 'great' albatrosses, the wanderer and the royal albatross, are so closely matched in size that any genuine differences are occluded by the cloud of uncertainties necessarily attendant on any attempts to measure them. Another quote from Robert Cushman Murphy conveys one aspect of the difficulty:

> Finally I may report that the same figure (11 feet 4 inches or 345.4 centimetres) was the greatest expanse noted among the Wandering Albatrosses collected in the South Atlantic and at South Georgia. From all this evidence I conclude that a wing spread of about 11½ feet, with the wings of the dead bird stretched out as tightly as possible, represents the maximum of any known bird. The 12-foot albatross needs verification; the 13-foot albatross is probably a myth. (Murphy 1936)

Wingspans are not widely used in formal avian studies because they are extremely difficult to measure accurately. Different observers get different results, and there is a definite knack to it. This is so even with a small bush bird that can be handled by one person, but it is asking a good deal of an albatross to expect it to lie, inert and docile, flat on its back, while two husky researchers hold it down and pull its wingtips 12 feet apart. On a boggy moorland, with no flat, level ground… In the pouring rain… Or a high wind…

For what it's worth, published records of albatross dimensions tend to favour the royal over the wanderer as the world's biggest flying bird – but by a very small and possibly spurious margin. But in field conditions, with living birds, truly meticulous measurements of this especially awkward kind are both impractical and ethically suspect, and it is possible that the point may never be decided to everybody's complete satisfaction.

2

THE SPECIES

Albatrosses come, as it were, in four basic styles or models, which might for convenience be informally dubbed the sooties, gooneys, mollymawks and ('great') albatrosses. This notion was first advanced by the taxonomist Reichenbach in 1852 when he formally proposed the genera Phoebastria, Phoebetria and Thalassarche to set alongside the genus Diomedea set up by Linnaeus in 1758. In a landmark study published in 1998, C.J.R. Robertson and G.B. Nunn used DNA evidence to, in effect, ratify this proposal, which has since received general acceptance throughout the seabird specialist community.

Much more controversial was the simultaneous proposal to promote most of the island populations of the albatrosses of the Southern Ocean (mostly already known as subspecies) to full species status. For much of the twentieth century, the number 13 was accepted as the world's total roster of albatrosses (much later, that became 14 species, but even that was debatable). The proposal brought into being 24 species at a stroke. It is perhaps fair to say that the new order was taken up with some enthusiasm by many in the conservation and field observer communities but with some reservations in the more specialist fields. In any event, so many species are listed in so many field guides and popular works on albatrosses in today's marketplace that some exploration of the difficulty seems essential here (the website of the influential conservation organisation BirdLife International, for example, at the time of writing lists 22 forms as full species).

Contributing to this state of affairs in the modern world is the sad fact that much conservation legislation, whether national or international, is phrased in such a way that only full species are 'visible' to the system. Albatrosses are gravely endangered birds, in urgent need of funding for research, management and protection. But 'mere' subspecies tend to be, in effect, disenfranchised, and so it seems entirely understandable that conservation-oriented researchers might not challenge any device that promises to reduce bureaucratic delays in the funds-gathering process. There are other considerations along broadly similar lines: in brief, there are pragmatic as well as more esoteric advantages in accepting an albatross classification system that holds 24 or so albatross species.

But there are still sceptics. The matter remains controversial, and the world of albatross enthusiasts remains divided into 'splitters' and 'lumpers'. In 2004 the researchers John Penhallurick (of the University of Canberra) and Michael Wink (of Heidelberg University in Germany) together published an analysis of albatross taxonomy (along with that of other seabirds) that approached the matter from a somewhat different direction (Penhallurick and Wink 2004). It might be fair to say that they exploited the notion that, no matter how controversial, experimental or flawed any ruler might be, you can still use it with confidence to find out if A is bigger than B or smaller than C if you're careful to use the same ruler for all the measurements. They analysed the molecular structure of the DNA (from the mitochondrial cytochrome b gene, to be specific) of nearly all of the albatross populations of the world to derive a measure of 'genetic distance' or divergence for each of some 250 possible combinations (the technicalities need not concern us here).

Their results undeniably brought aid and comfort to the lumpers. To quote one particular example by way of illustration, the divergence value they found for the royal albatross of New Zealand relative to any of the wandering albatross populations was 3.2 per cent or more, whereas the maximum value found between any of the wanderer populations themselves (many now often treated as full species) was only 0.52 per cent; similarly, the two populations of the royal albatross are themselves often treated as full species, but the genetic difference between them is only 0.0009 per cent. Overall, they found divergence values among the various island populations of traditionally recognised albatross species were all well under 1.0 per cent, whereas the comparable values between traditionally recognised species themselves were all comfortably over 2.0 per cent. It should be noted that in comparable studies using this particular 'ruler' on many other birds around the world over the past decade or so, a divergence value of somewhere around 2.5 per cent has gradually emerged as marking the lower limit for a good species (most bird species are around four per cent), with a corresponding firming of consensus on the logical corollary: anything showing less than 1.0 per cent divergence just hasn't made it yet.

Genetic studies of this kind are evolving rapidly, but many areas of uncertainty remain. It seems unlikely that these particular studies will prove to be the last word on the matter, and it may yet take some time to arrive at a definitive answer to the question: 'Just how many species of albatross are there?'

The table on page 114 sets out the various albatross populations. Column three lists the species according to what might be termed the 'traditional' view, while beside them column four lists their respective island populations. In a nutshell, column three encapsulates the lumper's view (condensing the species to only 13 full species), column four the splitter's (expanding the species to 24), and to arrive at the latter you need only mentally ignore column three. The vital point to note is that nothing else changes.

Great albatrosses (*Diomedea*)

Two species are traditionally accepted in this group, the royal albatross and the wandering albatross. Taken together, their most obvious feature is their enormous size. In terms of wingspan they are the largest of all birds by a comfortable margin, though by weight more or less on a par with other large flying birds such as swans and pelicans. Exactly how big is a complicated question, because there are at least seven island populations, all differing significantly in size, and males generally outweigh females by around 20 per cent. There is a gradual trend in increasing size from north to south, but a big southern adult male weighs around 11–12 kilograms and may reach 3.5 metres in wingspan. Also notable is the bewildering sequence of plumages these albatrosses go through as they mature. When they fledge and go to sea, most forms are essentially chocolate brown with white faces, becoming mainly white on reaching maturity. But this progression from 'mostly brown' to 'mostly white' occurs over a succession of several annual moults according to an intricate schedule that varies between the two sexes and from one island population to another.

The breeding islands of the royal albatross all lie in the New Zealand region, and non-breeding birds disperse eastward across the southern Pacific Ocean to seas off Chile, Argentina and southern Brazil. There are two populations, now often promoted to full species status: a large southern form epomophora, which breeds at Auckland and Campbell Islands; and a smaller northern form sanfordi, which nests on the Chatham Islands and (a single small colony) at Taiaroa Head near Dunedin on the South Island.

The wanderer's distribution is much more extensive: it breeds on many islands in southern seas from Gough in the Atlantic to Campbell Island in the New Zealand region, while at sea it occurs throughout the Southern Ocean. There are five distinguishable populations, several of which are often promoted to full species status.

Due to the unusually complicated plumage sequences of the great albatrosses, identifying the various island populations at sea is extremely challenging. It's largely a question of patient sifting through dozens of possible combinations of features, trying to work out how old your bird is and where it came from, before arriving at a species determination. The few constant field marks are not especially helpful. For example, the royal albatross has a diagnostic narrow black line running along the centre of the bill – but the problem is to see it.

Mollymawks (*Thalassarche*)

Originating in New Zealand, the term 'mollymawk' is widely used for the smaller albatrosses, in particular those now placed in the genus Thalassarche. There are five 'traditional' species, although, as already explained, some DNA evidence supports a move to promote several of the various island populations to form nine or perhaps even eleven full species. All are fairly similar in general appearance and biology, and are all confined to the Southern Ocean. The mantle (often called the saddle – that is, that section of the upperparts that lies between the outstretched wings) is black (or very dark grey) like the upper surface of the wings, in contrast to the great albatrosses, in which the mantle is white. The sexes are nearly indistinguishable in appearance, and immatures differ little from adults. Mollymawks lack colour in their plumage (parts that aren't white are very nearly black) but parts of the bill are often brightly coloured (though uniformly black in immatures). There is one large mollymawk (the shy albatross), one small (the yellow-nosed albatross) and three very similar medium-sized forms (black-browed, grey-headed and Buller's albatrosses).

Largest of the mollymawks (wingspan around 2.5 metres) – the shy albatross – is confined to the Australia/New Zealand sector of the Southern Ocean where it has its breeding grounds. There are at least four populations, often promoted to full species: cauta (which breeds on islands off Tasmania); steadi (Auckland Island); salvini (Snares, Bounty); and eremita (Chathams). It is also widely known as the white-capped albatross, in that several populations have pale grey heads that throw the pure white forehead into special prominence. The bird is no more 'shy' than any other albatross, though perhaps a shade less gregarious than some, and perhaps a little more reluctant to join the thick of a scrum around any fishing vessel dumping offal. It is common in shelf waters around southern Australia and New Zealand, frequently dives, and its diet seems to lean more to fish, less to squid than some other mollymawks. The underwing is distinctive, being white, only very narrowly and evenly bordered with black, with a small, diagnostic black mark in the 'armpit'. The bill is dull greenish-yellow.

The three medium-sized mollymawks (black-browed, grey-headed and Buller's) are so similar in size, general appearance and behaviour that in the field they often seem the same bird with, as it were, different paint jobs. All have a wingspan of around two metres. Nevertheless, there are subtle but important differences in their ecology. The black-browed albatross, for example, is markedly less pelagic than its relatives, foraging mainly over shelf waters; the grey-headed albatross, in contrast, is more mobile, and forages largely at frontal systems in the open ocean. The black-browed albatross is perhaps the most widespread of all the mollymawks as well as one of the most numerous. It has nesting colonies on most subantarctic islands and ranges almost everywhere in the Southern Ocean. In many areas it is the albatross perhaps most likely to be seen from land. Several nesting colonies contain tens of thousands of pairs, it freely congregates around fishing boats and similar craft, and even at sea away from the breeding sites it is sometimes possible to see hundreds at a time. It is also one of the easiest of albatrosses to identify, with white underwings broadly and irregularly rimmed with black and (as an adult) a bright orange-yellow bill. There are two populations: impavida, which is nearly confined to Campbell Island as a breeding bird, and melanophris (everywhere else). Albatrosses in general have dark eyes, but impavida is unique in having honey-coloured irides.

Though it often occurs together with the black-browed, and the two may even nest together in mixed colonies on some islands, the grey-headed albatross is far fewer in number and less widespread and, on the whole, tends to favour colder, more southern waters. In Australian waters it is very rare, for example, off New South Wales, though common enough off Tasmania. Buller's albatross breeds only in the New Zealand region, though it ranges westwards to seas off southern Australia and east to Chilean waters. There are two populations, often regarded as species: bulleri, which breeds on Solander and the Snares, and platei (Chatham Islands). The mollymawks are so similar in appearance that identification is often a matter of sifting through an intricate web of subtle details, but distinguishing between Buller's and grey-headed albatrosses is especially challenging for the inexperienced observer. Both are bright yellow along the upper and lower rim of the bill.

The yellow-nosed albatross is the smallest and 'neatest' of all the mollymawks, with a wingspan of under two metres. In other mollymawks, black areas of plumage usually look more like a sort of very dark dingy grey, but the yellow-nosed usually appears much more crisply black-and-white. The bill is black, narrowly rimmed bright yellow along the upper mandible. It is common and widespread, but tends to favour somewhat warmer, more northerly waters than other mollymawks. It has two populations: chlororhynchos, which nests on Tristan da Cunha and Gough Island in the South Atlantic, and carteri, which breeds on islands in the southern Indian Ocean.

North Pacific albatrosses (*Phoebastria*)

Albatrosses from the Southern Ocean cross the tropics and enter the northern Pacific Ocean only at very rare intervals and under exceptional circumstances, so that the four albatross species (Laysan, black-footed, Steller's and waved) resident in the North Pacific are for all practical purposes completely isolated from the mollymawks, sooties and great albatrosses of the Southern Ocean, and clearly have been for millennia. (Very rarely, there is traffic in the reverse direction: the Laysan albatross has been recorded, for example, in the Solomon Islands and at Norfolk Island in the Tasman Sea.)

The last-mentioned of this quartet, the Galapagos or waved albatross, is nearly confined as a breeding bird to the Galapagos (there is a very small colony on an island just off the coast of the Ecuadorean mainland) and it forages south-eastward to the coast of northern Peru. Of course, the Galapagos lie just south of the equator, so strictly speaking not in the North Pacific at all, but the convenience of stressing that all four species belong together in their own distinct genus, live far to the north of all other albatrosses, and are almost completely isolated from them means it makes sense to momentarily ignore this little bit of untidiness. The Galapagos albatross is neither as intensively nor so long-studied as many other species, but it has a number of strikingly unusual features. First, its entire distribution (where it is the only albatross species) encompasses less than one million square kilometres – a minute range by albatross standards. It relies far more on powered (flapping) flight than other albatrosses. It is much less inclined to follow ships. It has a strikingly short tail and long bill relative to other albatrosses (in its diet it seems to rely more heavily on crustaceans, less on squid, than other species, but it is far from clear why it needs a longer bill to catch them). And it appears to obtain a significant portion of its food by stealing it from other seabirds.

Approximately equal in size and shape (with a wingspan of about two metres), the Laysan albatross and the black-footed albatross share a distribution that sprawls across much of the North Pacific. Nevertheless, at any given region in any particular season, one greatly outnumbers the other. Both breed mainly on the scattered islets that sprawl westwards from the main islands of Hawaii (though seldom actually together) but, on the whole, the black-footed albatross tends to forage northward to Alaska and eastward to the American mainland, whereas Laysan albatrosses tend to roam north-westward to Japan and Kamchatka or south-eastward into the central Pacific. The at-sea distributions of both species were, until the advent of satellite tracking of Southern Ocean birds, the most thoroughly documented of all albatrosses, thanks to the efforts of shipboard observers on the busy trade routes between Japan and North America. As well, the Laysan albatross in particular has been closely monitored for decades at its nesting colonies, especially at Midway after that tiny island assumed pivotal strategic importance during World War II and the bird was famously involved in extraordinary confrontation with the United States Navy (discussed more fully in Chapter 8). The two species differ strikingly in plumage: the Laysan albatross looks not greatly unlike a shy albatross (mainly white, with black upperwings and a dull yellowish bill) except for more black in the underwing, but the black-footed albatross is more or less entirely dark sooty brown, with a narrow band of white at the base of bill and tail. In the Laysan albatross there is no variation in plumage by age, season or gender (its scientific name, immutabilis, means 'immutable, unchanging') but young black-footed albatrosses age through an intricate series of plumage changes still not clearly understood.

Steller's albatross, otherwise known as the short-tailed albatross, was once as widespread as the Laysan and black-footed albatrosses, and possibly even more numerous, but was nearly wiped out by plume hunters during the nineteenth century. Its breeding headquarters were in the vicinity of Japan, but it roamed across the Pacific to the American mainland, where subfossil remains have been found in middens at numerous archaeological sites. Early in the twentieth century it was believed extinct, but in 1953 a small colony was found on Tori-shima, one of Japan's outermost islands. Under rigorous protection from the Japanese Government, its numbers have steadily increased since rediscovery, but it remains one of the most critically endangered of all albatrosses. Mainly white in plumage, adult Steller's albatrosses have a distinctive dark half-collar and bold white patches in the mainly black upperwing, but juveniles are mostly dark dusky grey, and difficult to distinguish at sea from the black-footed albatross although they are a substantially larger bird.

Sooties (*Phoebetria*)

The two 'sooties', the sooty albatross and light-mantled albatross, differ strikingly from all other albatrosses by their sleek, slender flight silhouette, with narrower wings and a long, wedge-shaped tail. This group is made up of a pair of closely related, very similar species confined to the Southern Ocean. The two species are so similar that, as immatures, they are sometimes unidentifiable – even as museum specimens. Both species are almost entirely dark smoky brown in plumage but, as the name suggests, the back, or 'mantle', between the upperwing of the light-mantled albatross is a contrasting shade of light grey. The bill is glossy black, but at very close range, the sulcus (a narrow, fleshy strip running along the lower mandible) of the sooty albatross is orange-yellow, that of the light-mantled is light bluish-green. Typically, the sooty albatross appears dull smoky brown at sea, but the light-mantled albatross can often look distinctly bluish in hue.

Although they are every inch an albatross, there are several features that set the two sooties apart from all the others. They favour cliffs rather than plateaux for nesting, which emphasises a stronger aerial component in their courtship behaviour. Also, they are much more at home underwater: they frequently dive to 12 metres or more, whereas other albatrosses struggle to reach four metres. Anatomically, their strikingly different tongues hint at very different feeding behaviour, although it remains unknown what those differences might be. Scant data available suggest they may be more active hunters rather than scavengers like other albatrosses.

Although their distributions broadly overlap, the sooty albatross is most numerous north of the Antarctic Convergence whereas the light-mantled albatross is most numerous south of that boundary. In fact the light-mantled is the only albatross to commonly penetrate the region of pack-ice fringing the Antarctic continent itself. Nesting islands of the sooty albatross include Tristan da Cunha, Gough, Amsterdam, St Paul, Marion, Prince Edward, the Crozets and Kerguelen, whereas the light-mantled albatross breeds mainly on South Georgia, Marion, Prince Edward, the Crozets, Kerguelen, Heard, Macquarie, Auckland, Campbell and the Antipodes.

3

THE HABITAT (THE SOUTHERN OCEAN)

The fossil history of albatrosses is so fragmentary that it remains uncertain where or when the group arose. No fossil fragment that even might be an albatross is any older than about 32 million years. Several albatross species closely resembling modern mollymawks (and roughly comparable in size) roamed the North Pacific and the North Atlantic oceans during the Middle Miocene some 16 million years ago, but a mere handful of similar fossils of approximately the same age have been found in Australia and New Zealand. It thus seems nearly certain that the earliest albatrosses did not live in the Southern Ocean, yet the Southern Ocean is where the ultimate extension of the unique ‘albatross’ way of life arose. Notwithstanding the presence of albatrosses elsewhere in the world, there is a limited but legitimate sense in which the albatross lifestyle reaches its extreme development only in the Southern Ocean (although nearly approached in the North Pacific).

The Southern Ocean formed during the break-up of the ancient supercontinent Gondwana. Around 100 million years ago, the last of the major fragments – what is now Australia – detached and left what is now

Antarctica completely isolated. This event gave the Southern Ocean its current configuration, though not its extent, as a band of ocean completely encircling Antarctica. The cooling of that continent began around 70 million years ago. For millions of years the ocean gap steadily widened as fragments drifted apart, while average temperatures of the region gradually trended downwards, until the entire Southern Ocean ecosystem reached a point roughly recognisable as its present state some 35 million years ago.

This does not imply stability, however. There have been episodes of warming, and extreme environmental fluctuations of one kind or another, especially over the past million years or so as the entire planet progressed through several Ice Ages. Little is known of these climatic perturbations with respect to their effects on the Southern Ocean in general and the distributions of albatrosses in particular, but the speculation is nearly inescapable that they must surely have been profound. As recently as 45 000 years ago, for example, South Georgia, now one of the major albatross nesting sites, was entirely icebound, offering no possible haven at all for nesting seabirds.

The sea

The Southern Ocean is one of the largest ecosystems on the planet, with a total area of some 113 million square kilometres. It completely encircles the globe, so it effectively has no east–west boundaries. Its southern boundary may well be taken as the coast of the Antarctic continent itself, but its northern extent is a much more amorphous matter, and the boundary is usually undefined. The Southern Ocean varies in width from little more than 1000 kilometres between the Antarctic Peninsula and the southern tip of South America to some 2600 kilometres south of Tasmania and about 3900 kilometres south of Cape Town, South Africa. To the north it merges with the Atlantic, Pacific and Indian oceans.

The Southern Ocean derives most of its characteristic features from its proximity to the highest, driest and most frigid of continents, Antarctica. At its southern extent its temperature is forever close to freezing, ranging to around 18°C at its northern limit. However, the temperature gradient is not even; there are two especially well-marked and more or less permanent discontinuities. The first of these meanders around Antarctica between about 50°S and 60°S and marks an abrupt change in surface water temperature of some 2–3°C. Known as the Antarctic Convergence, this discontinuity marks the point where cold water flowing northward from the continent meets, sinks and slides under water masses flowing southward, steadily rising as they move. Near 40°S there is a second discontinuity, also marking an abrupt change in surface water temperature, of some 4°C, called the Subtropical Convergence. In both cases the shift takes place in a band often less than 10 kilometres wide, and often visible at the surface as a narrow zone of markedly increased surface turbulence.

Much of the Southern Ocean is between 4000 and 6000 metres deep, but the seafloor is far from being a level plain. The deepest point is a trench near the South Sandwich Islands nearly 9000 metres deep, but there are also numerous undersea plateaux and seamounts. Such large-scale irregularities on the ocean floor, even at great depths, impose a significant blocking action because they deflect deep-ocean currents upwards, the flow bringing with it nutrient-rich bottom sediments to promote phytoplankton and zooplankton blooms near the surface. Such areas of upwelling in turn strongly influence the foraging distributions of albatrosses and other seabirds. Prominent features of this kind in the Southern Ocean include the South Sandwich Ridge east of Drake Passage between the Antarctic continent and South America, the Kerguelen Plateau in the Indian Ocean sector, and the Campbell Plateau and the associated Macquarie Ridge extending south of New Zealand. All three of these, as well as several other lesser features like them, have extensive north–south components, thus running counter to the prevailing flow of currents in the Southern Ocean, which are west-to-east.

At the southern margin of the Southern Ocean, hard up against Antarctica itself, in a feature known as the East Wind Drift, a strong countercurrent flows westward. At the western margins of the deep embayments of Antarctica this current is deflected northward to form huge clockwise ocean gyres, notably in the Ross, Bellingshausen and Weddell seas; these gyres of very cold Antarctic water locally influence surface conditions nearly as far north as 50°S latitude. Similarly at the northern margins of the Southern Ocean there are counterclockwise (anticyclonic) gyres that act to deliver warmer water from the north, penetrating far into the Southern Ocean itself. The most prominent of these lies just east of New Zealand. The overall effect of these factors is to make the Pacific sector of the Southern Ocean markedly warmer than the Indian and Atlantic sectors – and coldest of all in the Weddell Sea.

The cycle of the seasons imposes further complexities on this dynamic. In winter Antarctica effectively doubles in size as vast areas of the Southern Ocean are covered by pack-ice. Ocean salinity rises steeply as freezing progresses, the salt dumped from frozen water being added to the burden carried by water not yet frozen. Water density rises as salinity rises, meaning it sinks faster, which in turn accelerates the flow of warmer water from elsewhere replacing it. This part of the cycle is reversed in spring, when surface waters are rapidly diluted by vast quantities of freshwater entering the system from melting ice. Thus the freezing/melting cycle imposes its own dynamic – nearly unique in all of the world's oceans – on the mixing of water in the water column, and in turn on the overall dynamics of the Southern Ocean.

Enormous strides have been made in human understanding of this dynamic, especially in the past three decades with the advent of satellite surveillance and monitoring. But the fact that so much of the Southern Ocean is hidden from view for so much of the year by pack-ice, even from the most sophisticated sensors of modern technology, means that a great deal is yet to be discovered. Nevertheless, the base conclusion has been clear for some time: the Southern Ocean is very far from being the inert, homogenous expanse of water it might otherwise appear.

The air

The currents of the Southern Ocean are ultimately driven by the atmosphere. The links are often varied, complex and tortuous, but in the end, current flows have their origins in relentless winds blowing over an endless ocean through aeons of time. And those winds are driven by forces generated by the spinning of the earth on its axis. Antarctica is the highest as well as the coldest of all the continents – essentially one enormous mile-high plateau – where air pools over the centre, becomes intensely cold and therefore denser, sinks to the surface, and flows downhill to the coast, accelerating as it goes. The influence of these nearly constant katabatic airstreams extends for hundreds of kilometres out to sea. The shores of Antarctica are the windiest places anywhere. The Coriolis effect is an artefact of the Earth's spin; exactly zero at the equator, it intensifies towards the poles, and results in a leftward (counterclockwise) deflection in any moving mass (air, water or indeed anything else) in the southern hemisphere (the deflection is clockwise in the northern hemisphere).

A band of low pressure encircles the Antarctic continent near its margin, reaching northward to, roughly, 60°S. Winds within this zone reach very high velocities and generally trend from the south or south-east. North of this zone, and dominating much of the Southern Ocean, is a band of high-velocity eastward moving air spanning, again, very roughly, 60°S to 35°S, which dominates the climate of the Southern Ocean. This zone is, in fact, the ‘Roaring Forties’ and ‘Furious Fifties’ so dreaded by early mariners.

This relatively constant circulation is periodically deformed by cyclones (otherwise known as low pressure cells or Lows) and anticyclones (high pressure cells or Highs). The former may be generated in low latitudes, especially over South America, Australia and the Tasman Sea, but the most frequent, intense and fast-moving of such systems are Antarctic Lows, generated in the far south and moving rapidly eastward, together with their associated cold fronts, and often veering northward to cross 40°S and not infrequently reaching 30°S. These are the famous ‘Southerly Busters’ that so often affect the weather in south-eastern Australia, particularly in summer when they can drop local temperatures 10°C in an hour, bringing welcome relief to sweltering urbanites in Sydney and Melbourne.

Storms eddy like whirlpools; this means that, although the disturbance as a whole moves eastwards, the winds at the northern rim are opposite in direction to those at the southern rim. The most distinctive and cogent characteristic of the Southern Ocean is that, in the east–west dimension, it is effectively limitless, and such disturbances are free to circle the Antarctic continent indefinitely. There are no large landmasses to deflect, collapse or fragment them. At any given point in time several Lows may be traversing various parts of the Southern Ocean simultaneously, and the region can often be viewed as a virtual conveyor belt of storms endlessly rotating the southern continent. Often Lows follow each other only a few days apart, or there may be a dozen or so disturbances, Highs interspersed with Lows in a complex dynamic that completely encircles Antarctica. In short, the meteorology of the Southern Ocean is so extreme that the region might reasonably be viewed as essentially one enormous, endless storm. One with random patches and periods of relative calm, true – but broadly speaking Antarctica is ringed by an eternal torrent of high-velocity air.

This abundance of high-velocity air in the Southern Ocean and the rotating nature of weather disturbances together offer a potential ‘transport system’, in any direction needed, to any seabird that can evolve the physical and behavioural means to exploit it. Most seabirds use this approach to a greater or lesser extent, relying less on powered flight and more on the wind to solve their transport problems. It is in this respect that albatrosses are unique, having gone further along this path than any other group of birds. And even among this group of elite high-speed gliders, the wandering albatross emerges as the extreme of this development, having very nearly abandoned muscle power altogether.

The islands

There are about 20 oceanic islands in the Southern Ocean. Nearly all are in the Indian and Atlantic sectors, none at all in the Pacific sector east of the Chatham Islands. Most are small and isolated, associated with submarine ridges and seamounts, but scattered in such a way that few are more than 1000 kilometres or so from any other. Latitudinally they vary widely, from the frigid South Orkney and South Sandwich islands in the far south to the comparatively balmy Tristan da Cunha group in the South Atlantic. The islands of Tristan da Cunha and Chatham Islands, for example, lie approximately on the Subtropical Convergence (which also passes just south of Tasmania and through Cook Strait between the North and South islands of New Zealand). The islands of the Prince Edward group and the Crozets, on the other hand, lie approximately on the Antarctic Convergence, whereas the other New Zealand islands (including Macquarie Island) lie between the two convergences, and Kerguelen lies well to the south.

The climate of most of these islands is cool temperate – windy, wet and overcast; on Macquarie Island, for example, it is nearly always windy, it rains most days, and the mean annual temperature is 4°C. On islands at the northern fringes of the Southern Ocean, such as Amsterdam or Tristan da Cunha, mean monthly temperatures for all months are above 10°C, and temperatures rarely fall below freezing. On islands at the southern fringe, all months are close to freezing, and permafrost extends down to sea level; such islands are unsuitable for albatrosses if for no other reason than they are unable to build nests in the hard, nearly vegetation-free ground. Some islands are mountainous; on most others the terrain is perhaps best characterised as boggy moorland.

There are also a number of continental islands, notably in the Scotia Arc bridging the South America/Antarctica gap, the Falklands, and the scattered islands around Tasmania and to the south of New Zealand. From the albatross perspective, continental islands may be more numerous, but on the other hand, by their very nature lying on continental shelves, they may be more distant from oceanic feeding areas. One of the reasons why the black-browed albatross, for example, may be so much more abundant and widespread than several other species is that it forages more intensively

Few of the islands of the Southern Ocean are large, and most are nearly as tiny, desolate and exposed as this one, Middle Sister in the Chatham Islands east of New Zealand.

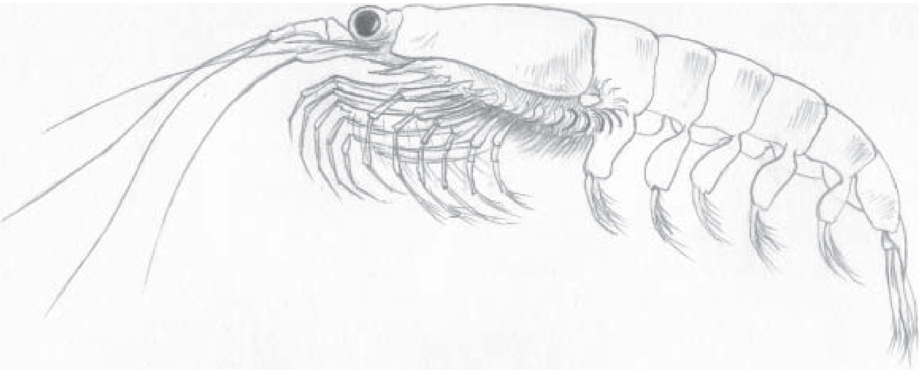
over inshore and shelf waters, which in turn means that a wider range of islands falls within acceptable parameters for successful breeding.

There is some evidence of albatross nesting attempts on nearly all of the islands of the Southern Ocean, but in general albatrosses don't breed on the South Orkneys, South Shetlands or St Paul – at least not in any significant numbers. Major albatross nesting concentrations occur, on the other hand, on the Falklands, Tristan da Cunha, South Georgia, the Crozets, Prince Edward, Macquarie and the islands south of New Zealand. Many of these have several albatross species, and on a few, such as South Georgia and Macquarie, there may be four or five species nesting together (although nearly always in segregated colonies). Islands are, of course, where islands are, and are not necessarily located in the most convenient place from the perspective of any seabird that might seek to nest on them. Many a prospective colonisation attempt in the past has surely failed because the island happens to fall too far from the nearest worthwhile foraging areas, so that the birds cannot successfully provision their chicks.

Food resources

A brief review of the major food resources potentially available to albatrosses in the Southern Ocean is probably helpful, despite the fact that the fauna is so little known that even the names are obscure. Albatrosses do not dive, at least not to any significant depth, which means that only animals living (or carrion floating) in the uppermost few metres of the ocean's surface are available as potential prey. All else is largely irrelevant to their biology. Potential prey living near the surface of the sea is of three main groups: krill, squid and fish. Less important members of the sea-surface community include jellyfish, tunicates, salps and one or two other groups. Salps and tunicates, in particular, are sometimes important in the diet of yellow-nosed albatrosses and coelenterates (notably the familiar blue stingers swept up so abundantly in summer on Australian beaches) in that of the Galapagos or waved albatross.

Krill is a collective term for several species of pelagic crustaceans that are extraordinarily abundant and widespread in the Southern Ocean. Several whale species feed almost entirely on krill. Mainly red or deep pink in colour, they look a bit like shrimp, although they are not especially closely related (roughly the same relatedness as owls to parrots, for example, or koalas to foxes). The most important species, Euphausia superba, grows to a length of about six centimetres. This species may well be the most numerous animal on Earth, with a total biomass approaching half a billion tonnes. Krill spawn in the surface layers of the open ocean, and the eggs sink to a depth of several hundred metres, where they hatch. The minute young rise slowly back to the surface, developing as they go and reaching the surface about a month later. Krill are gregarious, but their behaviour is so complicated that it has proved necessary to develop a whole series of technical terms to categorise aggregations by size and persistence. Of special relevance to albatross studies is the 'super-swarm', which forms under exceptional but as yet unknown circumstances, but



Krill: ***Euphausia***

which may span hundreds of kilometres, retain its integrity for several days, and incorporate a total biomass approaching one million tonnes. The dominant characteristic of krill as a potential food resource for albatross is its extreme patchiness and extreme seasonal variation in abundance – the details remain unclear despite several decades of intensive research but, in a nutshell, krill is available in summer but not in winter.

There are some 70–80 known species of squid and their kin in the Southern Ocean, although there are surely many more yet to be discovered. Two groups, Sepia (the familiar cuttlefish) and a related group called Onychoteuthis, are known to be important food of albatrosses but are more numerous over continental shelves and inshore waters. Many others are truly pelagic predators – sleek, torpedo-shaped, agile and fast moving, with a general body configuration not greatly unlike that of many of the highly mobile fish with which they share the upper ocean environment. There are also deep-water forms that seldom approach the surface. Most are so little known that they lack English names, but some prominent groups include Kondakovia (around 80 centimetres in length), Todarodes (75 centimetres) and Moroteuthis (30 centimetres). The biology of this community of oceanic predators is almost entirely unknown, but some evidence suggests Moroteuthis may be predominantly Antarctic in distribution whereas Todarodes penetrates the Southern Ocean from warmer, more northerly waters. Kondakovia may feed mainly on krill. In contrast to krill, there seems little evidence of marked seasonal variation in squid availability to albatrosses; Kondakovia, at least, is known to spawn in winter in the vicinity of the Crozets.

The total biomass of fish in the Southern Ocean is very high but biodiversity is strikingly low: there are something close to 22 000 species of fishes in the world, yet fewer than 300 occur south of the Antarctic Convergence. Most of these live near the bottom of the sea rather than at the surface, and many live under the ice along the continental shelf of Antarctica rather than in the Southern Ocean itself. Indeed, a striking characteristic of the Southern Ocean is the absence of the epipelagic (that is, confined largely to the surface layers of the deep ocean environment) fish families so prominent in other oceans. Those relatively few species that do occur in the Southern Ocean all have bottom-feeders in their immediate ancestry. Among true fishes, three families dominate: Channichthyidae, Nototheniidae and Myctophidae. The first of these are the icefishes, notable for lacking haemoglobin and being white- rather than red-blooded in consequence. The second are the notothens, which are essentially bottom-dwellers lacking swim bladders. The group is notable for its radiation of species evolving back into upper waters, and which have evolved large sacs of oil in their bodies in lieu of swim bladders to achieve neutral buoyancy. The myctophids are the lantern fishes, widespread in all oceans and notable as much for their extraordinary abundance (the total world standing stock of lantern fish has been estimated at 600 million tonnes) as for the characteristic row of bioluminescent photophores along their flanks. Many of the myctophids, in particular, migrate to the ocean surface at night. Several other families, notably the jacks and scads of the family Carangidae, which are important in the diet of the shy albatross in particular, penetrate the northern fringes of the Southern Ocean from somewhat warmer seas to the north.

One important thing from the brief sketch of the Southern Ocean outlined above – summarising its history and physical characteristics, its oceanography and meteorology, its currents, storms and islands, and its wealth of living things below the surface – has been left unsaid. It is that, perhaps paradoxically, oxygen dissolves more readily in cold water than in warm water. Also, a fact that we are all familiar with, in summer the day length increases steadily towards the poles, which means that polar regions receive nearly constant sunlight for several months of every year. Put these two factors together, and the result (notwithstanding the somewhat less than temperate weather) is a veritable storm of life. This is especially true for birds. Huge numbers of penguins, cormorants, petrels, shearwaters, skuas and other birds breed at most of the islands scattered across the Southern Ocean. However, most of these are more or less confined to the immediate neighbourhood of their rocky refuges. Only one bird can truly be said to have fully unlocked the resources of the Southern Ocean, due largely to the way it has evolved to deal successfully with the most ferocious winds on the planet. That bird is the albatross, and the Southern Ocean is its home.

An incubating shy albatross. Note the 'pedestal' nest characteristic of all the mollymawks. Nests are used and reused year after year, although several months of occupancy by a restless chick, coupled with storms and bad weather through the ensuing winter, means the nest is often so badly damaged it effectively has to be rebuilt for each breeding attempt.

An adult royal albatross at sea. The royal albatross breeds only in the New Zealand region, but most birds then cross the southern Pacific to spend the non-breeding season in near-shore waters off Chile and Argentina.

Top: A light-mantled albatross near its nest. Both this species and the sooty albatross favour cliffs or steep slopes for nesting; all other albatrosses prefer more level ground.

Bottom: Black-browed albatrosses at the Steeple Jason colony, Falklands. The adult black-brow is perhaps the most easily identified of all the albatrosses because of its bright yellow-orange bill.

A group of royal albatrosses in display at the famous Taiaroa colony near Dunedin, New Zealand. This small colony is one of only a handful of locations around the world where albatrosses nest within convenient reach of significant human settlement.

Royal albatrosses in display. Only the wandering and royal albatrosses incorporate this impressive, outspread-wing pose in their displays; all other albatrosses display with wings closed or only partly extended.

A black-browed albatross chick awaits its next meal. Among albatrosses, parental care is almost entirely confined, after several weeks of brooding the chick immediately after hatching, to delivering food for it. Photo: Tui de Roy/AUSCAPE International

Top: A royal albatross incubating. Albatrosses lay only a single egg per breeding attempt, which is incubated by both parents in alternate shifts lasting several weeks.

Bottom: A mob of black-browed albatross scavenging off the stern of a fishing vessel off Campbell Island, New Zealand. These are of the population *impavida*, which nests only on Campbell Island; they have straw-coloured eyes that are unique to this population – all other albatrosses have dark eyes. Photo: Ann Lindsey

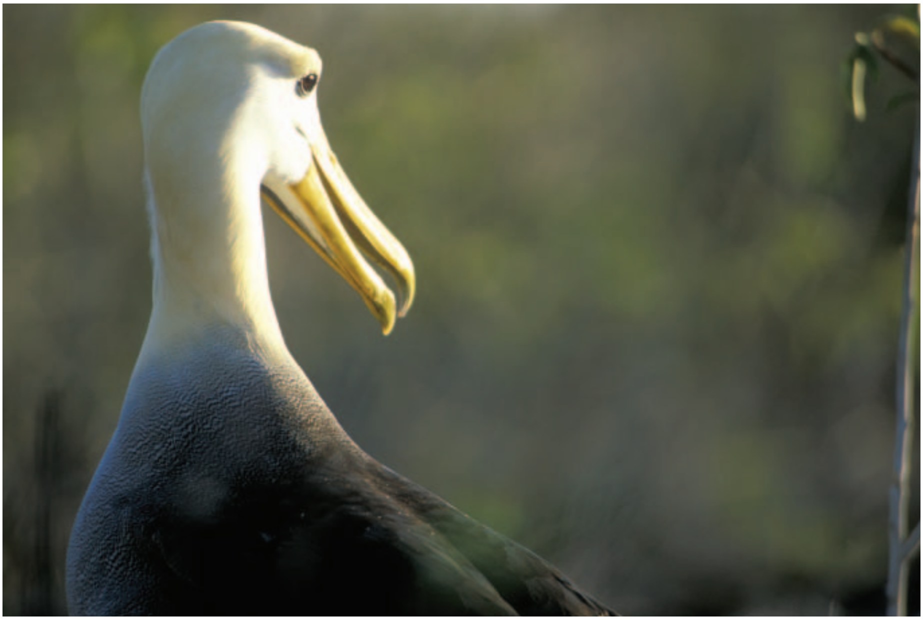
Top: An adult Laysan albatross at its nesting grounds. The Laysan albatross is distinctive among goonies in that fledged birds of any age differ little in appearance.

Bottom: A Laysan albatross nesting colony, with several well-grown chicks. Laysan albatross nests are usually spaced several metres apart.

Top: Part of a shy albatross nesting colony on Disappointment Island in the Auckland Islands group, New Zealand. This population (*steadi*) appears to be closely related to the Australian population (*cauta*), differing in its somewhat larger size but, most strikingly, in that its nesting cycle is delayed a full two to three months relative to birds nesting in Tasmania.

Bottom: A pair of Buller's albatrosses (population *platei*) at their nest on the Chatham Islands, New Zealand.

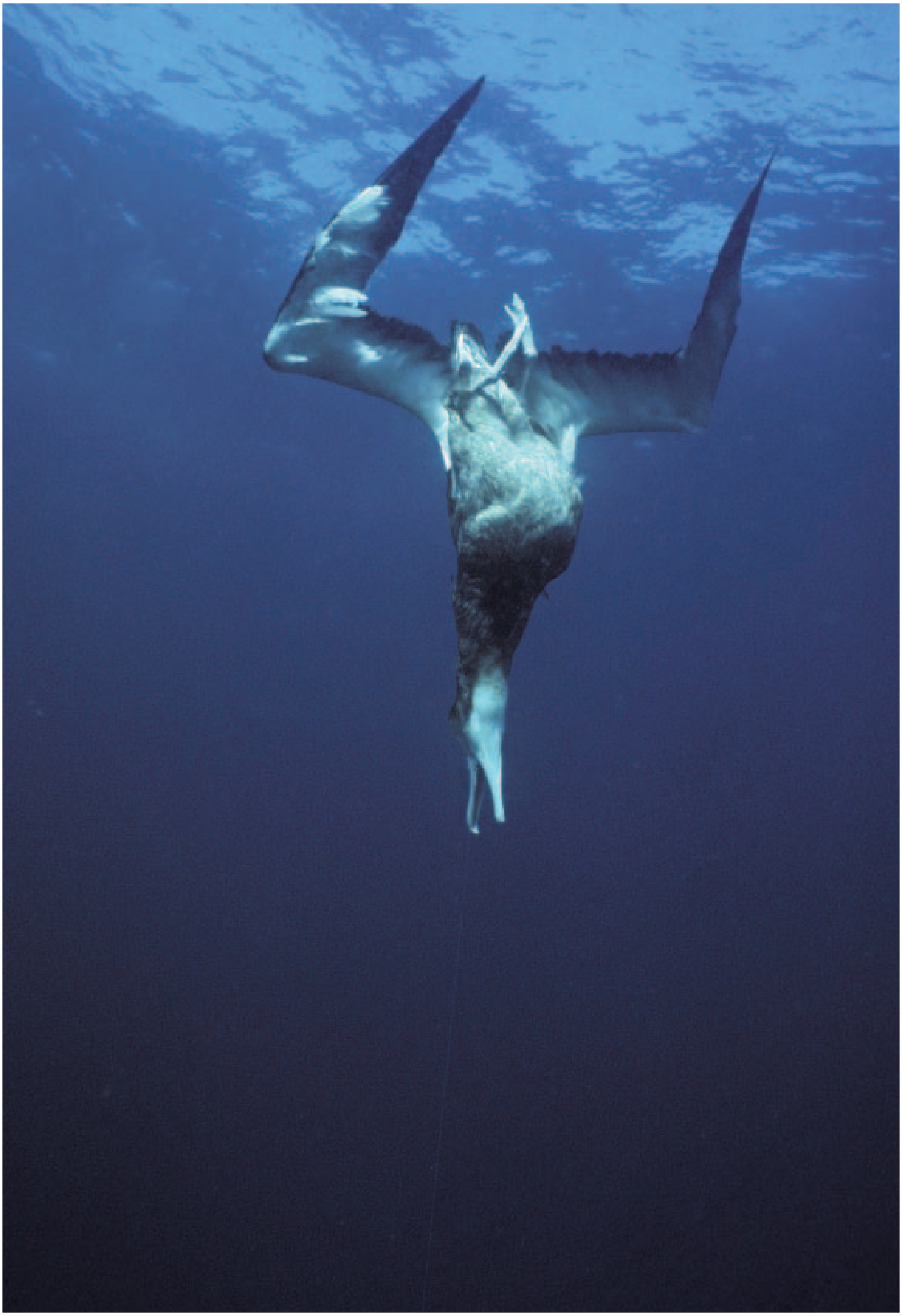
The black-browed albatross nesting colony at Steeple Jason, Falkland Islands, one of the largest albatross colonies in the world, and by far the largest in the Southern Hemisphere.



Top: Portrait of a Galapagos or waved albatross. Two distinctive features of the species are well displayed: the unusually long bill and unusually prominent eyebrow ridges.

Bottom: A pair of Galapagos albatrosses. Uniquely among albatrosses, this species does not build nests, nor even maintain a permanent nest site: eggs may be moved as much as 10 metres in a day in the normal course of incubation.

A baby royal albatross (*sanfordi*) being prepared for weighing at the famous colony at Taiaroa Head, near Dunedin, New Zealand. This tiny colony is monitored so closely that all chicks are christened as they hatch: this one's name is 'Toroa'.



A drowned wandering albatross, victim of a lethal temptation, hooked and dragged under while trying to snatch the bait during the deployment of a long-line set for tuna. Photo: Graham Robertson/AUSCAPE International

4

FOOD AND FORAGING

Food is the single most immediate survival imperative for any animal. Therefore, establishing the natural diet of any endangered animal is a critical consideration for those who seek to preserve it. The animal cannot be protected unless its food supply can somehow be secured at the same time. When it comes to albatrosses, the problem is more than usually fraught with difficulty, and progress in unravelling their natural diet has been more than usually a case of dogged detective work, with many different researchers spanning several decades, each contributing a piece of the puzzle, addressing the core problem from many different perspectives. A land bird can usually be simply followed around until it reveals what it eats, but a foraging albatross disappears out to sea bound for unknown feeding grounds that may be several thousand kilometres away, and it may not return for a fortnight. It has been a matter of common knowledge since the very first explorers penetrated the Southern Ocean that albatrosses are attracted to ships and that they scavenge galley refuse. But what needs to be established is what albatrosses eat when there are no humans around to feed them.

Aside from the nature of the food itself, pivotal questions also include: Do albatrosses dive for their food, or do they merely snatch it from the surface? Do they feed by day or by night – does it matter which? Is the prey dead or alive (that is, are albatrosses hunters or scavengers)? How do they locate it? And how do they actually catch it?

The first thing to explore in solving this conundrum is the nature of the food supply itself. The open ocean is vast, and any food items (whatever they might be) available on the surface can therefore be expected to be extremely sparse and widely scattered. It seems highly improbable that any hungry albatross can afford to pass up an opportunity to seize any item it might encounter on the grounds that it 'prefers' some other item. It is far more likely an albatross would seize anything edible it might happen upon, alive or dead, regardless of species, place or time of day. In short, it is very unlikely that we would encounter any extreme dietary specialisations in such an environment.

In 1994, Peter Prince and two colleagues published the results of a study on a number of albatrosses on their breeding grounds. The researchers fitted the birds with tiny depth recorders and these devices were retrieved when the birds returned from foraging, and the results analysed. The study recorded 14 light-mantled albatrosses that spent a grand total of 119 days, five wandering albatrosses that spent 54 days, 21 black-browed albatrosses that spent 76 days, and 12 grey-headed albatrosses that spent 40 days out at sea. For the first time researchers had some real data with which to assess the diving abilities of albatrosses. Briefly, the results were not startling, though perhaps a little better than expected. None of the wanderers exceeded a depth of one metre in this study – in fact one bird spent 19 days at sea without, so far as could be detected, any submersion at all. (That is not the same as never – they are occasionally seen plunge diving from a metre or so above the surface, and there is at least one report in the literature of a wanderer diving to about two metres to pursue prey.)

The black-browed and grey-headed albatrosses dived much more frequently, and both typically reached two to three metres, but a black-browed albatross on at least one occasion reached 4.5 metres, only to be sidelined by a grey-headed albatross that attained a depth of six metres. Perhaps most surprising were the results from the light-mantled albatrosses: their mean depth was nearly five metres, they not infrequently reached 10 metres and the maximum recorded depth was 12.4 metres (sooty albatrosses, in particular, have since been recorded diving to even greater depths).

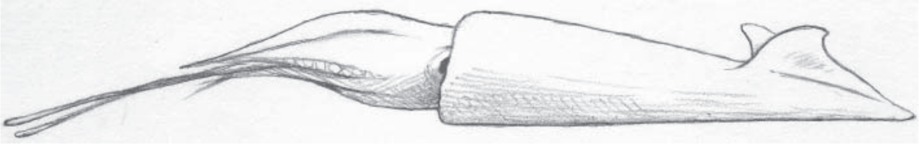
This study reinforced the earlier impression that wanderers seldom dive. Nevertheless, the impression gained from a century or more of scattered incidental and anecdotal information remains, broadly speaking, intact: whatever it is that albatrosses eat, it's mostly obtained from the uppermost metre or so of the ocean's surface. The generalisation seems pretty solid for the wanderer, less so for the smaller and more agile mollymawks, but somewhat severely dented for the two sooty albatrosses.

In 1998 indirect evidence for the diving abilities of albatrosses came from another direction when Graham Martin of the University of Birmingham caught two grey-headed and two black-browed albatrosses on South Georgia, took them into the laboratory, and subjected them to a thorough ophthalmoscopic examination before returning them to the point of capture. He reported: 'Results for the two species were very similar and indicate that the eyes are of an amphibious optical design suggesting that albatross vision is well suited to the visual pursuit of active prey both on and below the ocean surface.' He found the corneas to be relatively flat, their curvature similar to that of other birds that chase prey underwater but substantially less than those that capture prey in air: the albatross eyes were, in fact, very similar in their optical characteristics to the eyes of penguins, which catch all of their prey below the surface.

Since direct observation is impractical, the earliest attempts to investigate the diet of albatrosses involved examination of the food they bring back to their chicks. This approach at least has the advantage of procedural simplicity. All you need is a bucket, something to serve as a sorting tray and a can of cat food. You visit a chick on its nest, wait for the parent to return and feed it, upend the chick over the bucket and induce it to disgorge, feed it the contents of the can (to compensate for its lost meal), tip the bucket into the sorting tray, and start sifting through the mess trying to find something identifiable.

It is at this point that one of the less obvious consequences of the albatross's far-flung foraging emerges. The bird has taken so long returning to its nest that the inevitable digestion is well advanced; little recognisable is left in the resultant mush, especially in the case of squid. The only resistant structures are the beaks of squid and ear-bones (otoliths) of fish. In the early days of such studies in the 1960s, these structures were entirely unidentifiable, seriously impeding further progress, and it wasn't until the 1980s that reliable identification of squid beaks became routine.

In 1975 M.J. Imber and R. Russ published a study on the diet of the wandering albatross breeding on the Auckland Islands in the New Zealand region. They had available to them the stomach contents from only seven birds, but this was very nearly the first available data. All material consisted of either fish or cephalopod remains: no other organic material was



Squid: ***Onychoteuthis***

detected. Squid dominated, mainly Histioteuthis, Gonatus and Moroteuthis, which were probably most important nutritionally because of their larger size. Gonatus is surface-living and non-bioluminescent, but the other species live normally at considerable depths and are bioluminescent.

Over the next decade, similar studies were conducted elsewhere in the Southern Ocean, notably on South Georgia and the Prince Edward Islands, using more or less the same approach – that is, the examination of cargoes brought back to the nest by parents feeding young. Subjects included the wanderer as well as several mollymawk species. In most of these studies, squid was found to be the dominant food. For example, in 1986, Brooke and Klages published their analysis of food fed to chicks of both grey-headed and yellow-nosed albatrosses on the Prince Edward Islands. Kondakovia and Moroteuthis dominated. Extrapolating from the size of the beak, many of the squid in life were quite large. Some were over two kilograms, and one was estimated at 8.26 kilograms, surely far too big to be subdued by a four-kilogram albatross. As in other studies of the day, it seemed much was found dead rather than killed. It was also speculated that albatrosses might attend sperm whales (which also feed mainly on squid) to scavenge vomit or the leavings of their kills. However, it was also widely recognised that weight estimates might be heavily biased in favour of larger prey because the bigger the squid the bigger the beak, and these therefore last longer in the albatross gut.

Accepting that albatrosses mainly eat squid, the next reasonable question to arise is, are those squid alive or dead when the albatross swallows them? Are albatrosses basically hunters or scavengers? Nobody knows for certain, but most are plainly both. However, a surprising body of indirect evidence can be marshalled to illuminate the question. For example, there is at least one record of a wandering albatross actually seen to kill and eat a squid about 40 centimetres long, which would probably have weighed around 500 grams. Suppose we tentatively take 500 grams as the upper limit at which albatrosses can successfully capture living squid, and see where that takes us. This figure may not be implausible: in their study of the diet of the much smaller grey-headed albatrosses, for example, N. Huin and P.A. Prince (1997) estimated that their birds caught about eight prey items per day weighing between 75 and 150 grams. Thus, if an albatross returns to feed its chick seven squid each weighing 100 grams, then these may have been killed; but if the same albatross returns with two squid each weighing 600 grams, it would seem fairly safe to conclude they were scavenged. This core concept could be developed to yield a useful statistical tool.

In 1994 the albatross specialists J.P. Croxall and Peter Prince published an analysis of this whole question, based on their own experimental subjects on South Georgia, in which they developed this and several other suggested lines of approach. One involves the buoyancy of squid: some species float when dead, others promptly sink beyond the reach of birds; it follows then that if an albatross turns up with a bellyful of one of the latter species, it must have killed them. They also raised the further stimulating thought: if all albatross food is scavenged, then we can expect to find no statistically significant differences, either by weight or number, in squid cargoes brought back to the nesting colony. In terms of its floating dead squid resource, any given expanse of ocean is close to a level playing field for all albatrosses searching it, regardless of species. It would seem likely then that any statistically significant differences that might be found in returned cargoes must be directly attributable to predation.

> Data on the average size of squid prey … show that a considerable range in size is taken. For several species (Gonatus, Histioteuthis, Alluroteuthis, Galiteuthis) there is a strong similarity in the average size of prey taken by each of the four albatross species [breeding on South Georgia]. Significant differences, however, occur in Kondakovia and Martialia, where wandering albatrosses take much larger prey. These differences are interesting, because if all albatrosses were scavengers on dead squid one would expect them, to the extent that their ranges overlap, to take prey of similar sizes. (Croxall and Prince 1994)

These and comparable approaches together lead with some reliability to the conclusion that wanderers, in particular, are essentially scavengers, whereas mollymawks are very mixed. On the other hand, the fact that the two 'sooties' dive so frequently, so skilfully and to such depths, strongly suggests they may more often kill their prey. Nevertheless, the situation remains that no technique exists for direct observation of albatrosses foraging, save in the hopelessly artificial situation of albatross attendance on fishing vessels dumping offal and bycatch.

The question of nocturnal versus diurnal foraging was particularly intriguing in the early days of such investigations, especially when it emerged that squid are the dominant prey of most albatrosses. Many of the squid found in albatross stomachs are bioluminescent species (that is, they glow in the dark) that migrate to the ocean surface at night, retiring to the ocean depths by day. Assuming albatrosses are hunters rather than scavengers, it seemed reasonable to predict that albatrosses might be mainly nocturnal in their foraging behaviour.

Some tantalising evidence came to light in support of such a conjecture when it was discovered that the eyes of Laysan albatrosses are richly endowed with rhodopsin, a photosensitive chemical heavily involved in nocturnal vision. Such things are conventionally measured in units called optical density units per gram, but that need not concern us here because we’re interested only in comparative values. Laysan albatrosses score 16 on this scale, not too far behind, for example, owls with 20; the Laysan’s closest relative, the black-footed albatross, in contrast scores only 2. This data seems especially relevant when set beside the already known fact that Laysan albatrosses eat far more squid than black-footed albatrosses do.

The final decade of the twentieth century saw the accelerating deployment of devices usually called ‘archival loggers’ or ‘archival tags’ in research into albatross behaviour. In essence an archival tag is a minute computer (10 or 20 grams in weight is typical) coupled with a battery and a sensor (or even several sensors), together crafted into a package designed to be attached to a bird that is otherwise free to go about its normal business, and programmed to store data until it is practical or convenient to retrieve the device and its data for later analysis. The data collected can be almost anything (compass heading, temperature, light intensity, heart-rate and so on): the sensor makes a reading and reports it to the logger, the logger records the transaction as an ‘event’ together with its value and the time it occurred, and adds it to the accumulating data store. In short, something similar to the more familiar flight recorder in a commercial aircraft, but much smaller and simpler.

Sometimes the resulting record is later streamed up to some suitable satellite, but more often it proves easier just to wait till the bird returns to its nest, recapture it, detach the device and read its contents directly. The logistical details vary with the circumstances of the experiment: the key point is data storage. The researcher ends up with a sort of 'diary' that sets out in detail exactly what the bird did while it was away, and exactly when it did it. Configurations capable of recording several events per minute continuously for several months are common, so the technique is capable of generating large quantities of very precise data.

Archival loggers are often used in conjunction with the satellite tracking approach, but in passing it might be noted that the system can readily be extended to include exactly where the bird did whatever it was doing at the time. For example, longitude can be deduced from light intensity at local noon, which can be sensed directly. The analysis and computational requirements are very large, but for modern computers that's a trivial consideration – the number-crunching can be done on any laptop. To date, pinpointing location by this means is much less precise than by satellite tracking, but it is also vastly less expensive.

Archival loggers have been used to investigate the nocturnal/diurnal question in several albatross species. In this configuration the system is coupled with an immersion monitor designed to trigger an event whenever it gets wet. The result in this case is a data stream from which several parameters can readily be compiled: total time away, total time in the air (monitor reads dry) and total time on the water (monitor reads wet), or indeed the mean frequency of 'splash-downs' and their average duration. From there it is an elementary step to divide and compare the events that occurred by night with those that happened during the day. On the reasonable assumption that albatrosses land on the water only to seize prey, such an exercise quickly amasses a persuasive body of evidence addressing the question of whether the birds focus their foraging activity at night or during the day.

One of the earlier exponents of this approach were Patricia Fernández and David Anderson, who in 2000 published their findings involving trials with Laysan and black-footed albatrosses in Hawaii. In this preliminary exercise they retrieved useful records from six black-footed albatrosses and seven Laysan albatrosses on foraging trips lasting an average of about three days each. Interestingly, they found no decisive difference between the two species in nocturnal over diurnal activity, despite the difference in visual acuity already mentioned (it remains a mystery why Laysans can see so well in the dark and black-foots can't). Both species were roughly equal in range (around 1600 kilometres) and in time spent aloft (80–90 per cent). The six black-footed albatrosses made one to nine landings by day per trip against one to three landings by night, while the seven Laysan albatrosses made one to eight landings by day per trip against one to three by night. Overall, only about 20–30 per cent of these birds' total landings were at night. Against the assumption that the birds might have landed merely because they were tired, these researchers noted that more than two-thirds of all immersions had a duration of less than 100 seconds. It seems highly unlikely that a tired bird might recover in little over a minute, thus reinforcing the assumption that landings represented genuine foraging activity.

By and large, these experiments and many others like them have tended to reinforce the original notion that albatrosses hunt by sight and so tend to favour daylight for their foraging, but that above all they are adventitious hunters, always ready to take immediate advantage of whatever food resource they might encounter, regardless of place or time of day. Several times, for example, a distinct rise in nocturnal landings has been detected on moonlit nights.

But there are other parameters that might be explored. If an albatross is observed flying in (more or less) a straight line for a minute or so, it may well be foraging. On the other hand, if the same albatross is observed flying in a straight line for, say, two or three hours or more, then it is highly unlikely to be foraging. It is much more likely to be commuting – that is, travelling purposefully to some distant area where it might begin foraging. The key here is the frequency of changes in direction, and this too can readily be investigated by an appropriate modification of the archival logging protocol. This approach has been vigorously pursued over the past decade on several albatross populations, and has proved extremely fruitful.

In nearly every case, a distinct clumping of the data into two groups is immediately evident. Albatrosses generally divide their foraging activity into two distinct phases: commuting (the outward journey to and return from a foraging area, characterised by very small and very infrequent directional changes) and searching (in which the bird is actively searching for food, characterised by a relatively abrupt transition to very large and very frequent changes of direction). As well, average flight speeds are normally substantially higher when commuting relative to those maintained while foraging. The main thing that emerges from these studies is a strong sense of destination. Seeking food for their chicks, both individual birds on successive trips and various other individuals from the same colony repeatedly follow similar routes to the same general foraging area to begin their search, returning in roughly comparable times with

Albatrosses generally forage alone, but they squabble vigorously over food, like these two wanderers off New Zealand, whenever appropriate circumstances arise. In fact a measurable percentage of the overall albatross diet is obtained by stealing it from other seabirds.

roughly comparable loads. Enough data have probably now accumulated to convince even the most sceptical that albatrosses ‘know’ where to go to find food, or at least can locate at a distance areas of high prey density where a search is likely to prove productive.

It might not seem evident at first sight, but a successful predator’s challenge consists of several distinct, consecutive tasks. Let’s paint the simplest possible picture: mother fox trots from den to fetch a rabbit for her kits. First she must convey herself somehow to a place where there might be rabbits (commute). Second, she must actually find a rabbit warren (search). Third, she must select one particular rabbit (select). Fourth, she attacks that rabbit (kill). Fifth, she carries it home. Each is in its own way a distinct challenge to overcome, each calling upon a different array of faculties and skills. With only trivial adjustments, the model applies to any conceivable predator in any conceivable environment. And in the end, a predatory species cannot survive for long unless profits (bunnies brought home) on average balance overheads (time and effort invested in all six tasks together). (Six? Merely to complete the picture, even digestion costs energy, so presumably there’s always a better way to do that too, but here we’ll focus on the front end of the sequence.)

We tend to see only the snap of the slathering jaws, but the whole process is what really matters. The stages need not necessarily be equal in importance. In principle, it's at least plausible that a predator might be relatively mediocre in killing yet hold the whole thing together by being extremely efficient at finding its victims. The way in which the investment is apportioned is strongly influenced by several key characteristics of the target species. Small prey is easier to kill but a predator has to kill more of them. When we explore this analytical approach it also helps us assess the influence of learning and experience in the whole process: it is immediately obvious how experience might help in looking for places where prey might be, perhaps less obvious how it might help in the actual kill.

If we take the whole thing a step further – and this is of particular relevance to albatrosses – we have to consider that prey might be common or uncommon, or clumped or widely scattered; uncommon prey throws more emphasis onto the search part of the sequence, widely scattered means a higher overhead in the commuting phase. In gaining insight into any process, it is often useful to examine the simplest or most extreme examples of that process, and it is difficult to imagine how much simpler or more extreme the situation could get than a lone dead squid floating in the middle of the Southern Ocean and a wanderer trying to find it.

Nobody yet has any idea how albatrosses deal with the fifth step (navigating safely home with their cargo). In one recent project, wanderers were fitted with magnetic headgear designed to compromise any magnetic senses they may have. The results didn't prove wanderers don't have magnetic 'compasses' in their skulls (lots of birds do), but they did show quite persuasively that they don't need them: cargoes of food for hungry chicks continued to be delivered at the same payload and frequency as for a nearby control group lacking the trendy new headgear.

The selection of victim and the kill itself are two components of the predation process that have been intensively studied worldwide in a very wide range of predators large and small, both in terms of the mechanics of the process itself and in a comparative approach involving different but coexisting predators. However, the first two components, 'commute' and 'search', have historically proven extraordinarily difficult to examine in any precise, rigorous fashion. Imagine trying to come to grips, for example, with the complexities of what's going on in the case of three coexisting dragonfly species over some garden pond. The whole thing needs to be slowed down and spread out considerably before even preliminary estimates are possible.

And then someone came along to demonstrate the practicality of using satellites to spy on albatrosses. Here the same old drama is played out, but on a stage thousands of kilometres across instead of mere metres, to rhythms spanning days instead of milliseconds. And thanks to the technological wizardry of the Global Positioning System, the relevant measurements can all be made with a precision and accuracy several orders of magnitude better than anything attempted before. Indeed, so difficult of investigation are the commute and search phases that two of the earliest investigators of the new technique could be forgiven a little extra complacency in reporting their results because in tracking foraging wanderers they achieved several breakthroughs at a stroke: very nearly the first rigorous investigation of phases one and two for any predator of any kind anywhere; the first field demonstration of the existence of phase one in the first place (in contrast to the theoretical recognition that it must be there, waiting to be discovered); the first detection of the 'phase boundary' between the two – and they even provided the basis for a workable protocol to assess the boundary for good measure.

The wanderer may prove an ideal subject in further development along this path, and that is in the investigation of foraging behaviour itself. This very rapidly becomes far too esoteric for a book of this kind, but a few tentative first steps into the morass help illuminate the place of the albatross in its world. The investigation has its basis in an old mathematical recreational puzzle: a bloke parks his car and goes into a pub one dark night, and on the way in he drops his car keys. Several hours and a number of schooners later he emerges, reaches into his pocket for his keys and … How does our inebriated (and criminal) slob find his car keys? It's dark, so he can't just stand in the doorway and scan the pavement. He's drunk, so any capacity for rational thought or conceivable skills, training or experience he might or might not have relevant to the task is unavailable to him. Can he ever find his keys? Well, there must be a way, because wanderers find dead squid every day, and the challenge confronting the albatross is identical to the challenge confronting the drunkard in every way that matters.

One extremely fruitful way to explore an animal's behaviour is to work out what it ought to be doing to optimise its chances of a successful outcome for any given task, then go out and watch your animal until you discover if that's the way it does it. So, too, with our investigation. One possible approach to the drunkard's predicament is to start with the simplest conceivable strategy, program it into a computer, then start running simulations. The simplest (Rule No. 1, always begin at the beginning) possible 'blind' protocol runs something like this: take one step ('stride' or 'path') forward; inspect the ground at your feet; turn a random number of degrees in any direction; repeat the first three actions; keep repeating the sequence until you find the keys. This is the famous 'Drunkard's Walk'. Now the big question: is there any other way? Perhaps the first improvement that comes to mind emerges from noting that, using the existing protocol, there is a chance, however slim, that the drunkard might end up on a point already visited, thus wasting time repeating an inspection already known to be fruitless. It is early days yet, but some evidence emerging from statistical analysis of satellite tracking data suggests that wanderers already have the point covered: they seem to avoid areas already visited. Another possible way forward comes from noting that the existing protocol assumes a 'stride' or 'path' of unit length (one step). Suppose the distance were made to vary randomly as well as the direction? It's a tad more complicated than that, but in essence a Lévy path is a drunkard's walk in which each step is a random distance in a random direction. Here too, albatrosses got there first: wanderer foraging tracks have been shown to be Lévy paths.

It might seem there is nowhere left to go – until we notice that the rules specify only that the search must begin with zero information. Perhaps there is some way of using information accumulated along the way to somehow modulate the protocol 'on the fly' – but here it seems the wanderer has not (yet) unwittingly divulged any more of its hunting hints. But it's worth noting that, although it is obviously impossible for any real live predator functioning in the real world to begin each foraging sortie with absolutely zero information, the wandering albatross comes closer to that abstract extreme than any other predator on earth. In its foraging it is as close to being the living embodiment of the mathematical abstraction known as the Drunkard's Walk as we can ever expect to find. Hence the theoretician's interest in the creature.

Satellite surveillance has already revealed distinct differences between wanderer and mollymawk foraging strategies. Wanderers appear to favour a 'search-while-travelling' tactic, and from a sky-high perspective their foraging paths from the nesting colony describe great loops or figures-of-eight on scales of 1000 kilometres or more across. It seems they have to cover more distance to find fewer squid, but presumably the advantage is they don't have to contest ownership of whatever they do find with other albatross competitors. Black-browed, yellow-nosed and grey-headed albatrosses, on the other hand, from the same perspective typically show a more distinct commuting path to distant foraging areas, travelling relatively fast and direct. Mollymawks, when actively foraging – that is, engaged in searching for prey – may do so on a scale only scores of kilometres across, apparently sometimes much less. Here current technology limits more detailed analysis because, if the foraging mollymawk remains in an area less than about 10 kilometres across, current satellite surveillance lacks sufficient resolution to distinguish between foraging activity and resting quietly on the water – the best that can be said in such circumstances is that the bird is not travelling.

However, there is much evidence that albatrosses – including wanderers – rely a great deal on experience for at least the first (commute) phase of their foraging, even though it is not yet clear how a young bird might gain that experience. A large body of data is accumulating to show that mature wanderers, at least, do not wander the Southern Ocean at random during their year-long absence from the nesting colonies; instead they tend to have favoured foraging grounds to which they return regularly.

Also notable in several populations is a definite gender bias in preferred foraging areas: males head off in one direction, females another. Moreover, it has more recently been found, in wanderers at least, that parents alternate between long and short trips, perhaps as a tactic to compensate for unexpected shortages and hence 'even out' the flow of food delivered to the chick. All of this argues for a highly evolved strategy far removed from mere random searching. Whether this talent is innate or learned remains largely an open question: it seems more likely the latter.

One especially ingenious recent extension of this general archival logger approach is to incorporate an internal temperature sensor into the system. This approach exploits the fact that the albatross is a homeothermic ('warm-blooded') animal while its prey equals the ambient ocean temperature – that is, markedly lower. The albatross swallows a squid, it enters the stomach, the temperature abruptly drops, and the event is logged; the temperature then gradually returns to its original value, at a rate proportional to the mass of the object swallowed. In short, for any given foraging trip, the researcher now knows not only exactly when and where each prey item was captured, but also how big it was. Henri Weimerskirch and his collaborators (1994) used this approach on the Crozets to estimate that, on average, on a typical foraging trip during incubation, a wandering albatross ranges 3600 kilometres, encountering prey at 4.4 hourly intervals for a total consumption of 2.1 kilograms per day.

Several niggling areas of uncertainty remain. The extent, if any, to which the adult diet might differ from that fed to albatross chicks remains uncertain, even though most archival logging experiments have tended to focus on incubating or brooding birds, which are provisioning for themselves, not their chicks. However, for several reasons, it seems unlikely that there is any significant difference. As well, it is known that albatrosses occasionally vary their foraging techniques to include resting quietly on the sea (especially at night) alert for anything that might drift by, but available techniques have not yet evolved sufficient precision to enable evaluation.

So the diet of albatrosses emerges as an extraordinarily intricate and dynamic mosaic of shifting percentages, and characterised as much by variations in exactly where prey is caught as precisely what is caught. In summary, squid predominates in the diet of all albatrosses, closely followed by fish. Wanderers and grey-headed albatrosses are especially reliant on squid, especially Kondakovia and Moroteuthis, while Galapagos albatrosses rely heavily on Histioteuthis and royal albatrosses rely heavily on Octopus and also Histioteuthis – but only inshore (not pelagic) species. Fish tends to be especially important in the diets of black-footed, black-browed, yellow-nosed and shy albatrosses. Krill is a major prey of the two sooty albatrosses, but it also makes up 10–20 per cent of the diet of most mollymawks. Black-footed albatrosses feed their young largely on flying fish eggs. Black-browed, shy and royal albatrosses forage commonly over shelf and inshore waters; others are more rigidly oceanic. But all these are trends only; moreover, they shift both regionally and seasonally. For example, at least at South Georgia, black-browed albatrosses rear their young largely on krill – yet the telltale absence of carotenoids (the same organic dye that makes carrots red, and is also abundant in crustaceans such as krill) in their eggs reveals that, whatever else 'expectant' black-browed albatross mothers feed on, it isn't krill. Overall, albatrosses are strongly opportunistic foragers able to exploit any animal resources encountered on the surface of the open ocean, by night or by day, dead or alive.

5

FLIGHT

Nearly all of the seabirds of the Southern Ocean are spectacular in a high wind. They've been dealing with storms at sea for several million years, and they are very good at it. Peter Harrison, who forged a career as deck-hand on fishing-vessels around the world in the 1970s (with the sole aim of seeing all the world's seabirds first-hand), chose the white-headed petrel as the most spectacular of all. He later wrote of the species:

> Flight strong and swift, with wings held bowed and angled forward, rising and falling in great arcs. Strength of flight best judged in raging storms, during which I have seen them hanging motionless against the storm some 50 m above the water, strangely gull-like, only to slip into the maelstrom and allow the wind to carry them in a wild and towering flight – a truly remarkable sight. (Harrison 1983)

Others agree, although personally I would be reluctant to dismiss a challenge from its near relative the great-winged petrel. To me the great-wing attacks a gale in much the same way some best-of-the-best Olympic skier might attack some suicidal slope in the Swiss Alps, recklessness and impetuosity in every line, hurtling along in great towering upward surges and breathtaking swoops, seeming to find a constant precarious balance on the outermost razor-edge of disaster.

The first thing any beginning enthusiast is likely to notice on leaving land far behind to watch seabirds on the open ocean is that few birds fly high. Regardless of species, nearly all of the action takes place quite close to the ocean surface. The ‘ceiling’ varies somewhat with wind and sea conditions, but is generally within 30 or 40 metres of the surface.

But the kind of action varies widely. Nearly all shearwaters, for example, are strongly gregarious, typically travelling in dense packs of scores or hundreds, occasionally even thousands. They seldom fly more than a metre or two above the waves. They bank steeply from side to side, but glides are relatively brief, constantly interspersed with flurries of brisk, ‘stiff-armed’ wing-beats. Speed and heading are relatively constant: shearwaters convey a strong impression of having a definite destination in mind and being eager to get there. A few differ: the wedge-tailed shearwater is highly idiosyncratic with respect to this profile. They are much less gregarious: there may be scores or hundreds in view at any one time, but they will be widely scattered, not densely packed. And the wedgie flight style is so characteristic it can be distinguished, with a little practice, even if the bird is merely a distant speck on the horizon: languorous, drifting, with few wing-beats, much banking and tilting, and much lazy undulation from high to low and back again.

Most petrels of the genus Pterodroma (and their close kin) are very different again. Unlike shearwaters, they tend to be solitary at sea. Whereas shearwaters freely congregate around fishing vessels, petrels, in contrast, totally ignore (usually) shipping of any kind. And their flight style is very different – higher, faster and wilder. As suggested above, and especially in a high wind, they often seem to be having the time of their lives. Other seabirds have other styles. Dense flocks of prions have been likened to viewing dust motes caught in a shaft of sunlight through a magnifying-glass. Storm-petrels flutter and bounce, dangling their toes in the water.

Despite their diversity in flight, all of these birds have one thing in common: they are all ‘flap-gliders’, relying at least partly on muscle power to stay in the air.

Albatrosses are different again. Most strikingly to even the most casual observer, they very seldom flap their wings. Even at high speed, with frequent changes of height and direction, the wings remain locked in the outspread position, very slightly angled downwards (but markedly so in the wanderer). The beginner is likely to become completely engrossed in the attempt to detect the nearly undetectable – extraordinarily subtle shifts in balance, attitude, trim, achieved without any discernible effort. Whatever the minutiae of keeping a glider stable in a high wind, the wanderer seems to do it somehow by sheer willpower rather than any muscular exertion – except even ‘willpower’ somehow conveys too much effort to successfully encapsulate the flight of a wanderer. As the polar wildlife artist Keith Shackleton remarked (1986) of a wanderer in a Force 9 gale: ‘Close up, they give not the slightest hint of concern.’ The bird almost looks bored. It seems to flow from one state to another as naturally and as effortlessly as water, fire, smoke, wind …

It’s a similar story with the two sooty albatrosses. Similar, yet in some nearly indefinable sense, very different. Sooties in flight are exquisite, the closest thing to sheer poetry in motion to be found among birds.

Of course, all this is strongly subjective. There are no clear-cut boundaries: it is not difficult to find an exception to any of the above, yet even the beginning enthusiast usually soon comes to realise, after a few hours of observation, that every sighting in contradiction of such profiles is outweighed by a hundred that conform. As well, these generalisations are heavily influenced by conditions of wind and sea, normally in a trend escalating with increasing wind speed. The tubenoses all share flight behaviour evolved to cope with gales: in a light breeze all struggle nearly indistinguishably, and in a dead calm most give up the struggle altogether, and settle to loaf idly on the surface. As well, different people see different things, and such things can be endlessly dissected and debated. In the sports world aficionados can readily distinguish one ace tennis star or golf pro from another merely on different styles of play, and could even if their champions were playing in stocking masks and boilersuits. So too, with seabirds. Nevertheless, the mere fact that such subtle nuances can so consistently be detected and shared among seabird aficionados surely means that there is something there that might be explored more rigorously.

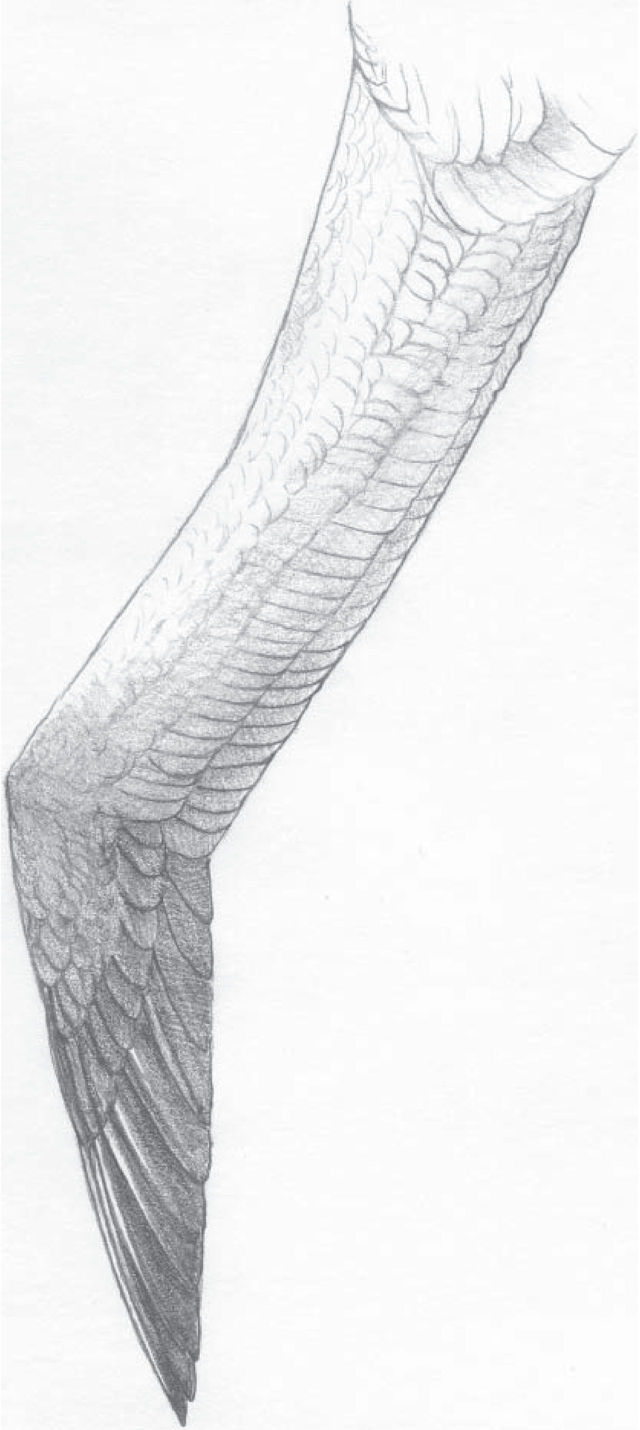
Anatomy

Perhaps counter-intuitively, a long narrow wing is much more effective for efficient gliding flight than a broad, short wing. This is partly because, in the absence of some agent of propulsion, all heavier-than-air craft (organic or mechanical, it doesn’t matter) must fall; the essence of gliding is to delay this as long as possible. Expressed in technical terms, the aim is maximum reduction of the rate of sink, and the most effective way of achieving this is to maintain the highest possible airspeed (ground speed is, again, entirely irrelevant), and here the shape of the wing is important. Long-and-narrow, in a nutshell, is much faster than short-and-broad. Two parameters are important from this perspective: wing-loading (the relationship of total weight to the surface area of the wing) and aspect ratio (the ratio of wing length to breadth).

In keeping with this, the albatross (and in particular the wanderer and the royal albatross) has the longest, narrowest wing of any bird – or any other creature, for that matter. The skeletal anatomy of an albatross wing is greatly elongated even in comparison with other tubenoses, especially with respect to the radius/ulna and the humerus, so that the shoulder, elbow, wrist and wingtip are nearly equidistant. This extraordinary extension is also reflected in the remiges counts (the main flight feathers on a bird's wing are called the remiges, divided into three sets: the primaries (arising from the manus or hand), secondaries (arising from the radius or forearm), and humerals (arising from the humerus or upper arm)). All tubenoses have 10 primaries, but albatrosses have 25–34 secondaries, shearwaters about 20, and storm-petrels only 10; moreover, only in albatrosses are the humerals incorporated into the aerodynamic or lifting surface of the wing.

A wanderer with a mass of around nine kilograms and a wingspan of three metres has a total wing area of about 0.6 square metres, a wing loading of about 140 and an aspect ratio of about 15; among mollymawks the aspect ratio is somewhat lower, around 13.8. By comparison, one of the smaller petrels, such as a cape petrel, weighing 0.4 kilograms with a wingspan of 0.9 metres has a wing-loading of about 55 and an aspect ratio of about 10. Similarly, a Wilson's storm-petrel, among the smallest of all seabirds (and also the nearest in general body proportions and wing shape to what most people would probably view as an 'ordinary' bird such as a pigeon or sparrow), with a mass of about 0.03 kilograms and a span of 0.4 metres has a wing-loading of about 19 and an aspect ratio of about 8.

The pectorals in flying birds are relatively huge, making up some 16–20 per cent of the total body mass, but in the wanderer the ratio is only six per cent. In soaring birds such as vultures and albatrosses, the pectoral muscle is partitioned, with a large superficial section of dark red tissue and a deep section of paler tissue; the ratio in total mass of the muscle is roughly 3:1. This partition is usually interpreted as a division between power for



flapping flight and a slow tonic inner section devoted to holding the wings outspread while soaring. Another of the anatomical peculiarities of albatrosses is a skeletal 'catch' on the long bone that holds the wings outstretched without muscular effort, a little like the mechanism on an umbrella that holds it open once unfurled (the structure is almost unique in all flying animals, shared only with a couple of the largest species of the albatross's closest relatives, the petrels).

Technique

High winds at sea whip up mountainous waves; just as cliffs and steep slopes on land produce strong updrafts that can be ridden by hang-gliders, big waves also produce updrafts along their windward slopes. There is another effect: regardless of the strength of wind, the velocity of the moving air is always somewhat less exactly at the surface of the sea because it is reduced by friction with the water and to some extent by the 'roughness' of a turbulent surface. The magnitude of this effect lessens with increasing height until it fades away altogether some 20 metres above the surface. In other words, wind over water produces a velocity gradient that extends, roughly, from 0–20 metres above the surface.

Either or both of these effects could be used, at least in principle, to supply the lift to keep an albatross in the air, the first by using a technique known as 'slope-soaring' (well-known by hang-gliders), the second by a technique called 'dynamic soaring'. There has been considerable debate in the literature about which technique an albatross might actually use ever since dynamic soaring was first formulated as a theoretical possibility by the English peer Lord Rayleigh in 1883.

The essence of dynamic soaring is a cycle of trading potential energy for kinetic energy and back again. Starting high, the rate of sink is through progressively slower-moving air as the albatross descends, which necessarily increases its relative airspeed, which in turn extends its glide-path. The bird then executes an abrupt 'pullup', using the last of its kinetic energy to gain enough height to expose the full extent of its wings to the full force of the wind at the top of the velocity gradient in order to renew the cycle. According to this model, increasing wind speed should increase efficiency as it progressively steepens the velocity gradient. The possibility has been variously explored by direct observations at sea, mathematical analysis and computer simulation. The relevant equations are esoteric and extraordinarily involved, but in essence come to agreement as a theoretical possibility in wind speeds of six metres per second or more, with pullups to a height of around 18 metres.

C.J. Pennycuick (himself a glider pilot) expressed some reservations when he investigated the flight of seabirds at South Georgia with the British Antarctic Survey in the summer of 1979–1980. From his measurements of wanderers in flight he concluded that there is insufficient energy contained within the velocity gradient to allow the bird to maintain enough airspeed to stay aloft. However, he conceded the possibility in downwind flights, for which he was unable to obtain data.

> The cycle would begin with a crosswind glide, close to the surface, along a wave, followed by a pullup in which most or all of the energy would be derived indirectly from slope lift. If the bird were to turn into the wind for the climb, some additional energy could be obtained from the wind gradient. An extended downwind glide would follow, in which the glide angle would be progressively flattened as the bird descended through the strengthening wind gradient. (Pennycuick 1982)

In any event, the towering pullup, when the bird heels over at the top of its climb to expose maximum surface area to the full fury of the wind, is a common feature of the flight of a wanderer in a gale, and would seem to indicate dynamic soaring rather than the slope-soaring that is so characteristic at more moderate wind speeds. Albatrosses are also strongly suspected of using the vortex of turbulent air that forms just off the very tip of any moving aerofoil to ‘kiss’ the ocean surface, extracting a little extra kinetic energy to sustain the glide, but the aerodynamics of such a manoeuvre are beyond the reach of current theoretical analysis.

Navigation

Staying in the air indefinitely is all very well, but there is one obvious drawback to relying on wind to supply the necessary airspeed, which emerges the moment an albatross encounters the need to actually get somewhere – such as, for example, the nesting colony, or perhaps a better foraging area. When the triremes loaded their cargoes of grain in Egypt to feed the urban masses of ancient Rome, they were forced to defer their departure until the wind happened to blow in the right direction. It took centuries for mariners to work out how to swivel their sails to move at an angle to the wind. The global exploration of the oceans had to wait several centuries more while marine technicians worked out the intricacies of rigging and spars and all the related paraphernalia, so that mariners could go where they chose rather than where the wind happened to blow them.

It is just the same for the albatross. The albatross, too, does not generally sail with the wind, but across it. It can fly into the wind when necessary, but most often its course lies within the arc lying between 110° and 170° of a following wind.

A few years ago, Durno Murray and several collaborators used the results of satellite tracking a number of wandering albatrosses in combination with standard meteorological weather charts and published a series of papers outlining their findings. Since meteorological charts are routinely updated every six hours, and the data streams from their albatross subjects contained times and location fixes recorded several times per hour, they were able to overlay the two data sets to yield a nearly hour-by-hour picture of the flight paths of their birds together with the major weather patterns influencing them. These paths spanned several thousand kilometres over several consecutive days. They were able to show a strong correlation between the two.

> When flying directly southwards, Wandering Albatrosses … used the N-NW winds ahead of cold fronts associated with LOWS, returning northwards in the S-SW winds behind the fronts. Birds flew eastwards in the SW winds between a LOW and a following HIGH, and in NW winds. In westerlies, they flew north-east or south-east and such flights zigzagged across the ocean. Most of these flights were in weather systems in which Antarctic LOWS were a dominant component. Where an extensive stationary HIGH develops over the southern Pacific Ocean, a belt of accelerating winds can develop at the southern interface with circulating southern LOWS, and, in these stronger winds, very rapid transoceanic flights are possible. (Murray et al. 2003)

Their results are truly extraordinary. Speeds of 50–60 kph were common: one of their birds maintained an average speed of 50 kph over 800 kilometres. (Pierre Jouventin and Henri Weimerskirch, working with breeding wanderers at the Crozets, reported 80 kph as the typical average speed of a wanderer commuting to its feeding grounds.) Such speeds may not sound great, but they are quite respectable in comparison with most other fast-moving animals, especially since they are sustained over substantial periods of time, not merely desperate sprints over short distances. Moreover, these were point-to-point measurements, a bird being recorded at this location on the globe at such-and-such a time and another location some hours later. The actual paths travelled by the birds are markedly zigzag, resulting in much greater distances actually travelled and hence a greater velocity – by an unknown but plainly substantial margin. By far the greatest distances were covered during the hours of daylight, but even at night some progress was made, and the birds were never on the surface of the ocean for more than about an hour at a time.

But it is not the raw speed that is so remarkable – it is that the rate of progress, itself quite respectable, is maintained hour after hour, day after day. Several birds covered 1000 kilometres in a day – that's the equivalent of Sydney to Melbourne via Canberra; you or I might find this a gruelling journey in the comfort of a fast car. One bird covered 1730 kilometres (roughly Sydney–Adelaide via Broken Hill) in 1.5 days; another flew 3000 kilometres in 3.8 days. In the high-speed zone in the Pacific sector, wanderers were routinely spanning 10° longitude per day for several consecutive days, traversing half an ocean in a week. Nothing else on the planet can move so far so fast. The nearest rival contender is among those sandpipers and plovers that nest on the shores of the Arctic Ocean and migrate to the Southern Hemisphere where they spend the northern winter. Golden plovers nesting in Alaska, for example, fly non-stop directly to Hawaii in a single flight spanning about 4000 kilometres and lasting about 36 hours. Impressive indeed – but once landed, the plover is effectively grounded for a week while it refuels; the wanderer, meanwhile, is just hitting its stride. The birds achieve this extreme mobility by exploiting the properties of high-velocity weather systems. Albatrosses in general, and a variety of their close relatives the petrels, use this unique mode of travel, but enough data has now accumulated to single out the wandering albatross as its ultimate exponent. In a word, the wanderer is, literally, the Storm-Rider.

> At any point along a flight path the birds could have changed the direction of flight, but the chosen direction was maintained for several hundred kilometres, sometimes through several weather systems … Some birds even paused when winds were unfavourable, and resumed flying in the chosen direction once

> winds became favourable. We believe that these are flights of ‘intent’ and a learned behaviour; Wandering Albatrosses are master, not subjects, of the wind. (Murray et al. 2003)

Wanderers may be the most spectacular users of the high-speed ‘albatross freeway’ around Antarctica, but they are not alone. In 2005, a team headed by John P. Croxall of the British Antarctic Survey published the results of their work on the migration of grey-headed albatrosses based at South Georgia. Because grey-headed albatrosses breed only every alternate year, this means that a typical bird of this species has a ‘sabbatical’ lasting about 18 months between breeding attempts. Croxall’s team fitted archival loggers to 22 grey-headed albatrosses and succeeded in tracking them throughout this period at sea. Three distinct migration strategies were detected, but perhaps most striking was the tendency for some males to spend their sabbatical circumnavigating the Southern Ocean. Three of their birds did it twice. Speeds were not too far short of wanderers on the same route – several covered 950 kilometres per day for several days at a time. At their standard cruising speed, a complete circumnavigation of the Southern Ocean could in theory be achieved in 30 days by a grey-headed albatross; so far line honours go to one of their birds that completed the trip in 46 days.

Marvellous as all these extraordinary techniques, skills and adaptations may be, they have their limitations. The most obvious is lack of wind. In completely calm weather, albatrosses cannot continue long in the air, and once landed, are severely hampered in their ability to take off again. Even the smaller mollymawks sometimes visibly struggle, and a sooty albatross was once observed pounding across the surface for two kilometres before it finally succeeded in hoisting itself into the air. The even larger and heavier wandering albatross finds it nearly impossible to lift off in a dead calm.

This inability to cope with calm weather is almost certainly the reason for the lack of albatrosses in the North Atlantic, and for the rigid segregation of northern and southern species in the Pacific. Albatrosses of the Southern Ocean are confined within their river of wind by the doldrums, that narrow zone of frequent calm and light and fitful breezes that lies on either side of the equator. This region of unreliable wind represents, for albatrosses, a barrier that can be penetrated only under exceptional circumstances and at infrequent intervals. But breakouts do occur, especially among mollymawks. Solitary vagrants are reported almost annually in Europe, and sometimes the individual concerned revisits annually. Perhaps the most notorious was a young female black-browed albatross that showed up at the Faeroes in 1860, and returned annually to spend the summer for 34 years in succession before she finally disappeared. A similar occurrence in 1967 involved another black-browed albatross, quickly dubbed 'Albert' (though of unknown sex), that showed up at Bass Rock in the Firth of Forth, Scotland. This bird later moved to the Shetland Islands, where it spent each spring and summer for the next 20 years.

Seabirds are similarly forced from their comfort zone whenever some misadventure brings them over land. The behaviour of wind over water is very different from that of the same wind over land, and seabirds are highly evolved for the former but not the latter. In parts of New Zealand, the extreme south-west of Western Australia, and several other places, dead seabirds are washed up on beaches with some frequency, especially after storms, and occasionally in numbers sufficiently large to attract the attention of the local media. Occasionally even albatrosses are caught up in such disasters. Especially in earlier days, the resulting newspaper reports typically milked the pathos for all it was worth, painting a colourful and harrowing picture along the general lines of 'our poor feathered friends desperately fleeing Nature's fury', and so on. In fact, the perspective is almost ludicrously awry. The situation has more in common with that of, say, a group of small children riding a toboggan down a snowclad slope. Glee and giggles turn to panic when they realise their toboggan has veered unexpectedly and is now headed directly towards the only tree stump on the entire hillside. The drama and trauma reside in the stump, not the snow. Similarly with the seabirds: avian disasters of this kind happen at places where storms at sea most frequently make first contact with land. They occur when high-speed weather disturbances heading east veer to the north, as they occasionally do, and collide with land. The birds are fleeing the land, not the storm – but a continent is a hard target to miss; they quickly become exhausted, fall into the sea, and end up wrecked on the beach.

Early attempts to estimate the energy expenditure of albatrosses in flight yielded results up to as much as three times basal metabolic output, but were soon revised downward to about 1.4 (or around four Watts per kilogram); even these estimates proved much too high. Perhaps the most striking experiment along these lines was when Henri Weimerskirch and several collaborators, working with wanderers on the Crozets, attached heart rate monitors to seven birds and tracked their foraging flights via satellite. They made the reasonable assumption that heart rate varies directly with oxygen consumption, which in turn is a measure of energy consumption. They found that heart rate peaked during take-off and landing, but not in flight. Remarkably, in sustained flight at the highest speeds, their birds' heart rates remained steady at barely above the base rate of some 80 beats per minute characteristic of long periods of incubation on the nest.

In an earlier and alternative approach to the problem, J.C. Pennycuick (1982), arguing the general thesis that animals with large foraging ranges are under heavy selection pressure to evolve large body size (in other words, the wanderer is the world's largest flying bird because it has the world's largest foraging range), used an estimate of one per cent of body mass to represent the fuel load for a routine foraging trip. He then used standard physiological and metabolic equations to calculate range and time. Using these assumptions, a wanderer (the largest tubenose) could stay in the air for 29 hours and cover nearly 1000 kilometres before its 'fuel' was exhausted. In contrast, a Wilson's storm-petrel (one of the smallest tubenoses, and one that seldom glides) could stay in the air for less than two hours, covering a mere 39 kilometres.

Bird flight is dependent on feathers, but feathers wear out. The primaries, in particular, soon become frayed and abraded to the point where their ability to provide lift and apply power is severely compromised. Most birds moult – that is, shed old feathers and grow new ones – at least once a year, sometimes more often. In a typical bird, the combined weight of its plumage makes up roughly a third of its total body weight, so the metabolic demands of replacing it are heavy indeed. As a result, the annual moult is among the most intricate and rigorously orchestrated procedures any bird undertakes in its yearly routine, especially with respect to the crucial flight feathers. The basic pattern involves shedding one flight feather plus the corresponding feather on the opposite wing simultaneously, then waiting for the replacements to be about half-grown before shedding the next feather in line. But here the devil, as they say, is in the details. In a typical songbird, the whole process takes three weeks or so, and is usually undertaken in late summer, when the stresses of nesting are safely behind it but the food supply needed to fuel the process usually remains abundant. But for tubenoses in general, and albatrosses in particular, there is no optimum time – any bird that spends nearly its entire life on the wing in stormy weather needs its aerofoils in peak condition all the time. Here again albatrosses emerge as most unusual birds.

Among albatrosses, moult is suspended while breeding (although it seems most species begin moult of down and body plumage towards the end of the nesting cycle). However, this means that for the critical flight feathers the process cannot be observed directly – the birds are permanently away at sea while it happens. The best that can be achieved is to photograph the outspread wings of many known-age, identity-tagged birds at the nesting colony, note their moult status, and rely on statistical analysis to deduce what must have happened to get the birds to their observed state. This is a lengthy, meticulous task that has only been attempted for a few species – notably the wanderer and the Laysan and black-footed albatrosses – and finalised for none. In the Laysan and black-footed albatross, the primaries are moulted in two series, the outermost five (p6 to p10 in descending sequence) and the innermost five (p5 to p1 in ascending sequence), in alternate years. In wandering albatrosses the sequence seems similar, except its direction remains unknown. On the other hand, in black-browed albatrosses the outermost three primaries (p10–p8) are replaced every alternate year.

But among wanderers, at least, the intricacies proliferate further, with respect to the secondaries: at any given time, adolescent birds have three generations of secondaries, of ages one-year, two-years and three-years old, simultaneously. One study on South Georgia and the Crozets found that, as four-year-olds, males still had, on average, about two-thirds of the original secondaries they fledged with, while as five-year-olds, females still had around 17 per cent of their original secondaries. In short, the pattern of moult of the flight feathers changes markedly with age, differs between males and females, and spans several years instead of just one. Many of the details remain to be worked out, but in these features, wanderers appear to be nearly unique among birds.

6

COURTSHIP

Albatrosses live exceptionally long lives compared to nearly all other birds; they live nearly as long as humans. Even more exceptional is the delay in reaching sexual maturity and achieving recruitment into the breeding population. In the great albatrosses (wandering and royal), this process alone may take 15 years, though it's more often around 10. When a typical male wandering albatross fledges and takes to sea, he remains at sea for four or five years, or even longer, then finally returns to the natal colony. His first task is to establish a territory, in the form of a nest site. That done, his second major challenge is to find himself a mate. Overcoming these two hurdles frequently takes several years, and he may achieve nothing at all on his first season back at the colony, or even the second.

Albatrosses typically mate for life. Pairs occasionally 'divorce' and each member of the pair finds itself another mate, but this is likewise uncommon – although in several of the smaller mollymawks the pair bond may be sustained only for three or four seasons in succession. The essential point, however, is that, at least among the larger albatross species, the pair bond is nearly permanent.

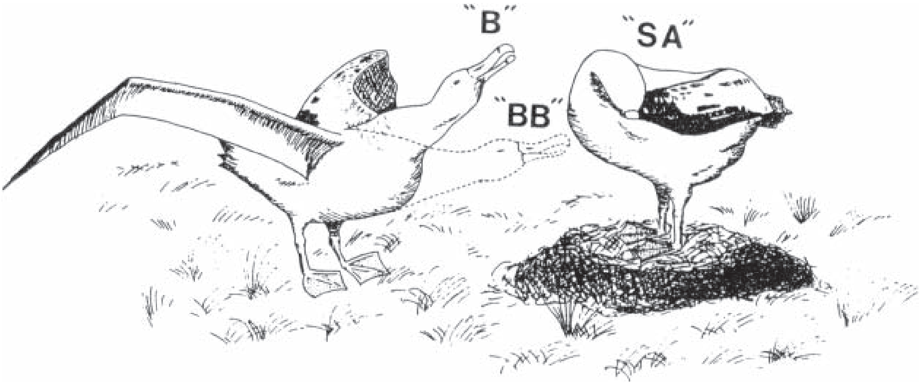
The pair bond is established gradually, typically over several successive seasons, through multiple repetitions of mutual displays, at first infrequently but with many partners, then with increasing frequency but with a steadily narrowing field of partners, until finally a single partner is selected by mutual accord.

Commonly called dances, these displays are among the most spectacular, impressive, highly ritualised and elaborate examples of courtship behaviour to be found anywhere among birds, and rank as one of the most strikingly distinctive aspects of albatross biology.

The first few moments of a wanderer dance, as it might appear to any casual observer who happened to be sitting quietly nearby, might go something like this: Female A approaches male B on nest. B stands erect, points bill at sky, spreads wings wide in heraldic pose, utters loud call. A climbs on B's nest. B turns to face A. A turns head to jab at shoulder feathers. B 'clappers' mandibles together very rapidly, making a noise like the wooden rattles clacked at a soccer match. A and B both utter braying call. Two other young females C and D approach B's nest. A and B both hold wings outspread. Female E approaches. A folds wings, bill horizontal, points bill-tip away. A faces C, stands erect, points bill at sky, spreads wings. Subadult male F also approaches, but halts at periphery, spreads wings, points bill at sky. A and B face each other, point bills at sky, slowly touch bill-tips. B charges at F, bill wide open, yammering …

And so on. A first impression might be bewilderment; a great deal is going on too quickly to take in the details, even though wanderer displays are quite sedate affairs. Such a performance may last from just a few seconds to 15 minutes or so, averaging somewhere around four or five minutes. Displays are common in any large, busy colony, especially early in the nesting season. Most often there are only two participants, but any other birds that happen to be nearby may become caught up in the excitement, and either cluster around to gawp, act as enthusiastic audience or even join in. Sometimes males will display to males, or females to females. Normally, to the human observer there is a stately, elegant, intense aura about the performance, but occasionally any structure the display may have collapses in a noisy melee of half a dozen over-excited birds, with lots of passion and temper and drama in evidence. At the other extreme, very young, diffident males, perhaps on their first return to the colony, may even quietly go through the motions alone, without a partner.

The focal point of the display is usually an occupied nest, but some colonies of some species, such as wanderers, may have communal display grounds, at some little distance from any active nest. This is also notably true of both Laysan and Galapagos albatrosses. Albatross displays,



A pair of wandering albatrosses perform the bowing ('B', left bird) and side-preen ('SA', right bird) components of their display. From Jouventin and Lequette (1990), reproduced with permission.

incidentally, are not necessarily confined to the nesting colony, whether nest-site or communal arena: there are several observations in the literature reporting courtship displays taking place among loafing groups of albatrosses at sea, well away from any breeding colony. However, observations of this kind are uncommon.

Males tend to arrive before females at the breeding colony, and established males arrive earliest of all. Experienced males tend to set about re-establishing ownership of their nests more or less immediately, whereas very young males on their first arrival back at the colony may loaf idly about in loose groups until the first females begin arriving a week or so later. Any incoming female may be approached by such a group soon after landing, and the young males may initiate displays.

> The males leave their squatting-posts to cluster about the first females, which are commonly besieged by from two to six, or even more, ardent yet orderly suitors. The males throw forward their breasts, stand upon their toes so that the metatarsal joint clears the ground, stretch out one or both wings, raise and spread the tail, gobble and squeal, and then touch bills with the female, which also responds in kind to most of the other gestures. (Murphy 1936)

More often, especially a little later in the season, displays are initiated when a female approaches an established male at its nest. Such territorial males may visit a communal arena, attract a potential mate, and lead her back to his nest, but perhaps just as often a female may wander through the colony, pausing whenever a resident male's display happens to attract her attention. She may participate in a mutual display, or she may soon lose interest and wander off. She may return later. Wanderer pair bonds are gradually built up through multiple repetitions of such interactions, at first brief and casual, later more intense, frequent and focused.

Although the hypothetical field-sketch offered above glibly labels males and females, in fact it normally is not possible to sex albatrosses, at least not in the casual, on-the-fly fashion needed in this situation. Further analysis is greatly hindered in the absence of some reliable means of establishing the age and gender of the participants. Researchers normally address the problem by videotaping the display, selecting only those displays taking place in some part of the colony in which most birds have already been individually marked (usually by means of coloured plastic bands on the legs), then later examining the tape frame-by-frame.

Several significant details emerge from such an exercise, especially when combined with videotapes from a reasonable sample of similar displays. First, the movements of the birds are not infinitely variable. They are selected from a fairly restricted pool of stereotyped poses, postures or gestures – perhaps a dozen or so being typical. Second, each gesture evokes a response from other participants, and that response is also a stereotyped gesture; moreover, there is a high probability that it will be the same gesture on each repetition – that is, gesture A usually evokes gesture B, C evokes D, and so on. Very often the response is a repetition of the prompting gesture, so that the birds act in unison like mirror images of each other, but this is not necessarily so: the essential point is that responses are not randomly selected.

Two especially prominent components in the wanderer's display involve the bird turning its head backwards to bury its bill in the feathers of the back or 'shoulders' (usually dubbed 'Scapular Action', or 'Side-preen', sometimes coded as 'SA') and the second involving the bird extending its neck and throwing its head back to point its bill vertically upwards ('Sky-pointing', or 'SP'); sometimes a loud braying call accompanies the sky-point, yielding 'Sky-point Call', or 'SPC'. Sometimes a bird will deliberately touch the tip of its partner's bill with its own ('Billing', or 'B'), or bow low, with shoulders hunched, neck extended and bill horizontal ('Bowing', or 'BW'). Other components, more or less self-explanatory, include 'Walk', 'Walk Away', 'Turn Around', 'Yapping' and 'Whine'.

Not all components in the displays are postural or visual:

> The Wandering Albatross has a rich vocal repertoire (nine stereotyped acoustic signals comprising five vocalisations). All acoustic signals [are] performed by both sexes and all, except 'Groans' [are] more used by males than females. (Lequette & Jouventin 1991)

In all, about 30 stereotyped components have been identified in wandering albatross displays (nine vocal, the remainder visual), roughly comparable with other albatross species that have been closely studied. There is, incidentally, no formal structure in the names of display elements; they are usually coined by the researcher as needed, and the nomenclature achieves some degree of stability because each researcher tends to favour that used by any predecessor. However, because few researchers have had the opportunity to study many species, different albatross species tend to have only approximately congruent display nomenclatures.

In one rigorous study of wanderer displays, the French researchers P. Jouventin and B. Lequette used videotaped displays to compile a database of 12 027 individual display components. A total of 7108 of these (59.1 per cent) were performed by males and 4919 (40.9 per cent) were performed by females. 'Billing' and 'Bowing' together made up nearly half (44.6 per cent) of the total, and were performed nearly indiscriminately by males and females. On the other hand, the 'Grunt' and the 'Sky-point Call' were nearly always performed by males, but 'Walk Away' was mostly a feminine gesture. However, in this study no gesture was entirely exclusive to one sex; all were shared, though with varying degrees of preference.

Since displays nearly always consist of multiple gestures or postures, Jouventin and Lequette went on to examine their data in terms of the sequence in which gestures are performed. This analysis revealed, for example, a strong link between 'Yapping', 'Construction Activity' and 'Sky-pointing' for both sexes. Similar strong links were found between other clusters of display elements. The gestures were performed in a non-random sequence: in other words, there is a high probability that gesture A will be followed by gesture B but a lower probability that it will be followed by gesture C, and so on. This was equally true for males and females.

The remaining parameter to be explored is contained in the concept of a duet or dialogue, the extent to which a given gesture from one participant might evoke a particular response from another. Here again, analysis reveals strong links. For example, male ‘Turn Around’ usually evoked female ‘Billing’, but female ‘Turn Around’ usually prompted male ‘Whine’, and so on.

In other words, the strong subjective impression on the ordinary observer is largely confirmed – albatross displays are duets. They are, in effect, dialogues. Information of some kind is being exchanged, and the various postures, poses and gestures are signals, each prompting a specific and particular response from the other participant. From this perspective, a human dance is a fairly good metaphor for an albatross display (the risk lies in any facile assumption that comparable structure must imply comparable function, which of course does not follow). A ballroom dance such as a waltz or a tango is a duet, a highly ritualised sequence of individual dance steps or ‘gestures’, selected from a fairly limited array of allowable moves, which must be performed in the correct sequence, and each of which is matched by an appropriate response from the other participant. In this restricted, structural sense the parallels between a human dance and an albatross display turn out to be quite close. Just as human novices can be expected to make many errors with a new partner, but improve with practice, several analyses of albatross displays have shown that ‘errors’ are relatively frequent with adolescent, inexperienced birds, but the error rate consistently falls steadily through repeated displays with the same partner.

Analyses such as the one just described can generate networks or web-like diagrams that show the sequence and relationships of the various display elements, which can in turn be used to illuminate differences and similarities in other species of albatrosses. All albatrosses have such displays, though most are much less spectacular than those of the great albatrosses, and they vary in their details. For example, only royal albatross and wandering albatross displays have the impressive, heraldic, outspread-wing component (among the gooneys the wings are often flared, or half-opened, but not fully extended). Indeed, more subtle analysis suggests that the gesture may not be strictly a display component at all, but rather a means of emphasis, something along the lines of using a word in a sentence in italics or bold type to emphasise it.

Royal and wanderer displays themselves differ in minor details; for example the ‘Sky-point’ component is not quite identical in the two species. Similarly, in light-mantled and sooty albatross displays, an aggressive bill-thrusting component is performed with the bill open in the former, but closed in the latter. Displays of both of these species also include a strong aerial component that is lacking in other albatrosses. Courting couples spend a great deal of time in highly synchronised close-formation flights along the cliff-tops near their nests – one of the most breathtakingly lovely sights in all of nature.

The Galapagos albatross deviates perhaps most strikingly from other family members in its displays. Bryan Nelson (1968) remarked that watching a pair display was rather like watching two washing machines, 'each with the same repertoire but out-of-phase with each other'. In the first place, the Galapagos albatross has a unique high-pitched call, sometimes rendered as 'eelich-coo', that sounds quite unlike anything uttered by any other albatrosses, but which is frequently uttered during display. The birds display with folded wings, but they have a unique 'Sway-walk' component not seen in other albatrosses, in which the body is rhythmically swayed from side to side in a highly exaggerated fashion. 'Sway-walk' is usually performed in unison by both birds. 'Bowing' also differs in detail from other albatrosses, and the 'Stare' is especially striking: heads close together and tilted to one side, the birds stare fixedly at each other. Erecting the small feathers above the eye exaggerates the eyebrow ridges and imparts an oddly 'flat-topped' appearance to the skull.

Laysan and black-footed albatrosses share the most extensive repertoire of display elements of any albatross, both aural and visual. For example, at least four variations on the wanderer's 'Sky-point Call' have been distinguished: 'Sky-flick', 'Sky-moo', 'Sky-groan' and 'Sky-whistle', and several other components, such as 'Head-shake-and-whistle', 'Bob' and 'Bob-strutting' do not appear to have any close analogue in great albatross or mollymawk displays. Though broadly similar in their major features, gooney displays differ from great albatross displays in their much brisker pace, and they are somewhat more likely to end in sudden, violent squabbles if there are more than two participants. Tempers, it seems, just naturally run higher in crowded gooney colonies than in the more scattered colonies characteristic of the great albatrosses. Nevertheless, several features are common to both. Most often displays are initiated between two birds, but others are likely to join in. As in wanderer displays, the participants are not necessarily of opposite gender: in one study of 100 Laysan albatross displays, both partners were male in four cases and both were female in another nine instances. Most displays end quietly, with the female simply walking away.

When a male wanderer returns to the colony at the start of the nesting season, he tends to spend most of his time at his nest, but when a female first arrives, she may only spend an hour or two ashore. Her subsequent visits increase in frequency and duration as the season progresses but, even so, a marked gender imbalance in total time spent ashore persists, even in courting pairs. Males are more or less tied to their nests, while females come and go essentially at whim. A female may visit as many males as she chooses, but a male can only respond to those females who choose to visit him. He can maximise his choice of partners only at the cost of spending more time at his nest. But while he is at his nest waiting for potential mates, he cannot be away at sea foraging, which means, in a word, he starves. The more subtle consequence of this state of affairs is that, in the end, the female is selecting a male rather than the reverse, and she is selecting his 'quality' as a potential mate largely on his fasting ability – the less he needs for his own sustenance, the more foraging effort he can commit to a potential offspring.

Wanderer males, based on the size of their testes and the amplitude of their testosterone cycles, are plainly physiologically capable of breeding from their fourth year. Studies of their endocrinology and hormonal cycles show that females, on the other hand, are incapable of breeding until their seventh year. This latter conclusion is amply supported by field studies: in one data set of 1500 wanderer nests on South Georgia, for example, only two per cent of females were less than eight years old. Also relevant is the consideration that, among albatrosses, parental investment in their chick after fledging is almost certainly nil. This necessarily means a young wanderer must learn to forage for itself on the open sea right from fledging, a skill that plausibly takes several years to achieve efficiently. And it takes several more years to perfect to the point where taking on the additional burden of provisioning a chick is possible or practicable. Also relevant is the observation that wanderers are highly unusual among birds in that naive parents are just as successful at rearing their chicks as experienced birds. The usual way of interpreting all this is to hypothesise that the extraordinarily extended courtship and pair-bond formation is in fact a mechanism to defer breeding until both partners have accumulated sufficient experience and life skills to optimise the chance of success in a breeding attempt. Elsewhere, other birds as disparate as kookaburras and blue fairy-wrens have comparable mechanisms that work, in the end, to defer the first breeding attempt until the partners are in the best possible position to ensure success. Rearing, at best, only one young every two years means that wanderers, even granting lengthy lives, have unusually few chances of getting it right, and it seems reasonable that one of the most effective means of ensuring success lies in devoting unusual time and effort in forging uncommonly stable and intimate partnerships.

The temptation to categorise albatross species as either biennial breeders (wanderer, royal, grey-headed and both sooty albatrosses) or annual breeders (all the rest) is understandable, but works to obscure an important phenomenon: some pairs of nearly all species occasionally skip a year, or – rarely – even several. At any colony, the population as a whole breeds each year, but a few individual pairs may elect not to (such 'off-duty' pairs may or may not visit the colony). This not only blurs the distinctions, and such labels therefore apply only to most but not all of the population, but it also raises the question of the nature of the decision-making mechanism that might prompt such behaviour. Clearly some form of mechanism must exist, but what it might be remains largely unexplored. Even so, it is surely a reasonable speculation that, whatever its nature, it could only be facilitated by unusually intimate and robust pair-bonding behaviour.

Albatross displays are unusual among birds in several respects. The first is the question of display repertoire. Many strongly social mammals, for example, have strongly ritualised behaviours used in a wide range of contexts, not necessarily sexual. Most albatrosses appear to have only one – the display used in pair formation. Three repertoires have been distinguished in wanderers, and several components appear to have their origins in territorial defence rather than mate selection, but studies appear not to have progressed far enough to discriminate plainly among them. Another is the question of participation. Among the birds-of-paradise, for example, famous for their flamboyant mating displays, only the males perform, the female lacking any ritualised response beyond choosing to leave or to invite copulation. But albatross displays, in contrast, are mutual affairs, with more or less equal participation by both parties. Also, albatross displays are characterised by the combination of highly ritualised vocal signals and highly ritualised visual signals.

Finally, the albatross display – at least in the great albatrosses – is more elaborate than commonly found among birds in yet another respect. It has been suggested that the complete nuptial display in wanderers should properly be viewed as taking three to four years, because that is how long the mate selection process takes to complete. A typical wandering albatross pair does not actually tie the knot, as it were, until several years after they first begin mutual displays. Perhaps spread across several partners in the early days, the bond is steadily strengthened during the course of many displays, the relationship taken up again each season after a hiatus away at sea through the winter, the field of partners steadily narrowing to just one, their mutual displays gradually more closely synchronised and strongly ritualised, until, in the third or fourth season of the progression, the pair bond can finally be said to be fully established. This extraordinarily extended courtship is itself a distinctive feature of albatross behaviour relative to that of nearly all other birds, especially in the case of the wanderer and the royal albatross.

Among albatrosses, such elaborate courtship behaviour is usually interpreted as a strategy for maximising breeding success – the more closely parents can get their act together before the nesting attempt, the better the chances for a successful outcome. Such behaviour also has the subsidiary effect of inhibiting hybridisation between species, because the greater the differences in ritual, the greater the difficulty in ever cementing a partnership. In more immediate effect, this circumstance also isolates the mate selection process from the nesting cycle proper, at least among the great albatrosses. The New Zealand researcher L.E. Richdale asserted that royals abandon displays once the pair bond is established, but some ambiguity remains apparently unexamined with respect to wanderers. Robert Cushman Murphy, for example, specifically stated that ‘This turn and turn about [that is, displays], with the pair together, continues as a rule until the egg appears’ (Murphy 1936). In any event, the central fact that it takes several successive seasons to establish a pair bond is itself a strikingly distinctive characteristic of albatross behaviour, otherwise most unusual among birds.

7

THE NESTING CYCLE

Birds everywhere differ widely in their fecundity, or rate of reproduction. On the one hand there are species that mature rapidly but have low survival rates, are promiscuous and breed frequently, and have large broods that disperse far. On the other hand there are birds with opposite characteristics. Ecologists refer to the extremes of this axis as 'r-selected' (high fecundity) and 'K-selected' (low). This is not a dichotomy; instead it represents a spectrum of possibilities. Most birds – the pigeons, sparrows and mynahs of our back gardens – occupy a position more or less in the middle of this continuum. The topic is of considerable technical and theoretical interest, partly because of its obvious implications in the successful management of critically endangered species, and often it is possible to derive useful insights by studying features at the extremes not generally accessible at the centre. Albatrosses, and in particular the wanderer and the royal albatrosses, are of some considerable theoretical interest in this respect because they occupy a position on this continuum nearly as far to the slow end (K-selected) as it is possible for a bird to be.

As well as breeding very slowly, albatrosses are also strongly colonial in their nesting behaviour. In exploring the functioning of any avian nesting colony, five parameters are pivotal: persistence, segregation, density, philopatry and synchronicity, and their values are sometimes high, sometimes low, depending on the species involved. If the same colony is used year after year, persistence is high; if only one species nests there, segregation is likewise high. If its members return to the same location within the colony year after year, then philopatry is high, and if their activities are closely coordinated (nearly all eggs laid nearly on the same day, for example), then synchronicity is likewise high. Albatrosses tend to cluster toward the high end of the spectrum in all of these factors.

A typical albatross returns to the same mate at the same nest site on the same island year after year. Some birds do occasionally stray, and return to seek a new mate at a new site, or even attempt to nest at some entirely different colony, but such events are relatively uncommon. The tendencies for dispersal and colonisation among albatrosses are markedly lower than is usual among birds.

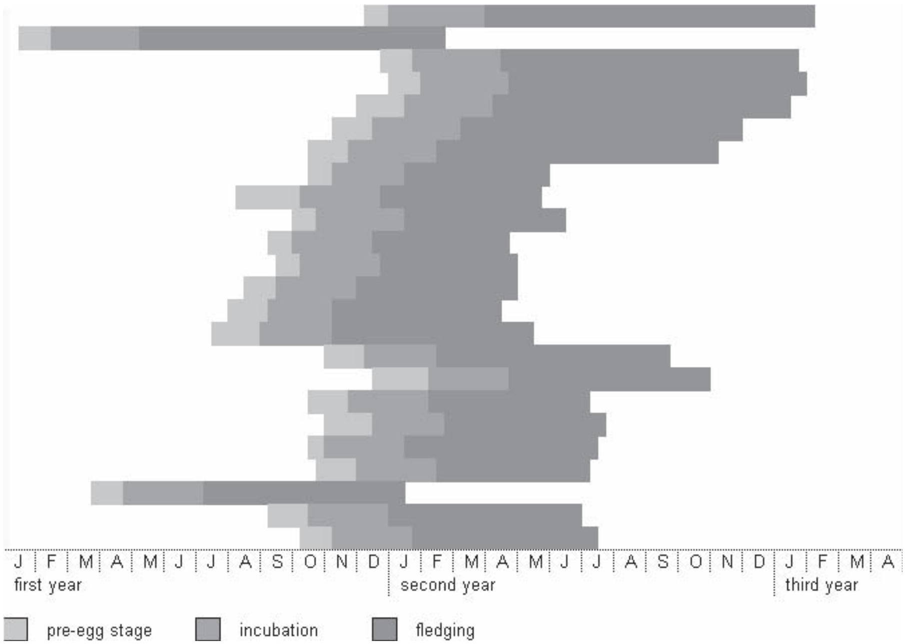
The nesting cycle can be divided into three significant stages: incubation, brooding and provisioning. Two factors dominate the first stage, one obvious, the other somewhat less so: the chick cannot be fed while it is in the egg so the parents cannot directly influence the outcome, and incubation depends on maintaining an elevated temperature for the duration of the process. While it is true that an embryo might survive brief chilling, in practical terms the risks to the embryo escalate so rapidly with neglect that adults must be viewed as committed to nearly 100 per cent attendance. A similar, though somewhat less stringent requirement pertains to the second, or brooding stage. Here the chick has successfully hatched, but cannot yet sustain its own body temperature. This means, again, that one parent must remain with it more or less constantly to brood and keep it warm, which in turn means that only one parent is left free to go to sea and forage for it. Baby wanderers take about six or eight days to clear this physiological hurdle, but demarcation between this stage and the third, or provisioning, stage tends to blur because it may take several more days to reach the point where it is big enough, strong enough and vigorous enough to defend itself against predators such as skuas. This hurdle cleared, the chick is effectively abandoned.

Colony

Albatrosses nest in colonies that range in size from just a few pairs to huge avian cities that may harbour tens of thousands of breeding pairs. At one extreme, such as black-browed albatrosses in the Falklands or the Laysan

Species	Population	Days
Wandering	*exulans*	386
	amsterdamensis	364
	gibsoni	355
	antipodensis	356
	dabbenena	356
Royal	*epomophora*	353
	sanfordi	353
Black-browed	*melanophris*	204
	impavida	259
Grey-headed	*chrysostoma*	236
Yellow-nosed	*chlororhynchos*	205
	carteri	202
Shy	*cauta*	231
	eremita	229
	salvini	270
	steadi	292
Buller's	*bulleri*	284
	platei	238
Laysan	*immutabilis*	236
Steller's	*albatrus*	243
Black-footed	*nigripes*	232
Galapagos	*irrorata*	264
Sooty	*fusca*	264
Light-mantled	*palpebrata*	254

Schedule and nesting cycle



Nesting cycles of albatrosses: timing and duration. The 'Days' column indicates the total span of the nesting cycle, from first arrival of adults at the colony to final departure of the newly fledged chick. The same caution as for the biometrics table (p. 116) applies: a great deal is based on estimates, or only the most fragmentary of data.

albatross in Hawaii, nest density may be extremely high – nests perhaps just a metre or so apart. At other colonies, nests may be much more scattered – perhaps 50 metres or more apart. In general, the wanderer and the royal albatross are much more likely to conform to the latter model, partly because they need more space for take-offs and landings. But, regardless of species, a typical nesting albatross normally has several neighbours at least within visual range. Few nest entirely alone. One conspicuous exception is the Galapagos albatross, which sometimes nests in scrub so dense that human observers have trouble finding the site. Albatross colonies are also usually characterised by a fairly high level of synchronicity – that is, all nests are built nearly simultaneously, all eggs are laid at nearly the same time, and all chicks fledge nearly together. Colonies are also normally segregated by species: that is, although a small island may support several albatross species nesting together, their colonies are usually distinct, not mixed. Most albatross colonies are segregated, but nesting grey-headed albatrosses sometimes mingle with black-browed albatrosses, black-footed albatrosses sometimes mingle with Laysan albatrosses. Similarly, philopatry is usually high, although Galapagos albatrosses show relatively little attachment to their nest sites – indeed, they often move their eggs even as they incubate them.

Arrival

In a typical albatross colony, males usually arrive about a week before females. The female remains with her mate for just a day or two, and almost all copulation is normally confined to this period. She then promptly returns to sea to forage while she forms her egg. However, yolk formation is already well advanced even when she first arrives at the colony, leading to the necessary presumptions a) that egg formation is triggered by some as yet unknown environmental factor, not copulation, and b) albatrosses must be able to store sperm until the egg has reached the appropriate point of development for fertilisation to occur. The period of absence from the colony varies somewhat from species to species. Among mollymawks, for example, the female black-browed albatross remains away at sea for about 10 days whereas the grey-headed albatross is away for about 16 days, but the total time for yolk deposition is 20–21 days for both. In contrast, it takes about 40 days for a female wandering albatross to form her single egg before laying it – about a month for the yolk, the final 10 days or so to wrap

it in albumin, membranes and shell. (In investigations of this kind, a common approach is to administer an oral dose of a harmless black dye to the female immediately upon arrival. The dye is incorporated into the yolk. If the egg is collected when laid, then deep-frozen, sectioned and examined under a microscope, the daily layers of yolk deposit are clearly visible, and the black layer of dye midway provides a calibration point.) The birds return to the colony about two days before laying their eggs.

Nest

Albatrosses of the Southern Ocean all build fairly elaborate nests, constructed of clods of earth, faeces, grass-clumps and whatever else is handy, raked together from the periphery of the nest-site to form a central truncated cone of material. The raking action often produces a sort of shallow ‘moat’ surrounding the structure. The size of the nest varies widely with species, local situation and dedication of the pair that built it, but roughly knee-high to an adult human is reasonably typical. Both sexes cooperate in forming the structure. Many birds complete their nest, then lay eggs in it, but among albatrosses there is seldom any clear-cut point of completion. Well into incubation, a brooding albatross may continue raking in nest material, or fuss and fidget with its arrangement. The nest is usually reused in subsequent seasons, but several months of trampling by the previous occupant, together with exposure to rain and winter storms, means that the structure is often so badly damaged it has to be rebuilt, or at least extensively repaired; this is normally the first order of business for the pair on returning to the colony. The egg is deposited in a shallow saucer-shaped depression fashioned into the top of the cone.

Egg

Like all tubenoses, albatrosses lay only a single egg for each breeding attempt. Older females tend to lay larger eggs than younger females, but the difference is slight. Size and shape vary quite widely but, freshly laid, a typical wanderer egg is oval in shape, with a rough, pitted surface and a chalky patina. It weighs about 490 grams and measures about 130 x 80 millimetres, with a volume of about 450 cubic centimetres. It is generally plain white in colour, though often with a faint dusting of pale reddish-brown freckles, blotches or dots. Smaller species lay correspondingly smaller eggs (a typical yellow-nosed albatross egg, in comparison, measures about 96 x 63 millimetres and has a volume of about 180 cubic centimetres) but, in general, an albatross egg weighs about 6–10 per cent of the total body weight of the bird that laid it. The egg soon becomes stained, marked and scuffed with mud or vegetation stains through contact with the nest and the brooding adult.

Early researchers examined the question of whether or not, should an egg be lost through accident or predation, it is replaced, as is the case in many other birds (but not among tubenoses). Given that the egg takes more than a month to form, it seems unlikely, but several observers stated unequivocally that it is replaced – in one case the assertion was within five days. In his study of the breeding behaviour of the two sooty albatrosses on Marion Island, A. Berruti confirmed that lost eggs are not replaced in these two species. In any event the anomaly seems never to have been rigorously examined.

Incubation

Albatrosses share incubation duties more or less equally, brooding in alternate shifts typically lasting a week or two at a time. But statistical analysis of pooled incubation data from many breeding pairs over several seasons has uncovered slight differences, even within the same colony. In the case of the wanderer, for example, the male's share (summed over all shifts from laying to hatching) consistently exceeds the female's by several days. One early study by John Croxall and C. Ricketts (1983) of the incubation behaviour of 111 pairs of wandering albatrosses on South Georgia, for example, yielded extremes of 22–68 per cent for males and 32–78 per cent for females. The female nearly always takes the first shift, but unless the male happens to be away at sea when the egg is laid (in which case she will incubate till he returns), her first shift may only last an hour or two, or even just a few minutes, before the male takes over. His first shift typically lasts some 10–15 days, until the female returns from feeding at sea to relieve him for the next shift, which is often a day or two less in duration. Subsequent shifts by either sex tend to become progressively shorter as incubation proceeds, though only on average and by a very small amount. Because wanderer eggs take a little under 80 days to hatch, the fact that each individual shift lasts around 10 days means that a total of seven or eight shifts (by either sex) is normally required for incubation, but even this may vary – known extremes for wandering albatrosses at South Georgia, for example, extend from 4–14 shifts, and for royal albatrosses in New Zealand from 6–19 shifts.

This is assuming that all goes according to plan. Perhaps one partner deserts or abandons the other. Albatrosses go to unusual lengths to establish stable and reliable bonds before embarking on a breeding attempt, so such desertions are rare. But they do happen. Or perhaps the absent partner meets with some sort of accident at sea, preventing his or her return. Or perhaps the egg proves infertile, and can never hatch. In such cases the brooding member of the pair usually remains with the egg until hunger or thirst compels abandonment. One case is known of a female wanderer at South Georgia, for example, whose partner happened to be at sea when she laid her egg, and failed to return. She incubated her egg for 20 days before abandoning it. Even greater extremes of commitment are on record here and there among albatrosses in general across the entire distribution of the family. Widowed or abandoned, one Laysan albatross at Midway remained on her egg for 50 days before yielding to the inevitable.

While an albatross incubates its egg it has no access to either food or water, so it steadily loses weight. In the case of the wanderer, incubating males lose about 85 grams per day whereas females lose about 80 grams per day. In both cases this equates, approximately, to 1.1 per cent of average weight (at the start of incubation). Intriguingly, male wanderers regain weight at sea more efficiently than females do. In a typical wanderer nesting attempt, assuming the egg successfully hatches after a typical incubation lasting 78 days, the typical male wanderer will spend a total of 42 days of that span on the egg and the remaining 36 days at sea. He loses weight on the egg at the rate of 85 grams per day, but regains it at sea at an average rate of 135 grams per day. The typical female on the other hand, might spend only 36 days on the egg, losing 80 grams per day, and the remaining 42 days at sea – but she regains it at only 75 grams per day. In short, most females end up barely breaking even in weight over the incubation period, whereas males often emerge from the same ordeal a whopping kilogram or more ahead of the game.

Hatching

Wanderer eggs take 78–79 days to hatch; smaller albatross species a correspondingly shorter time, down to around 60 days in the case of the waved albatross on the Galapagos. It takes the emerging chick several days to chip away at the shell until it has created a hole big enough to scramble out of. The parents offer no assistance, and the broken shell is kicked aside and discarded.

Brooding

When it first emerges, the albatross chick is covered with pure white down, but is more or less helpless. At first its metabolism is not sufficiently developed to sustain its own body temperature. Exposed to rain or storm, it will quickly get chilled and die, and so it must be brooded to keep it warm, more or less constantly for the first couple of weeks, somewhat more casually thereafter as its own thermoregulatory system steadily matures. As well, it is extremely vulnerable to predators such as skuas, so it must be constantly guarded by its parents. This brood stage lasts four to five weeks or a little longer, but by six weeks of age the chick can safely be left to its own devices, leaving both parents free to go to sea and forage for it.

At hatching a wanderer chick weighs about 400 grams. It is not fed for the first day or two, but tends to gain very little weight for the first few days even when it is fed, so the growth spurt generally doesn't truly kick in until after the first week. Thereafter it gains weight very rapidly, often passing the one-kilogram mark by the end of the second week. By the end of the brood stage at six weeks it has typically doubled its weight again. Some individuals may weigh three or even four kilograms at this point. As well, by the end of the brood stage, the sparse white down the chick wore at hatching has been replaced by a denser, pale grey coating of down. Through the provisioning stage there is generally a steady decrease in the frequency with which the parents visit to feed it, from every few days at first to only every week or so as it nears fledging – but there is also a marked tendency for manipulation of the payload, so to speak, in such a way that the quantity of food delivered, averaged out on a daily basis, remains remarkably constant.

Assuming average conditions (some seasons are, of course, better than others), a wanderer chick's weight peaks at about the 255th day after hatching, at which point some may weigh as much as 15 kilograms (although 11–12 kilograms is more usual) – far in excess of the average adult male weight of around 10–12 kilograms. From this point on the parents markedly reduce their rate of food delivery, with much smaller feeds delivered much less frequently (that is, the mean provisioning rate drops from somewhere around 265 grams per day to around 150 grams):

the chick accordingly loses weight (at around 100 grams per day) until, when it ultimately fledges some six or eight weeks later, it weighs more or less the same as an adult. Nevertheless, among albatrosses there is no definite desertion, as occurs in many other seabirds, and it is far from unusual for a chick to be fed the day before it fledges. During the growth stage a chick often endures fasts lasting up to 14 days or so, but after reaching peak weight it is seldom left unfed for longer than a week – even though the size of the meal may be very small. In all, at the last feed, a typical wanderer pair will have caught, transported and delivered a grand total of some 70–80 kilograms of food to their chick, a herculean provisioning feat nearly unmatched among birds, whether reckoned by distance travelled, duration of effort or sheer weight of material transported.

Parental care comes in many forms apart from the obvious one of feeding: other baby birds elsewhere in the world may be guided, guarded, escorted, educated, shaded from the sun, sheltered from the rain and so on. Not so with albatross chicks. Once the chick can safely be left alone, both parents devote their energies almost entirely to the sole task of finding enough food for it. Now and then a returning parent might rest companionably beside its chick for an hour or two after delivering its cargo, but that is very nearly the extent of direct parental care. The results of many studies indicate that parental energy expenditure varies with the task: wanderers, for example, work about 10 per cent harder provisioning a chick than while incubating the egg.

In 2004, Scott Shaffer had a somewhat different approach in a study based on a pair of wanderers on the Crozets. He found that, all up, a pair of wanderers invests a total of 2733 megajoules in rearing their single chick to independence, and they need to sustain an average intake of 1.7 kilograms of food per bird per day for the duration (an earlier study on Marion Island had arrived at a figure of 2263 megajoules per pair per year). This averages out at about 4130 kilojoules per day for a typical male and 3548 kilojoules for a typical female. (He also extrapolated his data to suggest that the entire wandering albatross population on the Crozets consumes something of the order of 340 metric tonnes of food per breeding season.)

A number of factors influence the rate at which the chick gains weight. Studies have detected statistically significant variations between colonies, and from one season to the next. Interestingly, however, among wanderers, parental experience has negligible influence. In one study carried out on wanderers at the Crozets in 1985–1986, for example, the researchers Benoît Lequette and Henri Weimerskirch divided their subjects into three parental categories: naive, moderately experienced and very experienced, and compared chick growth rates between their three samples. The only differences they detected were restricted to the first few weeks after hatching, when chicks of first-time parents lagged perceptibly in development relative to those of more experienced parents. Meals tended to be larger but much more erratic in delivery, so the chicks didn't do as well at first. But within weeks the naive parents had, so to speak, got the hang of it, their chicks rapidly caught up with their more advanced fellows, and after a month or so there were no detectable differences between the three samples. Nevertheless, older females tend to lay larger eggs than young females. These eggs, which take correspondingly slightly longer to incubate, yield chicks that weigh somewhat more at hatching. Mollymawks appear to differ in this respect, conforming more closely with most other birds; at least among black-browed and Buller's albatrosses, the chicks of naive parents have markedly lower survival than those of experienced parents.

For several successive years in the 1990s, Nicolas Huin and his collaborators studied the provisioning and growth of both black-browed and grey-headed albatross chicks on South Georgia. Each breeding season, about 10 chicks of each species were transferred to artificial nests incorporating an automatic weighing device that logged each chick's weight every 10 minutes from the time it was first left alone by its parents until it fledged. The parents were likewise fitted with radio transmitters that logged arrival and identity. The resulting data set included nearly one million weighings and the delivery of more than 5000 meals (including which bird delivered them).

In both species, both parents delivered roughly equal cargoes, except in poor seasons, when the male's share increased relative to the female's. Lumping together all data for all years of the study, black-browed albatross chicks were fed on average every 1.22 days with a meal weighing, on average, 569 grams, and grey-headed albatrosses were fed every 1.26 days with a meal weighing 616 grams. Black-browed albatross chicks reached their maximum growth rate of 42 grams per day at the age of 26.8 days, whereas for grey-headed albatross chicks the corresponding values were 37 and 30.3 respectively. In both, meal size climbed steeply at first, peaking at 45 days in the grey-headed albatross but extending to 75 days among the black-brows; black-brow chicks reached their peak weight at about 88 days but grey-headed albatross chicks not until about 103 days; thereafter chick weight, feeding frequency and meal-size all declined gradually until fledging at about 116 days (black-browed albatross) and 141 days (grey-headed albatross) respectively. Overall, grey-headed albatross success was more consistent from year to year than that of black-browed albatross, a result most plausibly linked with the fact that the former rear their young on squid whereas chicks of the latter are fed mainly krill. As a food resource, squid is scarcer but the supply is reliable relative to krill, which is abundant in good years but fluctuates far more erratically from year to year. Meanwhile, April Hedd and her collaborators were carrying out a similar study, using a similar protocol, on the shy albatross at Albatross Island, Tasmania. Their chicks were fed, on average, meals weighing 372 grams every 0.92 days, reaching a peak weight of 5.5 kilograms at 109 days, before finally fledging at 127 days weighing five kilograms. Although the researchers on South Georgia found marked variation in available food supply between years, there was little evidence of this at Albatross Island. The growth or development curves for each of the three species studied was quite different, but perhaps the most striking feature of the results was the abundant indications of consistent matching of parental effort with their chick's needs, right through the process (in one case, for example, when a male's performance temporarily lagged, his mate boosted her performance to compensate). In short, albatrosses rear their chicks in a far from haphazard manner.

The general impression, evident throughout the breeding process, that it is an extremely difficult task to produce a young albatross, and can only be done if the parents (wittingly or unwittingly is beside the point) follow the recipe exactly, is perhaps nowhere more evident than in the development of the primary wing feathers. The primaries are those large feathers towards the tip of a bird's wing, and absolutely critical to flight (if anything else is missing, the bird can often still manage to hobble along in the air somehow, but if the primaries are missing, it's grounded). The growth of the primaries is the final event before fledging (if they grew before needed, they might become damaged or severely abraded in the rough and tumble of colony life). They take about 150 days to grow, at a little over four millimetres per day. But they don't grow evenly, especially in the case of the outermost four primaries (technically referred to as p7, p8, p9 and p10, p10 being the outermost) and especially in the critical final few days before fledging. When this point is reached, the growth rate of p7 and p8 falls to zero (they're fully grown), p9 falls to 0.1 millimetre per day, while p10 continues at 0.5 millimetre per day. In other words, the entire process is precisely orchestrated to ensure the wingtip is finished last, nearly exactly on the day it's needed.

When small, the albatross chick does very little but huddle on its pedestal nest awaiting the next meal. Later, especially in the final couple of months before fledging, it becomes very active, exercising, stretching and flapping its wings, and generally exploring its surroundings. It may wander 100 metres or more from its nest, easily finding its own way home at any hint the next meal may be imminent. It may interact socially with neighbouring chicks. Some even build their own nests. But in the final days before fledging it spends more and more time facing into the wind vigorously flapping its wings, practicing take-offs. Sooner or later a gust of wind proves especially fortuitous, practice becomes the real thing, and the chick finds itself airborne. Clumsy and inept in the air at first, it is quite likely to land in the sea just offshore, where it may bob about on the surface for several hours. But ultimately it gets its act together, and takes off again for the open ocean. It may be five or six years before it returns, during which time it may never be even within sight of land.

In the case of the wandering albatross, the timing and duration of the whole nesting process is such that adults have already begun arriving at the colony to begin their next breeding attempt, several weeks before the chicks from the previous breeding season are finally ready to leave. In other words, despite synchronicity, there is a marked overlap between one breeding season and the next, and a large colony is seldom entirely deserted. This also means that, by the time any particular wanderer pair is completely done with rearing their chick, it is already too late in the current season to begin the process of rearing another. They are left with no alternative but to take the rest of the year off, as it were, and resume their own particular breeding program by rejoining their fellows at the colony the next following season. If their egg should prove infertile, or their chick is lost for any reason before fledging, then a wanderer pair, more likely than not, will try again the following year, but otherwise wanderers, as well as royals and a couple of other species, are constrained to breed on a two-year cycle, not annually like almost all other birds.

The foregoing account refers mainly to the wandering albatross, but not a great deal changes by the substitution of any other species. True, almost every species has some special feature that influences the strategy in some way, subtly or otherwise. Sooty albatrosses, for example, typically nest on cliffs rather than plateaux, which means they tend to nest more in scattered pairs than in discrete colonies, which in turn modifies social structures. Similarly, both the Galapagos albatross and eremita in the Chathams are effectively confined to very small stretches of ocean, which in turn has obvious repercussions on provisioning strategy – food-hauling is a positively local affair compared to the enormous distances wanderers must deal with. The black-footed albatross on the outlying islands of Hawaii nest on very low-lying sand cays in tropical waters. Here even relatively mild storms during the incubation and brood stages can have catastrophic effects, smothering large numbers of eggs and chicks alike in mounds of wind-blown sand. No other albatross has to contend so frequently with such severe losses so early in the nesting cycle. Moreover, low terrain and fitful breezes routinely hamper the fledglings on their first flight, meaning many barely make it to the shallows beyond the surf line, where sharks lie in wait to gobble them up. Again no other albatross contends with such heavy predation pressure (other albatross chicks elsewhere may succumb to disease or starve to death, but they seldom get eaten).

Provisioning

Provisioning is the term ecologists use for the entire process of finding, transporting and delivering enough food to the chick to enable it to grow at an optimal rate and to deliver it safely, in the minimum practicable time, to the point where it can fly off and find its own food. Success is a young bird disappearing over the horizon. Any other outcome is failure. It’s most useful to work out what would be the optimal strategy to achieve this outcome, then analyse the bird’s behaviour to discover how far it deviates from the model. For example, to deliver food at a rate less than the chick’s needs is an obvious recipe for disaster, stunting the chick’s growth and ultimately – if the inadequacy is sustained – resulting in starvation and death. On the other hand, delivery faster than the chick can utilise it might be nearly as bad. At best it’s wasteful, but it also might tend to magnify peripheral risks. Worst of all, the chick might end up obese, and so heavy that when the time comes to fledge, it might be unable to fly. There is some evidence that this happens on occasion in albatrosses, and at least one research project is currently under way exploring the implications of this point. It might seem to matter little: surely the chick can simply sit there on its nest and wait until it sheds enough weight to reach take-off trim (and this does indeed happen on occasion in some species) but, on the other hand, while it’s on its nest it’s effectively helpless, and each day’s unnecessary delay is one more day of exposure to the risk of attack by disease, parasites or predators, or to being overwhelmed by storm, sunstroke or some other kind of severely inclement weather.

An adult wanderer feeds a hungry chick. By the time this chick can fly off to find its own food, its parents will have captured, transported and delivered a grand total of nearly 80 kilograms of squid.

Nesting albatrosses are relatively easy to study. The discomforts and logistical difficulties of transporting personnel and equipment to colonies far across gale-wracked oceans are formidable, but the birds themselves present fewer problems than many another bird that might be cited. They are big enough that there is little real risk of harm. Though sometimes testy, most are normally tame and unexcitable. When handled, they don’t panic, they don’t struggle madly and they show no sign of distress when the procedure is over. A range of studies have been conducted to explore any relationship between observer interference and breeding success among many species in many parts of the world, and the consistent result has been that there is little evidence that normal handling has any effect on either chick or adult. Indeed, there is a story – perhaps apocryphal – that Peter Prince, the doyen of early albatross researchers, while working with his birds on South Georgia in the 1970s and 1980s, had been known to slip a bottle of beer alongside the egg of one of his more amiable incubating subjects as he began his day in the field, so that by lunchtime the beverage might be brought to that temperature that, as everyone knows, the true Englishman prefers to savour his beer.

8

HUMAN IMPACTS

Doubtless for centuries, or even millennia, Japanese fisherfolk have raided island colonies of Steller's albatross for food, feathers and bait. Remains of this albatross are found in ancient middens along the Pacific coast of North America. Similarly, there must surely have been some predatory impact of early Polynesian peoples on albatrosses in the Hawaiian region. But otherwise virtually every albatross breeding island in the world was uninhabited or even undiscovered by humans before the tide of European exploration, exploitation and imperialism swept across the globe, beginning in the 1500s. Thus human impact on the fortunes of any of the albatross species was negligible before that time, and largely remained so until the first whalers, sealers, settlers and explorers began penetrating the Southern Ocean in the late 1700s and early 1800s.

At first the plunder was mainly for food. Eggs, chicks and even adults were seen as a welcome addition to the seafarers' diet, as well as that of early settlers. Very little was documented about this early harvesting. Nevertheless, contemporary accounts record that albatross eggs and flesh were sold in the markets of Cape Town, South Africa, in the early years of the nineteenth century. It is also in historical records that harvesting of the great albatross colonies of the Falklands began soon after those islands

'Warm reception that ye first albatross met with'. A contemporary sketch by Edward Moore portrays a contemporary fad amongst bored migrants on sailing vessels during long voyages from England to Australia in the 1850s, as sportsmen gather on the poop deck to blaze away at albatrosses accompanying the vessel. Courtesy of the National Library of Australia.

were settled by the British in 1765. A century later, sealers were active at southern islands as far-scattered as South Georgia in the South Atlantic, Macquarie Island south of Australia, and Campbell Island south of New Zealand, and at all these places albatross colonies were persistently raided for food. Even as recently as 1926, it is on record that the small settlement on Tristan da Cunha harvested some 4000 adults from the albatross colonies there, and such raids persisted at least into the 1960s.

Some of this early destruction had nothing to do with food. Through much of the nineteenth century large numbers of emigrants were ferried from English ports to Australia and New Zealand. These migrants spent months at sea in the Southern Ocean with nothing to do – until someone discovered that a baited hook could be used to snag an albatross. The difficulty of bringing it aboard, according to contemporary comment, was reminiscent of the noble struggle of landing a salmon. A fashionable 'sport' was born. In later years, groups of 'gentlemen' would forgather on the poop deck of vessels traversing the Southern Ocean, armed to the teeth with pistols, shotguns and rifles, blazing away at albatrosses accompanying the ship. A remark extracted from an anonymous contemporary diary conveys something of the flavour of this unusually shabby episode:

> We had an interesting discussion at lunch, whether it was justifiable to shoot those birds merely for wantonness and amusement, when it was impossible to reach them after they were dead. I had only Mr. Otterson and Mr. Barnicoat on my side of the question, so it was agreed by the sportsmen that they were justified to continue the sport if only for practice. (ca. 1845, quoted in Fell, 1973)

The damage wreaked on albatrosses, especially the wanderer, was considerable. There were almost certainly other factors involved; nevertheless, the contrast in contemporary accounts before and after is striking: wanderers were often described as ‘abundant’ in the early 1800s, but ‘sadly depleted’ by around 1870.

Towards the end of the nineteenth century, the worst of the depredations of the whalers and sealers began to abate, and with this the raids on southern albatross colonies eased. But then a new threat emerged. The body plumage of albatrosses yields soft, light down with excellent insulation properties, ideal for stuffing pillows, futons, doonas, parkas, sleeping-bags and a wide range of similar bedding and clothing items and cold-weather survival gear. Exploitation of the ‘cottage industry’ type arose, especially in Japan, and became especially well organised towards the close of the nineteenth century. Activity peaked around 1890–1910. By no means limited to the North Pacific, the trade also affected many of the albatrosses of the Southern Ocean. The shy albatross colony on Albatross Island off Tasmania, for example, originally described as ‘huge’, was reduced to a mere 250 breeding pairs by 1909. Similarly, the black-browed albatross colonies on Macquarie Island may have been completely wiped out by sealers or plume hunters – they were not recorded breeding there until 1946, and it remains unknown whether this was a new colonisation event or a rebuilding of much earlier colonies. Nevertheless, the albatrosses of the North Pacific bore the brunt; in fact one, Steller’s albatross, was driven to the brink of extinction.

At one time, this albatross was abundant, nesting on a number of islands in the Bonin, Pescadores, Senkaku, Izu and Daito groups in the neighbourhood of Japan. By around 1900, harvesting for feathers seems to have extirpated it on all but Tori-shima, one of the southernmost islands of the Izu group. An active volcano (major eruptions occurred in 1902 and 1939), Tori-shima is a caldera about 2.5 kilometres in diameter. In the 1880s it was visited by the Japanese ornithologist T. Hattori, who estimated the albatross population at about 100 000 birds, but when another Japanese ornithologist, Y. Yamashina, again visited the island in 1929, the colonies contained only 1400 albatrosses. Ten years later, in 1939, a survey party from the Yamashina Institute of Ornithology could find only 30–50 birds. A Japanese naval garrison of about 300 occupied the island throughout World War II; the fact that in 1945 a sailor evidently thought it worthwhile reporting to his superiors a 'large white bird' on the island might indicate that the albatrosses had already abandoned their last remaining colony. A visit in 1949 failed to record a single bird, and Steller's albatross was considered extinct. A population of several hundred thousand birds had been wiped out in less than half a century. Contemporary accounts asserted that, in a span of less than two decades, a grand total of five million birds had been destroyed for their feathers.

Happily, that grim assessment turned out to be, as Mark Twain so famously put it, greatly exaggerated. The Japanese naval garrison was withdrawn at the close of hostilities in 1945, but it was promptly replaced by a permanent team of meteorologists attached to the Tokyo Weather Bureau, who reported 'a few pairs' nesting in 1946. A survey in 1956 counted 12 pairs, and another in 1964 counted 26 pairs. The weather station was abandoned in 1965 because of renewed volcanic activity, and the island was subsequently left uninhabited. It was declared a Natural Monument by the Japanese Government in 1961, and vigorous protection, rehabilitation and conservation measures put in place to rebuild the albatross population have been sustained ever since. There are now well over 1500 pairs breeding on Tori-shima, and attempts are being made to establish small 'start-up' colonies elsewhere in the Izu chain.

As albatross stocks were decimated on islands close to Japan, the plume hunters shifted their attention eastward, to other albatross colonies on Midway, Laysan, Lisianski, French Frigate Shoals, and several others of the minute, low-lying reefs and islets that lie in a wide-scattered arc extending some 1200 kilometres north-westwards from Hawaii. Here there are two albatross species – the black-footed albatross and the Laysan albatross – which both, like Steller's albatross, nest in large dense colonies that are highly vulnerable to raids from plume hunters.

One of these islands, Midway, is notable for the contrast between its physical presence – little more than a heap of sand in the middle of the vastness of the North Pacific – and its influence in human affairs in the first half of the twentieth century. It first came to prominence around 1900, when it was selected as a way station on the telegraph cable link between Asia and the United States. Its importance continued through the 1930s, in the early days of trans-Pacific commercial flights from San Francisco and Los Angeles to destinations in Japan, China and Australia. A refuelling point was needed midway; Midway was selected, and became for a time a busy airport. But it wasn't until the 1940s that things really started heating up. Midway was selected as a base for both the US Coast Guard and the US Navy. After the Japanese attack on Pearl Harbor, Midway became, almost overnight, of pivotal strategic importance as a major supply base for naval operations in the Pacific.

The trouble was, Midway was already a major base – for the Laysan Albatross. Something close to one million birds nested on the island. They nested everywhere, including the approaches to the vast runways needed to safely land massive cargo aircraft. Albatrosses are far from agile in the air, especially when landing or taking off, and collisions with aircraft or airfield equipment and infrastructure quickly became an almost daily affair. Casualties were heavy on both sides. Thousands of albatrosses were killed as the planes landed or took off, and the resultant damage to aircraft was deemed unacceptably high. The US Navy declared war on the 'gooney birds', and over the ensuing decade or so almost every conceivable tactic short of outright slaughter was used to reduce the damage to expensive military assets.

> Various experiments were set up in an effort to get rid of the gooney birds without slaughtering them. Hoping to annoy them enough to make them leave voluntarily, smoke curtains were blown over colonies, without result. Stinking truck tyres were burned near nesting birds, which merely shuffled their eggs. Mortars were fired; bazookas blasted. The gooney birds barely blinked an eye and kept on dancing. Ultra-high sounds were tried out. They were as unsuccessful as the taped distress calls that followed. (Lanting 1988)

It took several years before it was finally accepted that the albatrosses could not be induced to leave of their own accord, so the next step was to try relocating them forcibly. In early trials of this approach, albatrosses were captured, taken to far-flung locations across the North Pacific, and released. Most of them very nearly beat the transport planes back home to Midway, resuming their nesting duties as though nothing had happened.

Even immature birds showed extraordinary homing abilities, and returned promptly to Midway. Finally a barge was loaded with some 2000 nearly fledged albatrosses, and the barge then towed to Lisianski Island, some 400 kilometres from Midway, and the birds released. Almost all returned to Midway.

Stalemate. Finally, it was noted that the albatrosses seldom strayed onto the runways themselves, so a broad swathe of hard-standing was laid down on either side of the main runways – effectively doubling their width – and this proved successful, or at least reduced bird strikes to a manageable level. 'Gooney bird' patrols were instituted, sweeping the runways before every take-off and landing. Any stray birds on the runway were carefully gathered up, put in the back of a pickup truck, and taken away to be released in some less sensitive part of the colony.

Midway became for a time both a bustling naval supply base and a wildlife refuge, and the albatross was fully protected. Standing orders and even local traffic ordnances dictated that albatrosses had right of way in all circumstances and at all times. The birds nested all across the island, in back gardens, in public parks and on golf courses. For several decades people and albatross coexisted in an extraordinary meld of ordinary American suburbia and thriving seabird colony.

This state of affairs lasted more or less intact until the US Navy withdrew from the island and it was handed over to the US Department of the Interior by presidential decree in the 1990s. The island was declared a Wildlife Refuge, and ecotourism is now the sole human involvement with Midway.

By somewhere around 1980, direct human predation on the world's albatrosses had become largely a thing of the past, or at least reduced to negligible levels. The crews of fishing vessels still occasionally kill albatrosses for food, and no doubt some small-scale illicit raiding of albatross colonies for their eggs still occurs, perhaps in the Falklands or on Tristan da Cunha, but on currently available evidence it seems reasonable to conclude that, if it occurs at all, this plunder is at a level unlikely to threaten the long-term survival prospects of any albatross population.

But there are several forms of indirect adverse human impact on albatross populations – two in particular – that call for concerted and far more urgent attention.

The first of these revolves around the damage caused to albatross colonies by introduced domestic animals – pigs, cattle, goats, cats, dogs, rabbits, mice, rats and so on. Most islands where albatrosses breed, in the Southern Ocean or elsewhere, have had at least one, usually several of these intruders, brought to the island by human agency in the early days of exploration or exploitation, and subsequently left to thrive in a feral state. Here the details of the threat vary widely from species to species and colony to colony. On Amsterdam Island, for example, the adverse impact on the local albatross (the critically endangered amsterdamensis) comes from feral cattle, whose trampling both directly destroys nests, and modifies the ground profile in such a way that the albatrosses cannot build new nests. The case on Macquarie Island is somewhat similar, but here the villain is the rabbit, not cattle. Feral cats take albatross chicks, rats eat eggs (and occasionally small chicks), and on The Snares in New Zealand only albatross colonies in those parts of the islands inaccessible to feral pigs have escaped severe damage from the rooting, grubbing, wallowing and predatory activities of this unusually destructive domestic animal. On Gough Island in the Atlantic the villain is the ordinary house mouse, which has been implicated in the deaths of young chicks of the dabbenena population of the wandering albatross.

The case of the cattle on Amsterdam, incidentally, offers an unusually vivid example of the importance of knowing in great detail the biology of a threatened species before wildlife managers come along to try and preserve it, and it hinges on a detail that might seem at first sight absurdly trivial. Most of us have seen a sparrow or a starling or some other local bird carry a twig or a blade of grass from some distant part of the garden to its nest and weave it into place. Among birds, nest-building is often a cooperative affair, the labour divided so the male fetches and carries material, the female decides where it will go. Sometimes it's the other way round, but some variation of this pattern applies to a wide range of birds everywhere. That is, except for albatrosses. You might say the genetic programming for nest-building among albatrosses does not include the concept 'carry'. Albatrosses use vegetation in nest-construction, but they don't carry it – it has to be within reach of the builder as it sits on its nest. The problem on Amsterdam is that the cows like to feed in exactly the same places the albatrosses like to build their nests, with the result the grass right there gets eaten up leaving none for the birds to build their nests with. It's a little more complicated than that, but that's the essence of the problem, reduced to a television sound-bite.

Even here there is some room for optimism. With a couple of conspicuous exceptions, most of these threats have now been contained, or very soon will be. The damage by mice on Amsterdam remains of concern because the threat may be acting on other islands as well, and it is not entirely clear how it might be curtailed. The situation on Macquarie Island was of serious concern because, although a management plan had been formulated, and the necessary expertise and technical resources brought together, implementation had become bogged down in bureaucratic red tape that in the end came down to a dispute over whether the bill would be paid from state or federal funds. However, this difficulty has now been resolved, and the eradication program is scheduled to begin in 2009.

But the worst threat of all was yet to come. For a century or more fishers in northern Europe have been using a technique for catching bottom-living fish that involves paying out a very long line from the stern of a vessel underway. Hooks, weighted and baited, are fixed at intervals along the line as it is paid out. Somewhere around 1950, Japanese fishermen modified this basic concept to include a flotation device designed to suspend the line some 50 metres or so below the surface rather than on the bottom, and began using the resulting rig to catch tuna on the open ocean. 'Long-lining' was born, and quickly became established as one of the core techniques by which the world's commercial fishing fleet went about catching its fish. At first the technique was used mainly in the North Pacific; but after some small-scale trials during the 1950s its use became widespread in the Southern Ocean from around 1960. At first Japan dominated long-lining, but other nations quickly joined the long-lining fleet through the period 1950–1980: Taiwan, Korea, Russia, America, South Africa, Chile, Argentina …

In a typical modern rig, the line is about 100 kilometres long, with hooks attached regularly a few metres apart, totalling some 2500–3000 hooks in all. When a long-line is 'set', a winch pays out the line, a deckhand baits each hook in turn – at a rate something close to 10 per minute – and tosses it far astern. Dragged under by the combined weight of the paid-out line and the hooks already tossed, each hook quickly sinks to its intended depth. But there is a brief but critical interval while it does so. If you follow very carefully the trajectory of the hook as it leaves the deckhand's fingers, it is possible to visualise each hook in a sort of conceptual 'box' some 10 metres high, 10 metres wide and perhaps 50 metres long, in existence for perhaps 10, 20, maybe even 30 seconds. This 'box', it turns out, is the killing zone for albatrosses.

As the long-line is set, the activity attracts seabirds by the score, who throng in the wake just astern of the vessel in a mad scramble to steal the bait from the hook before it sinks. Most of the seabirds are small species, sufficiently nimble that the hook itself poses no great threat. But the excited melee also attracts the much larger albatrosses, that swoop and snatch from above, or settle nearby and aggressively bull their way through the throng to grab the bait. In the confusion, the albatross may swallow the hook, or it may snag in the open bill. Or as the vessel heaves and wallows, the albatross may simply become wedged between the line and the surging sea. No matter the details, the end is all too often the same: the albatross is dragged under and drowned.

And the grand total of hooks set per year by the world's long-liners was, at its peak, something of the order of 100 million …

In the South Atlantic during the 1993–1994 season, one study reported an average mortality rate of 4.7 albatrosses per 1000 hooks. Another cited a grand total of 7500 albatrosses killed in New Zealand waters alone between 1987 and 1994. From all parts of the Southern Ocean, similar studies were undertaken, and all reported roughly comparable mortality rates. Worldwide, at its peak, and across all species, the catastrophe may have approached 50 000 drowned albatrosses per year.

For decades this appalling and futile slaughter went undetected, at least by the world at large and seabird specialists in particular. It seems to have reached a peak somewhere around 1980, but the link with the catastrophic decline in albatross populations was not established until around 1990.

The earliest hints were when the bodies of a few albatrosses banded in Hawaii began to trickle in to wildlife authorities via the Alaskan long-line fleet, but it was perhaps most thoroughly documented in the activities of a group of albatross enthusiasts operating from Bellambi, a small town near Wollongong in south-eastern Australia. The activities began around 1950, when Doug Gibson, the founder of this group, first caught a wandering albatross, fitted it with a small numbered metal band around one leg, and released it. To everyone's astonishment, the bird returned to Bellambi the following year. In the years immediately following, more bands and more recaptures resulted in more returns, and a database tracking the progress of known individuals through many successive years came into being. This database was to prove of crucial importance to basic albatross research in the decades that followed, as Doug recruited fellow enthusiasts, developed his procedures and set up the beginnings of an organisation to further the research. (Doug Gibson died in 1984, but the organisation continues under the aegis of several like-minded enthusiasts including Lindsay Smith, Janice Jenkin-Smith, Harry Battam and a number of others.)

The early returns themselves went far in establishing that at least some elements of some populations of wanderers are migratory; not all are nomadic as had previously been assumed. The fact that, at one time or another, representatives of nearly all of the various island populations of wanderers have shown up at Bellambi, to be caught, marked, measured, weighed and carefully examined before release, has itself shed new light on the movements and population dynamics of wanderers. Another of the early successes of this particular group lay in sorting out, once and for all, the bewildering complexities of wanderer plumage states as each bird moves from adolescence to full maturity (a process that in wanderers takes more than a decade – and each year is different). This monitoring station off the coast of New South Wales remains to this day the only one in the world away from the nesting grounds. Today, the wintering population of wandering albatrosses on the seas off Bellambi remains under scrutiny after more than half a century of careful, systematic study.

But more immediately relevant to the disaster that was overcoming the wanderer was the significance of the Bellambi station as a monitoring site. In the early years of its establishment, the group was catching and releasing several hundred albatrosses per year. Then in the decade 1984–1994, numbers plummeted from hundreds to a mere dozen or so. The early years were characterised by scores of birds that returned regularly to Bellambi year after year, to be recaptured, re-examined and released; in the 1980s and 1990s this pattern was replaced by one in which solitary birds were banded and let go, never to be seen again. In the early years, juveniles were abundant off Bellambi; nowadays decades may pass between visits by very young birds.

Plainly, something very bad had happened, but at the time it was far from clear exactly what.

> Nigel Brothers, of Tasmania's National Parks and Wildlife Service, was perhaps most intimately involved in tracking down the mystery killer, devising a solution, and persuading all involved to adopt it. Nigel had his own suspicions as to the cause, and was one of the earliest to sound the alarm. He spent months at sea on tuna-boats, working alongside the deckhands, to see for himself exactly what was going on and work out what to do about it. (Lindsey 1996)

One of the most effective devices, he discovered, is simplicity itself. A long, banner or ribbon-like streamer snapping in the wind astern disconcerts the albatross just enough to keep it from settling. A number of other effective mitigation measures have been developed since. Nigel himself invented a mechanical 'tosser' that makes the process much more efficient, and further technological improvements pioneered by the Russian fleet make it possible to deploy hooks at about 100 per minute instead of the six-per-minute hand-thrown method used in the early days, which dramatically reduces the opportunity the albatross is given to succumb to its deadly temptation. Even so elementary a move as deploying the line from the side of the vessel rather than from the stern dramatically speeds up the process and reduces the risk. Even shifting to nocturnal operations and banning daylight deployment of long-lines must surely reduce the carnage considerably.

But what will undoubtedly prove the most effective strategy in the long term emerged only gradually with the increasing body of evidence to the general effect that albatrosses don't wander the Southern Ocean at random. It would perhaps be closer to the truth to say, instead, that they have a distinct pattern of seasonal attendance at favoured foraging areas, to and from which they commute along a complex network of trails detectable (so far) only to albatrosses. This raises the possibility of regulating long-lining in such a way that it is conducted only at times and places in which most albatrosses are, as it were, safely on the other side of the ocean. A huge research effort has been directed for some years now at unravelling the details of this intricate mosaic of seasons, places and pathways.

The result of this work has already been a dramatic downturn in wanderer strikes. The probable cause has been pinpointed and a simple solution found, but can it be implemented in time? The problem seems solvable, at least in principle. After all, it is greatly in the fisheries' interest to cooperate from motives of profit, if for no other reason. From their perspective, the situation is a little like buying 100 Scratchie lottery tickets and throwing a dozen of them away unscratched. And the prize on these tickets is $20 000 each, the approximate market value of one tuna unloaded dockside.

Now is a period of uncertainty for those hundreds of albatross researchers around the world, both amateur and professional, who have made enormous professional, personal and emotional commitments to the challenge of finding some way of extricating the albatross from its lethal predicament. The situation is undeniably grave. Of all avian families, Diomedeidae has the highest proportion of threatened or endangered species. Several are critically endangered. Albatrosses live long and breed slowly. Their fecundity is among the lowest of all birds, so that any recovery, even if it comes, must inevitably be excruciatingly slow.

Yet there are grounds for cautious optimism. The threat is uncomplicated, solitary, clear-cut. It seems to have peaked around 1980, and seems to have been declining steadily, if slowly, ever since. In the Australian–New Zealand sector, for example, the Japanese tuna fleet alone set 32 million hooks in 1989, but by 1997 the annual total had fallen to eight million. A single, simple threat is diffused across dozens of nations, scores of fishing fleets, thousands of vessels, hundreds of millions of individual, potentially lethal incidents, so the administrative, logistical and technical difficulties inherent in any solution are huge – but at least compliance is not quite the hurdle it proves to be in nearly every other threatened species situation. No-one profits from a drowned albatross.

Evidence is accumulating to suggest that albatross populations may be more resilient than earlier suspected. ‘Archaeological’ studies hint that several species may have survived comparable disasters in the distant past. Several important colonies are presently showing disturbing downward trends, but several others have been increasing steadily, if slowly, for a decade or more. The total number of breeding pairs of Steller’s albatross has been rising steadily at around seven per cent per year since rediscovery in 1946 – despite widespread long-lining in the North Pacific.

But it’s still impossible to predict that these measures are sufficient to turn the catastrophe around, in the long term. Population dynamicists would feel more confident in their predictions if they had a database spanning at least one entire generation of albatrosses tracked from birth to death. It is a sobering reflection that albatrosses are such long-lived birds that even that first milestone has not yet been passed, at least in the great albatrosses. Nor is it known, with any certainty or precision, exactly when it will be reached. Albatross life spans rival that of humans, but nobody knows exactly how close the equivalence is. Even the mollymawks are exceptionally long-lived: the oldest known-age grey-headed albatrosses, for instance, are now 46 years old; it is suspected royal albatrosses and wanderers may reach 70 or even 80 years of age. Even for such long-studied species as the royal albatross in New Zealand and the Laysan albatross in Hawaii, that particular milestone may not be passed until 2020 or thereabouts.

What is certain is that, if humanity is serious in its efforts to sustain this magnificent ocean wanderer through its latest crisis, several decades of commitment, vigilance, diligence and sheer hard work lie ahead.

The ice was here, the ice was there,
The ice was all around;
It cracked and growled, and roared and howled,
Like noises in a swound !

At length did cross an Albatross,
Through the fog it came;
As if it had been a Christian soul,
We hailed it in God's name.

It ate the food it ne'er had eat,
And round and round it flew,
The ice did split with thunder-fit;
The helmsman steered us through !

And a good south wind sprung up behind;
The Albatross did follow,
And every day, for food or play,
Came to the mariners' hollo !

stanzas 15–18, The Rime of the Ancient Mariner,
Samuel Taylor Coleridge, 1798

Taxonomy of albatrosses: species, names and populations

	Diomedeidae (albatrosses)	Genus	Species	Population	Year	Author	Main breeding islands
1	Wandering Albatross	*Diomedea*	*exulans*	*exulans*	1758	Linnaeus	South Georgia, Prince Edward, Crozets, Kerguelen, Macquarie
2				*amsterdamensis*	1983	Roux et al.	Amsterdam Island
3				*gibsoni*	1992	Robertson & Warham	Auckland
4				*antipodensis*	1992	Robertson & Warham	Antipodes, Campbell
5				*dabbenena*	1929	Matthews	Tristan da Cunha
6	Royal Albatross		*epomophora*	*epomophora*	1825	Lesson	Campbell
7				*sanfordi*	1917	Murphy	Chatham
8	Black-browed Albatross	*Thalassarche*	*melanophris*	*melanophris*	1828	Temminck	Falklands, South Georgia, Crozets, Macquarie
9				*impavida*	1912	Matthews	Campbell
10	Grey-headed Albatross		*chrysostoma*		1785	Forster	South Georgia, Prince Edward, Crozets, Campbell
11	Yellow-nosed Albatross		*chlororhynchos*	*chlororhynchos*	1789	Gmelin	Gough, Tristan da Cunha
12				*carteri*	1903	Rothschild	Amsterdam, Prince Edward
13	Shy Albatross		*cauta*	*cauta*	1841	Gould	Tasmania (three offshore islets), Auckland

	Diomedeidae (albatrosses)	Genus	Species	Population	Year	Author	Main breeding islands
14				*eremita*	1930	Murphy	Chatham
15				*salvini*	1893	Rothschild	Bounty, Snares
16				*steadi*	1933	Falla	Auckland
17	Buller's Albatross		*bulleri*	*bulleri*	1893	Rothschild	Snares, Solander
18				*platei*	1898	Reichenow	Chatham
19	Laysan Albatross	*Phoebastria*	*immutabilis*		1893	Rothschild	Hawaii (Midway; Laysan)
20	Steller's (Short-tailed) Albatross		*albatrus*		1769	Pallas	Japan (Tori-shima)
21	Black-footed Albatross		*nigripes*		1849	Audubon	Hawaii (Midway; Laysan)
22	Galapagos (Waved) Albatross		*irrorata*		1883	Salvin	Galapagos (Española)
23	Sooty Albatross	*Phoebetria*	*fusca*		1822	Hilsenberg	Gough, Tristan da Cunha, Prince Edward, Crozets
24	Light-mantled Albatross		*palpebrata*		1785	Forster	South Georgia, Kerguelen, Crozets, Macquarie

This table lists all of the generally accepted populations (here portrayed as subspecies) of albatrosses of the world, together with the author and year of publication of the first formal scientific description, and the locations of their main breeding colonies. Names are not repeated to assist clarity, but should be thought of as continuing down the column until replaced by the next name. The format seeks to clarify a current debate among albatross specialists over the number of species to be recognised as valid. In brief, 'lumpers' regard column three as fully populated, whereas 'splitters' argue that nearly all those in column four should be 'promoted' to full species status and therefore shifted to column three (gibsoni and steadi are often excluded from this proposal). In other words, only the rank is involved in the dispute, nothing else.

Biometrics of albatrosses: population numbers and vital statistics

	Diomedeidae	Species/ subspecies	Population (breeding pairs)	Weight (grams)	Wing (mm)	Tail (mm)	Bill (mm)	Egg (grams)	Incubation (days)	Fledging (days)	Ratio
1	Wandering Albatross	*exulans*	17 000	9780	685	228	169	490	79	278	0.99
2		*amsterdamensis*	40	6970	656	209	146	412	79	257	0.94
3		*gibsoni*	5800	6600	651	202	152		78		0.94
4		*antipodensis*	5100	8300	652	200	151		78		0.94
5		*dabbenena*	4000	7300	627	198	150		78		0.90
6	Royal Albatross	*epomophora*	8500	10 300	695	217	185	425	78	241	1.00
7		*sanfordi*	6800	6800	655	191	169	416	78	240	0.94
8	Black-browed Albatross	*melanophris*	530 000	3710	540	220	119	257	68	116	0.78
9		*impavida*	23 500	3100	525	212	114	230	70	135	0.76
10	Grey-headed Albatross	*chrysostoma*	92 300	3680	534	225	117	276	72	141	0.77
11	Yellow-nosed Albatross	*chlororhynchos*	40 600	2199	500	194	112	212	66	130	0.72
12		*carteri*	36 500	2640	488	197	119	200	71	120	0.70
13	Shy Albatross	*cauta*	12 200	4350	560	222	132		70	130	0.81
14		*eremita*	5300	4000	565	235	122		69		0.81
15		*salvini*	31 400	4000	577	222	129				0.83
16		*steadi*	78 000	4400	605	222	132		69	167	0.87

	Diomedeidae	Species/ subspecies	Population (breeding pairs)	Weight (grams)	Wing (mm)	Tail (mm)	Bill (mm)	Egg (grams)	Incubation (days)	Fledging (days)	Ratio
17	Buller's Albatross	*bulleri*	13 800	3120	600	220	120	246	69	167	0.86
18		*platei*	18 000	2840	522	210	123				0.75
19	Laysan Albatross	*immutabilis*	437 000	2500	490	144	108	278	64	165	0.71
20	Steller's Albatross	*albatrus*	210	6000	550	167	135	348	64	155	0.79
21	Black-footed Albatross	*nigripes*	44 700	3400	515	146	108	304	71	164	0.74
22	Galapagos Albatross	*irrorata*	18 200	3500	560	150	148	284	62	167	0.81
23	Sooty Albatross	*fusca*	21 000	2700	524	275	113	227	70	164	0.75
24	Light-mantled Albatross	*palpebrata*	44 000	3360	522	271	111	243	70	157	0.75

Physical dimensions are based on those of a 'typical' adult male; among albatrosses, females are generally some 5–10 per cent smaller than males except among the various populations of the wandering and royal albatrosses, where the differential approaches 20 per cent. The last column is intended to convey an impression of relative size by setting the wing-length of epomophora (royal albatross) equal to one and expressing all others as a ratio. Caution: statistically acceptable published samples for many of the parameters shown above do not exist; much is based only on scattered individual specimens, with no way of knowing how representative they might be. The presentation is intended only as a crude, 'first-approximation' overview of the vital statistics of albatrosses.

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