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SURVEY OF ORNITHOLOGICAL WORK IN THE INDIAN OCEAN*

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ABSTRACT

The Indian Ocean and its oceanic islands were long neglected by ornithologists, though the writings of early travellers contain a certain amount of incidental information. The first systematic observations on the seabirds were made by Gould and Hutton in particular on voyages from Europe to Australia via the Cape of Good Hope, and on the landbirds by Edward Newton and his friends and correspondents in the last century, and the first observation on birds during the course of larger expeditions during the German 'Valdivia' expedition in 1899, and the Percy Sladen Trust expedition of 1905. Thereafter with only minor exceptions such as the observation by H. G. Alexander of the occurrence of a bird concentration off the south coast of Arabia there was little further work until after the last war.

In the early 1950s the British Royal Naval Bird-watching Society then instituted a sea report scheme, in which its members made regular observations of birds encountered on special forms. These rapidly became popular in the Navy, and soon in the Merchant Marine as well, so that by the end of this decade some scores of reports were available from most parts of the ocean, indicating a rich marine avifauna. When the International Indian Ocean Expedition was being planned the British Ornithologists' Union therefore agreed with the National Institute for Oceanography to send an ornithologist to participate in the British contribution on board RRS Discovery III, and selected Roger Bailey for the post, while several other nations also subsequently arranged ornithological contributions as well.

The main results of this programme of work are a fair understanding of pelagic seabird distribution in the area (poorest in the Bay of Bengal) and identification of areas with an increased bird density—along coastlines and around islands, near the convergences or fronts around 35°S and near the equator when the counter-current is present during the northerly monsoons, in the cool current areas off South Africa and especially western Australia, and where the surface water drifts offshore along the south coast of Arabia, the East Indies/and north-east Australia during the southerly monsoons. It is notable that when the counter-current disappears at this time a number of southern seabirds penetrate further north than is usual in other oceans to feed in the upwelling areas off the continental coasts. The investigation of the oceanic islands at the same time has revived interest in their remarkable endemic birds and drawn attention to the urgent need for further conservation measures, for which there is now growing support throughout the world.

INTRODUCTION

THE early exploration and development of the Indian Ocean occurred before the emergence of ornithology as a science. Hence, while the records of early voyagers tend to be full of references to animals as conspicuous and edible as birds, these lack precision. The leaders of later waves of exploration such as Captain Cook and his French contemporaries tended to pass rapidly through the area taking the first travelling naturalists with them, so that they did much of their best work further on, in Australasia and the Pacific. With a few conspicuous exceptions, therefore, the

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ornithological exploration of the Indian Ocean was carried out by secondary figures, often inarticulate collectors, long after human colonisation had caused major alterations to the natural environment. Ornithologists then tended to become bemused by the traces of past glories such as the giant flightless birds of Madagascar and the Mascarene Islands, and to neglect the less striking but still outstandingly interesting phenomena such as the smaller landbirds and the seabird colonies still visibly diminishing before their eyes. It is in consequence only very recently, and largely as a result of the stimulus and facilities provided by the International Indian Ocean Expedition, that a growing awareness has begun to spread that there is still much of interest worthy of study and conservation in the remaining avifauna of the area. It is the purpose of this paper to provide a guide and bibliography covering past work and a few comments on points that are now emerging as worthy of attention in the future to serve as a background to reports of work carried out during the International Indian Ocean Expedition.

The oceanic islands and most of their birds are described and figured in a guide prepared for the International Indian Ocean Expedition by Watson, Zusi and Storer (1963), which unfortunately does not list the literature (it is to be hoped that readers will treat their exhortations in favour of collecting with caution). The seabirds which may visit the area are also described by Alexander (1928), and there are textbooks of varying quality on the birds of most of the adjacent land masses, for example by Mackworth Praed and Grant (1953), Archer and Godman (1937-1968), Meinertzhagen (1954), Ripley (1961), Smythies (1953) and Serventy and Whittell (1951) if further assistance is required ; some confusion will be found over the dark petrels occurring at sea in most of these works, however, which need to be approached with particular caution (Bourne, 1960). There is also a vast background literature scattered throughout the natural history journals of the world, which it would be impossible to list in detail, but I am attempting to cite key reviews for the main island groups and the more important references to work at sea and on seabirds here.

I am indebted to the Chairman, Captain Gerald Tuck, and members of the Royal Naval Bird-watching Society and also M. Christian Jouanin for lengthy discussion over many years of observations in the Indian Ocean area, and Dr. Roger Bailey for a variety of information and for assistance in interpreting the observations as well. In addition to many people whose observations have been published and are quoted in the bibliography, I am also particularly indebted to Col. C. L. Boyle and Mr. G. S. Willis for reports of large series of unpublished observations in the days when I first became interested in the area.

The Islands

The historian of ornithology in the Indian Ocean should perhaps start by referring to the first important contribution relating to the most important single phenomenon in a key area, the account of the Roc, possibly one of the Elephant Birds *Aepyornis* of Madagascar, by Sindbad the Sailor in the Arabian nights. If he is wise he will then also pass rapidly over the rest of the neglected ornithology of this fascinating island, possibly the most interesting in the world after the New Zealand group (Rand, 1936 ; Paulian, 1961 ; Moreau, 1966) which forms a major subject in itself, to deal with the more manageable outlying archipelagoes of the Malagasy area, which incidentally once also contained the world's third most interesting insular avifauna in the Mascarene Islands (Hachisuka, 1953), as well as a major

concentration of its currently most threatened species. Here it is still possible to trace in some detail the story of the downfall with the advent of mankind of a whole series of remarkable endemic bird populations of varying distinctness and complexity, some including large flightless forms reminiscent of the fauna found on the main land-masses early in the Pleistocene, though a number of essential links in the form of bones and records on ancient voyages still remain to be unearthed and most of the surviving birds still require study in the field to complete the picture. The full story could provide the material for a great classic study of the evolution and decline of animal communities.

If we take the Mascarene Islands individually, mountainous Reunion is now possibly the least spoilt (Berlioz, 1946 ; Milon, 1951), and since renewed studies in recent years have revealed such phenomena as a double invasion and dramatic local variation among the local White-eyes (Gill, 1971) and the survival of two lost endemic petrels, *Pterodroma baraui* and *P. aterrima* not seen for 75 years (Jouanin and Gill, 1967 ; Jouanin, 1970), while the bones of even its reputed lost giant flightless Solitaire still remain to be discovered, it seems likely that much may still remain to be found there ; and meanwhile the local conditions are still considerably in favour of the remaining endemic birds. Unfortunately, the same can hardly be said of the other two main Mascarene Islands, Mauritius (Rowntree *et al.*, 1952 ; Newton, 1958 ; Gill, Jouanin, and Storer, 1970) and Rodriguez (Vinson, 1965 ; Gill, 1967a ; Bourne, 1968) which were more thoroughly explored in the past (Benson, 1970) while an increasing human population is now steadily eroding the remaining natural bird habitats in patches of montane forest and on offshore islets. Further north, fortunately the seabirds breeding on the Cargados Carajos shoals are still comparatively undisturbed (Staub and Gueho, 1968), though rats have got to Tromelin (Paulian, 1955 ; Morris, 1964).

North of Madagascar the damage has been less severe in the recorded past, though recent progress poses new threats. Many endemic landbirds still survive more or less unscathed in the mountainous Comoro Islands (Benson, 1960), but a parakeet and race of white-eye have been lost and a race of dove diluted by hybridisation with an alien form on the smaller, lower, more heavily populated and developed Seychelles (Gaymer *et al.*, 1969). The number of seabirds is probably reduced in these two archipelagoes, though no losses of either seabirds or flightless landbirds have been detected yet, but vast seabird colonies still breed on the many outlying atoll groups in the region, despite some exploitation on the Amirantes in particular, where the worst damage has occurred through guano extraction, notably on Assumption, which has lost the only population of Abbots Booby *Sula abbotti* in the area and several poorly defined endemic landbird races as a result of habitat destruction (Ridgway, 1895 ; Nicoll, 1906, 1908 ; Betts, 1940 ; Vesey Fitzgerald, 1941 ; Milon, 1950 ; Gibson Hill, 1952 ; Ridley and Percy, 1958 ; Morris, 1964 ; Bourne, 1966 ; Pocklington, 1967a ; Stoddart, 1967, 1970). Fortunately the threatened military base or staging-post on Aldabra has so far failed to materialise, and the Royal Society has established a research station there instead (Beamish, 1970 ; Royal Society, 1971).

Travelling east, the low-lying Laccadive-Maldive-Chagos atoll chain off the west coast of India has few landbirds and little studied colonies of the usual pantropical seabirds which may also be in need of conservation (Betts, 1938, 1939 ; Mathew and Amberdkar, 1964 ; Phillips, 1963 ; Loustau Lalanne 1962 ; Bourne, 1971), but the higher Andaman-Nicobar chain west of Malaysia have a much richer landbird fauna which fortunately still seems to be largely undisturbed (Abdulali,

1965, 1967). Little is known about the seabirds in this area and in the Sunda Islands west of Indonesia, but it seems possible that here also there may be important colonies in need of conservation. These are certainly present on the Cocos-Keeling and Christmas Islands to the south (Gibson Hill, 1948a, 1949a, 1950a ; Nelson, 1972) ; it is regrettable that while the normal pan-tropical species nesting on North Keeling in particular are apparently little disturbed (but there seems to be little recent information), the three extremely important endemic forms on Christmas Island, *Sula abbotti*, *Fregata andrewsi*, and *Phaethon lepturus fulvus*, are now threatened by accelerated phosphate mining of the type that has already wiped out the only other colony of the first species on Assumption. This island now presents one of the most worrying problems affecting seabirds anywhere.

Travelling south, the main breeding station for subtropical seabirds in the Indian Ocean area, the St. Paul-Amsterdam group, has been severely affected by the introduction of mammalian predators (Paulian, 1953, 1960 ; Jouanin, 1953 ; Jouanin and Paulian, 1960) so that it now only holds a fraction of its original breeding population, probably once comparable to that of the Tristan group in the Atlantic (Elliott, 1957). Further south, Kerguelen has also been affected by introduced mammals, but it is larger with numerous offshore island refuges, so the damage has been less here (Milon and Jouanin, 1953 ; Paulian, 1953). A breeding station for subantarctic birds to the south, Heard Island, is still comparatively undisturbed (Downes *et al.*, 1959), as are the Crozets and the Marion-Prince Edward Island group with an interesting mixed population of subantarctic and subtropical species to the west (Zinderen Bakker, 1967).

It is impossible to list briefly all the islands close to the land masses, which rarely have important highly differentiated landbirds or large breeding colonies of seabirds other than terns in any case, but a few deserve comment. In the west, most were dealt with by Moreau (1949, 1950) in the course of his pioneer review of African breeding seasons ; the recent discovery of breeding colonies of a subantarctic tern *Sterna vittata* in South Africa (Courteney Latimer, 1957) and another of Wedge-tailed Shearwaters off the west coast of Madagascar (Appert, 1965) deserve comment, however, as do the colonies of Blue-faced Boobies *Sula dactylatra* and Sooty Terns *Sterna fuscata* on Latham Island off Zanzibar (Pakenham, 1959) and Mait Island on the south side of the Gulf of Aden (North, 1946). In this last area there are also some highly distinct endemic landbirds on Socotra (Ripley and Bond, 1966), and a chain of colonies of boobies and Red-billed Tropic-birds *Phaethon aethereus* among other species along the south coast of Arabia and in the approaches to the Red Sea and Persian Gulf (Clapham, 1964 ; Morris, 1962 ; Jones, 1946 ; Bailey, 1966 ; Tuck, 1962, 1966), while another small isolated colony of Sooty Terns has also recently been discovered on the Daimaniyat Islands off the east coast of Oman (Smith, 1970), although they do not appear to breed in the large colonies of other tern species further up the Persian Gulf (Ticehurst *et al.*, 1925 ; Sales, 1965).

Further east, few seabirds except terns appear to have been found breeding until we come to the spectacular Brown Booby *Sula leucogaster* colony on Pulau Perak in the approaches to the Malacca Strait (Gibson Hill, 1950b), but another important string of breeding colonies of many tropical species are found along the north-west coast of Australia, overlapping with another group including some subtropical species south of Sharks' Bay (Serventy, 1952a).

If one may make a few generalisations about the information available for the remoter Indian Ocean islands, the first point that deserves comment is that it is

rarely satisfactory, either in amount or implications. The ancient records and fossil deposits have rarely been fully explored for information about lost birds yet, and surprisingly little is known about most of those that have managed to survive, except that they are often threatened too. Some important endemic forms have been quite simply lost for long periods of years ; two landbirds that were thought to be extinct, an Owl *Scops insularis* and a white-eye *Zosterops modesta* which were prematurely considered extinct have been rediscovered in recent years in the densely-populated Seychelles, and not surprisingly found to be in urgent need of conservation, along with three other landbird species of exceptional interest as well. Two petrels, Jouanin's Petrel *Bulweria fallax* and Barau's Petrel *Pterodroma baraui* have also been discovered for the first time, and found to be quite common, at opposite extremities of the Indian Ocean in the Arabian Sea and the Mascarenes during the same period, while a third species which had been lost for eighty years, the Mascarene Petrel *Pterodroma aterrima*, has also been rediscovered in the latter area (Jouanin, 1955, 1964, 1970). None of these petrels nor another extremely common resident in the Arabia Sea area, the so-called ' Persian Shearwater ' *Puffinus l'herminieri persicus* (actually a weak race of pan-tropical Audubon's Shearwater) has been found breeding yet, nor has a subspecies of Fulmar Prion *Pachyptila crassirostris eatoni* of critical taxonomic interest (Fleming, 1941) originally described from Kerguelen, though the closely-related Fairy Prion *Pachyptila turtur* has been found nesting on Marion Island far from its nearest recorded breeding stations in the Bass Strait region instead. Petrels are notoriously elusive in the breeding season (Bourne, 1965), and there might be others breeding in the area unsuspected as well.

Where the information on the mere occurrence of species, whether endemic landbirds or nocturnal petrels, is so deficient, it is hardly surprising that information on their life-histories and ecology is commonly non-existent, and where it does exist seldom rises above simple descriptions. Even at the present time ornithologists of all nationalities seem much too eager to collect the birds first, and only study them afterwards. There are a few honourable exceptions, mainly concerned with seabirds, (see especially Gibson Hill, (1951), Warham (1955, 1956, 1955-1957, 1958 a, b, c, 1964b) and Nelson (1971, 1972)) but there have also been two important studies of the endemic land-birds in the field, of the fodies of the Seychelles by Crook (1961) and the white-eyes of the Mascarenes by Gill (1966, 1971).

This all-pervading trigger-happy ignorance of the status and natural history of both the insular landbirds and breeding seabirds has serious implication for their conservation. A great deal of damage has already been done to both groups by introduced mammals and expanding human populations, either as a result of direct predation or as a consequence of the destruction of habitat, which is often particularly severe on the subantarctic islands (Holdgate, 1967). Sometimes the damage is caused by people who should know better, as when a distinguished museum ornithologist advised the authorities in the Seychelles to introduce Barn Owls *Tyto alba* to control rats, and they ate the local birds instead (Blackman, 1965). It seems likely that if more steps are not made to control it modern technology will soon lead to an acceleration of the damage. Transport is much easier and more rapid than in the past, leading to more opportunities for the introduction of alien plants and animals into protected insular environments. Political autonomy is liable to lead to the removal of restraining influences protecting the wildlife in some areas, though often local naturalists soon come forward to continue the work, as in the Mascarenes at the present time. The establishment of meteorological stations on remote oceanic islands could have disastrous consequences for the wildlife, and the construction of military bases even more so, especially because it is usually carried out in secrecy so that few people realise what is happening until too late.

The two most dramatic threats in recent years, the construction of a military base (or 'Staging post') on the remotest and least-spoilt major atoll in the whole Indian Ocean, one of only four of its type in the world, Aldabra, with the last remaining flightless bird, the rail *Dryolimnas cuvieri aldabrana*, and the last natural population of giant tortoises *Testudo gigantea* remaining in the whole Indian Ocean area, fortunately resulted in an international outcry from the scientific community and the construction of a research station by the Royal Society instead when the threat was deferred (Beamish, 1970). The International Council for Bird Preservation has given a similar lead in the Seychelles, where the construction of an airport threatens rapid development of an overwhelming tourist industry, by buying Cousin Island, home of one of the most interesting endemic forms, the warbler *Bebrornis seychellensis*, for a nature reserve, and the local authorities have responded constructively to this lead by reviewing their whole conservation policy (Mancham, 1970). It is to be hoped that these new departures may together give a lead for a more constructive approach to Indian Ocean ornithology in the future, and lead to the progressive development of cooperative research into and conservation of the remaining birds together with the rest of the wildlife, which offer most interesting possibilities for study in the future (Bourne, 1970).

Birds at Sea

Both the landbird migrations and the distribution of seabirds over the Indian Ocean provide exceptionally interesting objects for study (Moreau, 1938a ; Bourne, 1963), in the first place because of the movement of vast populations of landbirds breeding in the north to winter in the Ethiopian and Oriental or Australasian regions on either side, and in the second because of the redistribution of bird populations over the ocean itself to take advantage of regions of high marine productivity which shift with the monsoons. Since the breeding landbirds are doubtless also derived from stray migrants of both eastern and western origin (Gadow and Gardiner, 1907), an understanding of bird migration in the area is also essential for the interpretation of the zoogeography of the area.

Unfortunately, while the birds of the main archipelagoes have nearly all been the subject of reviews at some stage, of rather varying completeness, until lately the study of birds at sea has lacked any coherence at all, until systematic observations were begun simultaneously by observers of a number of different nationalities during the International Indian Ocean Expedition. Unfortunately, there only appears to have been limited collaboration in the presentation of their results (notably, in interpreting a remarkable migration of storm-petrels from the north-west Pacific into the Indian Ocean by Bailey, Pocklington and Willis (1968)), while nobody has attempted a comprehensive review of the scattered previous literature, so it may be useful to list some of it here, if only as a basis for some hypothetical future computor analysis of all the data of the sort currently being attempted by the Smithsonian Institution in the Pacific (King *et al.*, 1967).

While the early explorers sometimes recorded seabirds as well as landbirds, their notes on them were even less precise, so it is possible to give a firm date for the first important observations of seabirds in the area, which were made by the naturalists accompanying Cook's expeditions in the 1770s, and notably on Kerguelen in December 1776 (Lysaght, 1959). Thereafter it became an established tradition for naval explorers to collect occasional specimens and note observations of birds in their logs, though these were seldom written up, apart from an account by Sharpe

(1879) of all the specimens previously received by the British Museum from the area in the course of a report on those obtained during the British expeditions to observe the transit of Venus in front of the sun from Rodriguez and Kerguelen in 1874-5 (the specimens collected by the French expedition on St. Paul have also recently been listed by Jouanin (1953)). Layard (1872), Gould (1875) and Hutton (1865, 1867) also published observations made during voyages from Britain to Australia via the Cape of Good Hope and Butler (1877, 1878) others from the coast of Baluchistan at this time, after which there is an extraordinary gap of nearly half a century when few notes appeared to have been made at sea anywhere in the Indian Ocean area, with the honourable exception of some by Vanhoffen (1901 ; see also 1905) during the cruise of the research ship Valdivia in 1899.

There was a sudden resurgence of interest after the first world war, when W. B. Alexander (1920, 1922) became interested in seabirds while working at the Western Australian museum, and over the next few years a number of Australians published records of both local observations (Macgillivray, 1920 ; Ferguson, 1921 ; Iredale, 1923) and from voyages to Europe, a tradition which still continues (Le Soef, 1923 ; Elkington, 1929, 1930 ; Cleland, 1937 ; Taylor, 1947 ; Gibson, 1960 ; Peakall, 1960). Falla (1929, 1937) also made voyages in the Southern Ocean, the elder Kuroda (1928) a voyage from Europe to Japan, Borman (1929) and H. G. Alexander (1929, 1931) observations around Arabia, and Bolster (1930), Young (1932), Moreau (1931, 1938b) and Winterbottom (1936) others around Africa. Danish and Dutch research vessels also made some observations and collections in the area at this time (Jesperson 1933 ; Jung, 1941), though only on a casual basis, while a number of authors started to publish notes on particular bird groups, including Meinertzhagen (1925, 1937) and Lowe (1937) on phalaropes wintering in the Arabian Sea (discussed again by the Morzer Bruyns brothers in 1957), Brooks (1939) on the skuas, and Dixon (1933) on the albatrosses.

There was a hiatus in publications during the Second World War, though many further observations were made then and in the unsettled post-war years, when notes on growing series of voyages across the Arabian Sea were published by Maclaren (1946), Norris (1952), Elliott (1952), and Phillips (1947, 1950, 1954), and on the birds of the southern Red Sea by Smith (1953) and the Persian Gulf by Loppenthin (1951). The occurrence of concentrations of wintering Wilson's Petrels *Oceanites oceanicus* off southern Arabia (Brongersma, 1947 ; Bryson, 1949), southern India (Phillips, 1955) and north-west Australia (Serventy, 1952b) also began to attract comment now, and Parquin (1951) in particular remarked how bird distribution varied with the change in water temperature across the Arabian Sea. Routh (1949), Bierman and Voous (1950) Paulian (1953), Oordt and Kruijt (1953, 1954) and Ozawa (1958) also made important observations in the Indian sector of the Southern Ocean at this time, while Gibson Hill (1948b, 1949b) and Serventy (1953) made theoretical deductions about seabird distribution in the area, and Hutchinson (1950) reviewed its relation to that of deposits of guano.

By the late 1940s enough British sailors had become interested in birds to permit the organisation of an ornithological society, the Royal Naval Bird-watching Society, among them, which began to publish short notes of their observations in its annual report, ' Sea Swallow ', from 1947, and a systematic list of observations of each species throughout the world from 1961. Numerous observations from the Indian Ocean will be found scattered throughout its pages, and the original records are filed in the Bird Room at the British Museum (Natural History). Later Professor K. H. Voous began to collect observations from Dutch sailors as well, publish-

ing the outstanding ones as short notes in the back of the journal 'Ardea'. Individual notes worthy of special comment include those by Bourne (1961) on reports of concentrations of birds off the north coasts of Somaliland and Oman in winter, by Bailey and Bourne (1963) on the identity of petrels, by Morzer Bruyns and Voous (1965) on the occurrence of Great Skuas *Stercorarius skua* in the northern Indian Ocean, by Morzer Bruyns and Voous (1964), Jones (1964), Voous (1965) on storm-petrels there, and by Voous (1966) on the occurrence of prions off east Africa. Other contributions in this period include those by Serventy (1951) and Laird (1956) on landbirds and seabirds north of Australia, and by Warham (1964a) and Cheke (1966) on landbirds and seabirds in the central Indian Ocean, Rand (1962, 1963) and Storr (1964) on seabird distribution in the cold current areas off south-east Africa and south-west Australia, Smith (1970) on the birds of the Persian Gulf, Jouanin (1955, 1957) and Bourne (1960) on the dark petrels of the Arabian Sea, and finally the sequence of reports by Bailey (1966, 1968, 1971), Gill (1967b), Pocklington and Risebrough (1964), Ozawa and Seno (1966), Pocklington (1967b) and Shuntov (1968) from the International Indian Ocean Expedition, covering a series of transects at different times of year along meridians of longitude spread right across the area.

Conclusions to be drawn from this work will be discussed by R. S. Bailey and other contributors to this symposium, so it only remains to make a few points here. In general, the Indian Ocean still has a comparatively rich and numerous seabird population, despite serious damage by man and introduced predators at some sites such as St. Paul and Amsterdam, Mauritius and Rodriguez, and Assumption, and with reasonable precautions there are no obvious imminent new threats to seabirds visible in the area at the moment except an acceleration of guano mining on Christmas Island, which could have disastrous results for the astonishing concentration of well-marked endemic seabird species there.

It is notable that most of the more marine species (excluding the coastal terns) tend to breed on the oceanic archipelagoes, but that there are also some breeding stations along coasts with cool currents or cool upwelling water, notably those of South Africa (Liversidge, 1959), at different seasons off south-west and north-west Australia (Serventy, 1952a), and south-east Arabia (Bailey, 1966), though concentrations also sometimes occur in straits with turbulant currents, such as the approaches to the Persian Gulf and Red Sea, the Mozambique Channel, the Malacca Strait, and probably according to various casual reports also other straits between the East Indies that have not been investigated properly yet.

In addition to the species which breed locally, others migrate to spend the period of immaturity or between breeding seasons in the cool current or upwelling areas as well. In addition to birds from the oceanic islands these include the Red-necked Palarope *Phalaropus lobatus* and various skuas, gulls and terns from higher latitudes to the north, and the Great Skua *Stercorarius skua* and various petrels from the south. During the northern winter the pattern of surface water movement in the Indian Ocean is not greatly dissimilar to that in other oceans, with easterly equatorial currents on either side of the equator and an equatorial counter-current between them, and the migrants frequent upwelling areas along the northern, south-eastern and south-western coasts of the area much as they do in other oceans (though it is notable that the pattern of their distribution in the north has not received much attention yet). During the latter part of the southern winter with the development of the southerly monsoons the situation is rather different to that in other oceans, with the development of an abnormal clockwise circulation of water north of the equator, and it is notable that both migrants and the local breeding birds tend to

concentrate in upwelling areas off north-west Australia (Serventy, 1952a ; Shuntov, 1968) and south-east Arabia (Bailey, 1966) then. Bailey's detailed analysis of the situation off Arabia also suggests that species which normally move into higher latitudes in other oceans such as the Flesh-footed Shearwater *Puffinus carneipes* and Wilson's Petrel *Oceanites oceanicus* stay over the cooler water inshore there, whereas species that elsewhere rarely penetrate beyond the equator such as the storm-petrels *Palegodroma marina* and of the genus *Fregetta* stay over warmer water further offshore.

These findings were already fairly obvious before the International Indian Ocean Expedition (Bourne, 1963), though Bailey in particular has now documented them in much more detail. It was much less certain beforehand what would be found in the tropical Indian Ocean, though accumulations of guano (Hutchinson, 1950) indicated a good deal of seabird activity there as well. Information obtained during the expedition (Bailey, 1966 ; Ozawa and Seno, 1966 ; Ozawa and Nakamura, 1966 ; Shuntov, 1968) suggests that this involves birds taking advantage of a high marine productivity resulting from vertical water circulation in the region of the equatorial counter-current during the northerly monsoons, and possibly along the border of the monsoon drift during the southerly monsoons. In the past ornithologists impressed by the situation in some of the upwelling areas along the west coasts of the continents, and especially in Peru (Murphy, 1936) tended to attribute most importance to the element in this productivity resulting from upwelling, but as recently stressed by the Ashmoles (1967a) for the tropical Pacific it seems likely that in the equatorial seas the accumulation of floating organism in the regions where the water is sinking is important as well.

It is notable that different, though often closely related, seabird species appear to frequent areas of upwelling and sinking water. Thus for example a complex bird community of coastal terns, gulls and skuas, Red-billed Tropic-birds *Phaethon aethereus*, Blue-faced Boobies *Sula dactylatra*, Flesh-footed Shearwaters *Puffinus carneipes* Wilson's Petrels *Oceanites oceanicus* and Red-necked Phalaropes *Phalaropus lobatus* frequenting the south-east Arabian upwelling is almost entirely replaced by a distinct community of tropical terns, White-tailed Tropic-birds *Phaethon lepturus*, Red-footed Boobies *Sula sula*, Wedge-tailed Shearwaters *Puffinus pacificus* and White-faced and Black-or White-Bellied Storm-petrels *Pelagodroma marina* and *Fregetta tropica* or *F. grallaria* over warmer waters to the south. The possibility that some at least of the second group are adapted to exploit regions of sinking rather than upwelling water is indicated by the curious distribution of one of the most typical pan-tropical seabirds, the Sooty Tern *Sterna fuscata*, off Arabia, where it avoids the main upwelling areas entirely, but has small isolated colonies in what seem likely to be local areas of sinking water along the south-west shores of the Gulfs of Aden and Oman (North, 1946 ; Smith, 1970).

However, while it seems possible that many of the commonest pan-tropical seabirds such as the Sooty Tern *Sterna fuscata*, the two most widespread Frigatebirds *Fregata minor* and *F. ariel*, and the Red-footed Booby *Sula sula* may be adapted for the capture of drifting marine organisms along the equatorial convergences it also seems possible some are adapted to capture organisms frequenting areas of upwelling as well, notably the ' domes ' found in the area of origin of the equatorial currents and counter-currents. The occurrence of one off the East Indies (Wyrtki 1962 ; Cushing, 1971) could well explain the development of a highly distinct endemic marine avifauna on Christmas Island nearby. The occurrence of one of these distinctive forms, Abbotts Booby *Sula abbotti* on Assumption Island north of

Madagascar in the past suggests that similar conditions may occur there too. However, it seems possible that while upwelling may predominate in the eastern part of the equatorial Indian Ocean, sinking may predominate in the west, because the main breeding colonies of the species which appear to be particularly associated with sinking water are found there notably in the Amirantes and Aldabra groups. It is indeed possible to speculate that this may be the main nursery in the Indian Ocean for these species and that they disperse widely elsewhere when not breeding, in the way that Sooty Terns from the Dry Tortugas off Florida migrate east to spend the pre-breeding period in the Gulf of Guinea in the Atlantic (Robertson, 1969) or Lesser Frigate-birds *Fregata ariel* bred in the central tropical Pacific disperse west to spend the pre-breeding period around the East Indies (Sibley and Clapp, 1967), but in the absence of recoveries of marked birds there is little information on the extent of bird movements in the Indian Ocean yet.

In many parts of the world fishermen traditionally use the appearance of bird flocks as a guide to the location of fish shoals, and many of the pan-tropical seabirds seem to obtain much of their food where tuna bring fish-shoals to the surface, as remarked by Ozawa and Seno (1966) in particular during the International Indian Ocean Expedition and Silas (1969). It seems likely that a more detailed knowledge of the distribution and diet of seabirds might also provide information of value for locating fisheries on a much larger scale, as recently argued again by the Ashmoles (1968), especially since birds are the most easily observed of all marine animals, if only their behaviour could be interpreted more exactly. There is now a growing background of information on seabird distribution in the Indian Ocean, to which I have now tried to provide a guide here, although much more analysis of the growing volume of material now available is still required. It seems probably that the next useful steps to permit a better understanding of this information would be energetic marking campaigns to try and trace the birds' movements, of the type mentioned above, which are actually very easy to carry out, and a further investigation of their diet, at least at the breeding stations, of the type carried out by the Ashmoles (1967 a and b) and also at sea, in order to attempt to explain the significance of these movements.

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POSTSCRIPT

For the sake of completeness, it may be useful to note a number of publications which have appeared while this paper is in press. They include a long series of important reports on the French and South African subantarctic islands, those on the Crozets in special numbers in vols. 39 and 40 of l'Oiseau, those on Marion and Prince Edward Islands in a symposium edited by Bakker *et al.* (1971) ; also a detailed study of the Ile de l'Est by Despin *et al.* (1970) and a report of the discovery of the Flesh-footed Shearwater *Puffinus carneipes* breeding on St. Paul island by Segonzac (1970). Information on most of the islands around Madagascar not previously covered in the Atoll Research Bulletin is dealt with in No. 136, but a few omissions deserve note ; especially the report by Farquhar (1900) on the atoll of that name, while it may be noted that Malzy (1965, 1966) deals with Europa

and Juan de Nova islands in the Mozambique channel. I understand that Gloriosa will shortly also be covered in the Atoll Research Bulletin, together with the important seabird breeding station Latham Island off Kenya, where the important tern colonies on the Kiunga Islands have recently been described by Britton and Brown (1971). Procter (1971) has reviewed the conservation problems in the Seychelles, and the Government of the Seychelles (1971) described what they propose to do in consequence. Hoogstraal *et al.* (1970) mention the presence of a large, autumn-breeding colony of what must be Socotra Cormorants *Phalacrocorax nigrogularis* off Abu Dhabi in the southern Persian Gulf in the process of describing their parasitic ticks and an arbovirus which can infect man that they carry, Nelson (1971) has produced a good popular account of Christmas Island (I also overlooked the account of the birds by van Tets and van Tets (1967)), and Serventy (1972) has reported on the welfare of the important southern-hemsiphere colony of the white-breasted phase of Wedge-tailed Shearwater *Puffinus pacificus* at Sharks Bay, western Australia discussed by Falla (1962). Serventy *et al*, have also produced a major textbook on Australian seabirds. (1971).

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