SURVEY OF SEABIRD COLONIES IN THE CAPRICORNIA SECTION OF THE GREAT BARRIER REEF MARINE PARK

I The use of aerial photographs in assessing potential nesting areas of seabirds and the size of their populations.

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SUMMARY

The use of aerial photographs in assessing potential nesting areas of seabirds and the size of their population.

Calculations were restricted to five species of seabird because the sizes of the colonies of other species were not known. Sizes of colonies of five species of seabird were estimated using the amount of vegetation type in which a species nests and its nesting density. No species occupied more than 31 percent of the habitat that was assumed to be suitable and available. All the area covered by any vegetation type in which a species nested was assumed to be both suitable and available.

The sizes of colonies of each species were overestimated. More colonies need to be censused to enable one to determine if constant correction factors can be found to provide accurate estimates of the sizes of colonies.

The scale of aerial photographs may have to be larger to provide greater accuracy. A scale of 1 : 10 000 has an error of $\pm$ 50 m^2 which could be the size of a colony of Black-naped or Roseate Terns. A scale of 1 : 5 000 with an error of $\pm$ 25 m^2 would be more suitable for compiling maps of vegetation types and assessing the area potentially suitable as a nesting area.

Future Research

Colonies of each species in the region should be censused during the same breeding season. Characteristics of the nesting areas of each species should be described and the features to which seabirds respond when selecting a nesting area should be determined. These data can be used to test the reliability of using aerial photographs to estimate the sizes of colonies. If reliable this would enable one to census seabirds' colonies quickly and easily.

The breeding success of colonies should be measured to determine which colonies are viable, especially those on islands that are closed seasonally. Once the viability of each colony has been ascertained appropriate action can be undertaken to increase or maintain the viability of any particular colony.

The diet of each species of seabird and where it forages needs to be determined. This will enable one to determine what area of ocean around a colony is used by seabirds and may require protection to preserve their food supply.

These data can be collected by a research team of two to three people over two breeding seasons.

The extent of interchange of individuals between colonies and their dispersal during the non-breeding season needs to be measured. From these data one may determine rates of recruitment, mortality of each age group and the fidelity of birds to a colony. Banding of birds can be done by the research team that censuses the colonies and measures breeding success etc. Results from this aspect of a study would be accumulated over several years because it depends on sightings and/or recoveries of banded birds.

Another research team would be needed to study the impact of human activity on the viability of seabird colonies. This research team could liase with the team studying the feeding and breeding ecology of seabirds.

A third research team would be needed to study the use of garbage dumps by Silver Gulls. Because this work mostly involves censusing the gull population at dumps and banding gulls a large group of people is needed. Furthermore the three population centres where this study would be done (Gladstone, Rockhampton and Townsville) are far apart. Therefore a group of ten or more people would be needed.

1.0 INTRODUCTION

1.1 Seabirds of the Capricornia Section

The Capricornia Section of the Marine Park is an important breeding area for eight of the sixteen species of seabird that occur in the region. Five of the twelve islands in the region are ranked among the ten most important breeding sites for seabirds on the Great Barrier Reef (Lavery and Grimes 1971). The region has six principal colonies and twenty-one major colonies of seabirds in Queensland.

The Capricornia section is one of the most accessable parts of the Great Barrier Reef. It is close to the centres of population (Rockhampton and Gladstone) on the Central Coast of Queensland and within range of small boats powered by outboard motors. Also it is the closest part of the Great Barrier Reef to the populations of the southern states of Australia. Uncontrolled use of the area by people is potentially disastrous in terms of the impact that human activity can have on the wildlife in the region: marine, terrestrial and aerial.

1.2 Management of Seabird Populations

In order to enable people to have reasonable use of the Great Barrier Reef and yet protect it, both human activity and wildlife have to be managed. Managers of the Marine Park require answers to the following types of questions.

What population size is necessary for the long term survival of each species of seabird that breeds in the region?

Which islands are needed as breeding grounds for the long term survival of each species of seabird breeding in the region?

What is the direct and indirect impact of human activity on the survival of each species of seabird in the region?

What level and type of human activities are compatible with viable colonies of seabirds?

Are the present zoning plans adequate to ensure the long term survival of each species of seabird that breeds in the region?

In order to manage populations of seabirds, one needs data about the following aspects of each species:

1.2.1 size and distribution of the breeding population;
1.2.2 size and distribution of the non-breeding population;
1.2.3 the time of year the species nests;
1.2.4 duration of breeding season;
1.2.5 amount of suitable nesting area available;
1.2.6 breeding success of the population;
1.2.7 causes of mortality;
1.2.8 rate of mortality in each age class;
1.2.9 rate of recruitment to breeding population;
1.2.10 length of reproductive life;
1.2.11 movement of birds within colonies;
1.2.12 movement of birds between colonies;
1.2.13 dispersal of young and adults during non breeding season;
1.2.14 quantity of food needed by the population;
1.2.15 area of ocean around colony over which seabirds forage;
1.2.16 influence of human activity on the above.

The amount of suitable nesting area available and the food supply influence the size and distribution of the breeding population. The rate of mortality in each size class affects the recruitment rate to the breeding population and hence the size of the breeding population. The causes of mortality and the relative importance of each cause need to be determined so it is possible to control and if necessary manipulate to help control the size of the population. The time of year that each species nests and the duration of its breeding season must be known if some colonies need protection from certain human activities.

The size of the non-breeding population (immatures) is the potential reserve that could be recruited to the breeding population. The size and age structure of the non breeding population may give one an indication rate of mortality and dispersal of each age class of immature birds. The dispersal of young and adults during the non breeding season must be determined because it is inadequate to manage a population solely during its breeding season when it needs protection during its non breeding season. This is fortunately important when species disperse to other countries and co-operation between the relevant governments is required.

The functions of the Marine Park include conserving the Great Barrier Reef and yet allow for reasonable use of it. Therefore one must consider the influence of human activities in the populations of the seabirds. Then it is possible to take measures to minimize the impact of human activity on seabird populations.

In this report I deal with determining the size and distribution of the breeding population of each species of seabird and the area that is potentially suitable for nesting. These points are discussed in terms of the use of aerial photographs of islands.

2.0 MATERIALS AND METHODS

2.1 Study Area

The islands studied in this report were chosen on the basis of one or more of the following reasons:

2.1.1 populations of seabirds nesting on the island had been censused;

2.1.2 vegetation types in which various species of seabirds nest are known;

2.1.4 the island is an important nesting ground for turtles and might be an important nesting area for seabirds.

2.2 Aerial Photographs

Stereoscopic pairs of colour aerial photographs of Masthead, Wilson, Wreck, Heron, One Tree, Lady Musgrove and Fairfax Islands were examined. All photos were of the scale 1 : 10 000, except those of Heron Island which were 1 : 30 000. Sterescopic pairs of photographs were viewed through a stereoscope under 4X or 8X magnification.

2.3 Vegetation Types

My field experience of Heron and One Tree Islands enabled me to compile characteristics of vegetation types as they appear on aerial photographs. I identified seven vegetation types on the basis of shape, size, shadow, texture and photographic tone (Table). The 8X objective was used to verify characteristics of vegetation types.

The area of each vegetation type on each island was measured from the aerial photographs. A transparent overlay was placed over one of the photographs and the stereoscopic pair of photographs were viewed through the stereoscope under 4X magnification. The boundaries of each vegetation type were traced onto the overlay.

The resulting outline on the overlay was placed onto graph paper marked in a grid of $1mm^2$ squares. Each $1mm^2$ square on the photograph represented $100m^2$ on the ground. The number of squares occupied by each vegetation type was tallied. If half or more of a square was filled by a vegetation type then it was considered that the whole square was covered by that vegetation type. Otherwise the square was not included in the tally for that vegetation type.

TABLE 1: Characteristics of vegetation used to identify it.

Herbs:

shape	-	no definite shape.
size	-	plants so small that one cannot distinguish them from one another.
shadow	-	plants cast no shadow because they are very short.
texture	-	very fine grained.
tone	-	darker green than the shrub about the same as that of *Pisonia* trees.

Pandanus:

shape	-	individual trees have a circular crown. When in clumps the circular crowns of each tree could be seen through the stereoscope.
size	-	crowns of each tree were large compared to other objects.
shadow	-	indicated that the trees are tall.
texture	-	clumps of *Pandanus* have a lumpy texture given by the uneven height of the canopy.
tone	-	these trees were very dark green.

Pisonia grandis: These trees invariably occurred in clumps

shape	-	irregular shape.
size	-	the clumps were large relative to other objects in the photos.
shadow	-	indicated that the trees were tall.
texture	-	save for breaks in the canopy, its texture was fine in comparison with *Pandanus*.
tone	-	light green.

<u>Shrub</u>:

shape	-	small beads.
size	-	small.
shadow	-	no shadow.
texture	-	lumpy but a much finer texture than the canopy of *Pandanus* but much coarser than texture of herbs.
tone	-	varied from light green through to yellow-green.

<u>Sand/rubble</u>:

shape	-	band around the edge of the island.
size	-	narrow.
shadow	-	no shadow.
texture	-	fine.
tone	-	off-white to cream.

(Tournefortia)
<u>Small Tree</u>:

shape	-	circular through to irregular.
size	-	small single trees not as tall as *Pisonia* or *Pandanus* trees.
shadow	-	cast a small shadow.
texture	-	lumpy.
tone	-	darker green than *Pisonia* trees.

Casuarina:

shape	-	narrow structures surrounded by network of branches.
size	-	small diameter but tall structures.
shadow	-	cast long shadows on the beach. The shadows showed the threadbare structure of the tree.
texture	-	spindly and uneven texture caused by the needle-like leaves in combination with the spaces between branches etc. Finer texture than that of *Pisonia/Pandanus*.
tone	-	very dark green bordering on black.

2.4 Characteristics of nesting areas

Each species of seabird has specific requirements of the habitat in which it nests. There is some overlap between species in the types of habitat or types of vegetation in which they nest (Table

TABLE 2: CHARACTERISTICS OF NESTING AREAS OF NINE SPECIES OF SEABIRD

Species	Habitat used as nesting area
Black-naped *Sterna sumatrana*	open, usually on the beach just above the high water mark.
Roseate *S. dougallii*	open to vegetated, nests in unvegetated areas with Black-naped Terns but slightly higher up on the beach than Black-napeds. It also nests on herbs such as *Sesuvium* and short grass. It does not seem to nest under shrubs or in crevices in the Capricornia Section.
Bridled Tern *S. anaethetus*	nests under shrubs and small trees, crevices etc.
Lesser Crested *S. bengalensis*	nexts in open vegetated or unvegetated areas but vegetation is short, e.g., herbs.
Crested *S. bergii*	nests in open usually in vegetated areas especially on short grass or other herb, e.g., *Sesuvium*.
Black Noddy *Anous minutus*	nests in trees most commonly in *Pisonia grandis* and *Ficus*. In saturated colonies (i.e., more pairs than there are nest-sites in preferred trees) pairs nest in *Casuarina* and *Pandanus* sp.
Wedge-tailed Shearwater *Puffinus pacificus*	burrows under *Pisonia grandis* and in grassy areas. Where it burrows depends on the substrate which in turn affects the type of vegetation growing on it.
Brown Booby *Sula leucogaster*	nests in open or in sparsely vegetated areas. The only nesting area of this species is on Fairfax Island.
Silver Gull *Larus novae-hollandiae*	nests on vegetation, e.g., herbs, but also under shrubs and small trees.

2.5 Nesting Density

The number of nests/m^2 or nesting density was determined by one of two ways; the number of nests in an area of known size or the internest distance between nearest neighbours. The two methods provide different results. The internest distance provides the lower estimate of nesting density and therefore the lower estimate of the size of the population.

Where possible, I have used the internest distance to calculate nesting density. This will provide a slight overestimate of the nesting density because the internest distance is the minimum radius of the area, which does not contain nests around a nest. This area is given by the area of a circle (πr^2). (Table 3)

TABLE 3: Number of nests/m^2 for five species of seabird, based on data from One Tree Island

	Internest Distance (m)	Number of nests/ (m^2)	Nest area (m^2)
Black-naped	0.99	0.3	3.1
Roseate [1]	0.99	0.3	3.1
Bridled	2.66	0.05	22.2
Lesser Crested	0.34	2.8	0.36
Crested	0.35	2.6	0.38

1 Assumed nesting density of Roseate Terns is the same as that of Black-naped Terns.

3.0 RESULTS

3.1 Vegetation Types

The area of each of ten vegetation types on six of the islands is given in Table 4 . Initially, I identified seven major vegetation types from aerial photographs. These were *Pisonia* forest, *Casuarina* forest, *Pandanus* forest, small trees, shrubs, herb and sand or rubble. However, these vegetation types were inadequate when dealing with Masthead and Fairfax Islands. Therefore the vegetation types were expanded into three more categories to account for mixtures of the original seven types that I used.

Cribb (1975) used the term strand forest grass and herb zone to categorise what I have called *Casuaria* forest and *Casuarina*, palm and herb zone.

TABLE 4 Area of each of 10 vegetation types on six islands in the Capricornia Section of the Marine Park. Area is given in hectares.

	ISLAND						
HABITAT	MASTHEAD	WRECK	WILSON	FAIRFAX I	II	LADY MUSGRAVE	ONE TREE
Casuarina, palm, herb	1.95	—	—	—		—	—
Casuarina	0.84	0.14	0.23	0.06		0.81	—
Pisonia forest	31.34	1.58	—	1.38	1.99	6.98	0.32
Small Tree	0.11	0.98	0.31	0.19	0.62		0.18
Shrub		0.80	0.72	0.20	0.03	0.82	2.11
Herb	0.37				0.49	2.52	0.18
Sand/Rubble	9.24	5.08	2.37	2.11	4.00	4.86	0.31
Pandanus			1.38				0.15
Scatterred Shrub +> Herb					2.44		
> Shrub and Herb					7.99		
Beach Rock			1.30				
TOTAL AREA	43.85	8.58	6.31	3.94	18.96	15.99	3.25

3.2 Size of Population

The potential size of the population of any species was calculated from the amount of potentially suitable nesting area available to it and the nesting density of the species concerned.

The actual size of the population of any species was obtained from previous fieldwork or the literature. Tables 5 to 8.

The degree to which potentially suitable nesting area was used by a seabird was expressed as the proportion of potentially suitable nesting area occupied by the colony. No species of seabird in this study used more than 31 percent of its potential nesting area. This of course is based on the assumption that the total area of a vegetation type preferred by a species of seabird is suitable and available. I will deal with this particular assumption in the discussion.

I was restricted to using five species of seabird because the size of colonies of other species were not available or known. Even with five species not all of their colonies had been censused. The sizes of the colonies at Masthead Island were obtained from Jahnke (1975) and those at One Tree Island from Hulsman (1979). Unfortunately no counts of the sizes of colonies at Wreck Island and at Fairfax Islands were made by Booth (1970).

TABLE 5

Amount of potentially suitable nesting area available to Black-naped or Roseate Terns on six islands in the Capricornia Section of the Marine Park.
Nesting density is 0.3 nests/m^2.

ISLAND	AREA OF SUITABLE HABITAT (m^2)	POPULATION SIZE POTENTIAL (pairs)	POPULATION SIZE ACTUAL (pairs)	PROPORTION OF SUITABLE HABITAT OCCUPIED (%)
Masthead	46200	13860	3	0.02
Wilson	11800	3540	200	2.8
Wreck	25400			
One Tree	3100	930	138 60	14.8 6.5
Fairfax	30500			
Lady Musgrave	24300	7290	12	0.2

TABLE 6

Amount of potentially suitable nesting area available to Bridled Terns on six islands in the Capricornia Section of the Marine Park. Nesting density is 0.05 nests/m^2.

ISLAND	AREA OF SUITABLE HABITAT (m^2)	POPULATION SIZE POTENTIAL (pairs)	POPULATION SIZE ACTUAL (pairs)	PROPORTION OF SUITABLE HABITAT OCCUPIED (%)
Masthead	7200	360	12	3.3
Wilson				- -
Wreck	8000	400		
One Tree	21100	1055	326	30.9
Fairfax	10300	515		
Lady Musgrave	8200	410		

TABLE 7

Amount of potentially suitable nesting area available to Lesser Crested Terns on six islands in the Capricornia Section of the Marine Park Nesting density is 2.8 nests/m^2.

ISLAND	AREA OF SUITABLE HABITAT (m^2)	POPULATION SIZE POTENTIAL (pairs)	POPULATION SIZE ACTUAL (pairs)	PROPORTION OF SUITABLE HABITAT OCCUPIED (%)
Masthead	3700	10360		
Wilson				
Wreck	0			
One Tree	1800	5040	120	2.4
Fairfax	4900	13720		
Lady Musgrave	25200	70560		

TABLE 8

Amount of potentially suitable nesting area available to Crested Terns on six islands in the Capricornia Section of the Marine Park.

Nesting density is 2.6 nests/m^2.

ISLAND	AREA OF SUITABLE HABITAT (m^2)	POPULATION SIZE POTENTIAL (pairs)	POPULATION SIZE ACTUAL (pairs)	PROPORTION OF SUITABLE HABITAT OCCUPIED (%)
Masthead	3700	9620	270	2.8
Wilson				
Wreck	0	0	0	—
One Tree	1800	4680	800	17.1
Fairfax	4900	12740		
Lady Musgrave	25200	65520		

4.0 DISCUSSION

4.1 Reliability of estimates

The reliability of the estimates of potential population size of a species depends on the accuracy of -

4.1.1 identifying vegetation types;
4.1.2 measuring the area of vegetation types;
4.1.3 determining which vegetation types are suitable for a species of seabird to nest in;
4.1.4 determining the amount of suitable nesting area available to a species of seabird;
4.1.5 nesting density of a species of seabird.

The first, second and fifth points are easily measured to an accuracy suitable for obtaining reliable estimates of the size of the breeding population. But the third and fourth points are extremely difficult to measure. What is suitable and how is availability determined?

One way to overcome the difficulty of determining suitability is to argue that where seabirds have nested successfully in a habitat previously, then that habitat is suitable as a nesting area. This method's success depends on -

4.1.6 the suitability of a nesting area not changing in the short term, i.e., year to year;
4.1.7 that if nest-areas are not in short supply it is necessary to have prior knowledge of the proportion of suitable nesting area that is used by the population;
4.1.8 the extent of competitive interactions between species for nest-areas.

Strictly speaking, the suitability and availability of an area for nesting in cannot be determined until one knows what cues a seabird responds to when selecting a nest-area and what factors influence the availability of an area.

A possible way of overcoming the limitations of not knowing what is suitable and what is available is to assume that any species of seabird occupies the same proportion of habitat that is suitable as a nesting area. However, even this method grossly underestimates the size of some populations. But if most species of ground nesting seabirds occupy between 2.5 and 3.5 percent of the suitable habitat then the size of many of the colonies could be estimated.

Estimates of the sizes of colonies of Black-naped, Roseate, Lesser Crested and Crested Terns were grossly inaccurate without being corrected to the 2.5 to 3.5 percent level. A correction factor has to be used to obtain reliable estimates of the size of a colony of any of the four species listed immediately above. All four species hunt close to their colonies and so maintain small colonies (Hulsman in press).

Estimates of the size of colonies of Bridled Terns were also too high. There were too few censused colonies to determine a correction factor. Bridled Terns can hunt far from their colonies and accordingly are able to maintain larger colonies than species that hunt closer to their own colonies. Therefore one would expect that the correction factor for estimating the size of a Bridled Tern colony would be greater than that for the other four species of tern.

The method is possibly more useful in estimating the sizes of colonies of off-shore feeders compared to those of inshore feeders. This is because of two reasons - first off-shore feeders tend to nest in large colonies whereas inshore feeders nest in many small colonies. Second, off-shore feeders often show fidelity to a specific colony and recruits are attracted to established breeding colonies, whereas inshore feeders may vary the site of their colony from one breeding season to another.

The population size of Silver Gulls probably cannot be realiably determined from aerial photographs. The population of Silver Gulls in the Capricornia area has increased over the past decade. This increase has coincided with the increased development of the Central Queensland Coast. Gulls commute between the mainland and the islands. Juvenile gulls survive their first winter because of the large amount of food that is available to them at garbage dumps. This implies that food supply during winter was the limiting factor of the gull population. Now the garbage dumps of our towns and cities provide refuges for young gulls during winter.

No one species of seabird fully occupies the habitats that are suitable for it to nest in. But are islands fully occupied by their nesting seabirds? This is possible because there is some overlap in the types of habitat suitable as nest-areas for them. Since most is known about the colonies of terns at One Tree Island I shall use them as an example.

According to the data in Table 9 the island is not fully utilised by the terns. The island could support larger colonies of each species of tern (Table 9). This is provided that all of the island is not only suitable but also available to terns for nesting. Even if all of the island were suitable for a nesting area for seabirds the activity of humans renders part of the island unavailable to the birds. The buildings are on the north-eastern corner of the island and although the activity circle of people around the research station is small (i.e. cannot walk beyond the line of the buildings, cannot walk more than 20 m along the northern beach from the laboratory hut and cannot walk beyond the north-eastern corner along the eastern beach). Most of the northern beach and about half of the eastern beach is unavailable to the birds to nest on. Some 39% of the habitat that is potentially suitable for Balck-naped and Roseate Terns to nest in is not available to them. Therefore Black-naped and Roseate Terns occupy about 53% of potentially suitable habitat that is apparently available.

The colony of noddies at One Tree Island is so small because noddies started nesting there in 1978. The number of pairs nesting on the island are gradually increasing.

TABLE 9

Amount of potentially suitable nesting area used by terns at One Tree Island.

Species	Area	Nesting density nests/m^2	Population Size Potential	Population Size Actual	Area occupied (%)
Black Noddy	3200	1.1	3582	30	0.8
Black-naped ⎤	3100	0.3	930	138 ⎤	21.3
Roseate ⎦		0.3		60 ⎦	
Bridled	21100	0.05	1055	326	30.9
Lesser Crested ⎤	1800	2.8	4680	120 ⎤	19.7
Crested ⎦		2.6		800 ⎦	

The species which often nest together are bracketed together in determining the percentage of habitat occupied.

4.2 CONCLUSIONS

Currently there is insufficient data about the size of colonies of various seabirds available to allow one to test the reliability of using aerial photographs to estimate the size of a colony. The reliability of the method can be determined after data about the sizes of colonies in the region have been collected.

The main problems met in trying to estimate the size of a colony was determining -
4.2.1 what amount of habitat was suitable for a nesting area;
and 4.2.2 what amount of suitable habitat was available to the seabirds.

Photographs taken from a height of 5000 feet were extremely useful in measuring the area covered by each type of vegetation. In contrast photographs taken from a height of 15 000 feet were unsatisfactory for mapping vegetation types. A scale of 1 : 10 000 is possibly the smallest ratio that can be used for estimating sizes of seabird colonies. The percentage error in estimates of colony size depends on the nesting density of the seabird. The greater the nesting density the greater the error will be.

Photographs of a scale 1 : 5 000, i.e. taken from a height of 750 m (2 500 feet) with a lens whose focal length is 152 mm, would be more suited to this type of work. The error at this scale is $\pm$ 25 m^2. Some species of seabird have nesting areas of less than 50 m^2 and such a small patch would be missed on a photograph with a scale 1 : 10 000. Photographs used to determine vegetation maps of islands could be such a large scale (1 : 5 000) and still be very useful because the islands are small.

Aerial photographs are particularly useful in helping one decide where to site transects or quadrats when censusing large colonies of seabirds. Species such as the Black Noddy and the Wedge-tailed Sheanwater, which nest in many different types of vegetation, can be censused in the following way. The types of vegetation are categorised and their areas determined then transects or quadrats are set out to include these vegetation types to obtain a representative sample. If the nesting density of the bird is measured in several sections of a vegetation type one can extrapolate from the amount of each vegetation type and the nesting density of the birds to obtain an accurate estimate of the size of the colony.

Other species of seabird in the region nest in small colonies and these are of a size that each nest or incubating bird can be counted. However, if aerial photographs can be used to estimate the size of their colonies then large areas of the Great Barrier Reef could be censused more quickly and cheaply than if censused by conventional methods. The use of aerial photographs may also provide data on the amount of suitable nesting area is available to each species of seabird. This information is essential for the preparation of zoning plans. Furthermore, aerial photographs taken every five years or so would provide information on the changes in the area of vegetation types. This kind of information is necessary for managing islands in order to maintain certain amounts of habitat that are suitable as nesting areas for seabirds.

4.3 FUTURE RESEARCH

Several aspects of the feeding and breeding ecology of seabirds need to be studied if an effective set of management policies for seabirds are to be devised.

First, in order to test the reliability of using aerial photographs to estimate sizes of colonies.

4.3.1 a survey of all colonies in the Capricornia Section of the Marine Park should be done.

There has not been one survey of colonies on the islands ranked among the top ten sites for breeding seabirds on the Great Barrier Reef during the same breeding season. Because some species may nest on different islands from one year to the next, some colonies may have been included in the total number of colonies more than once. For example, the population of hesser Crested Terns that nest at One Tree Island in some years may be the same one that nests at Masthead Island (Hulsman 1979).

4.3.2 More field data are needed to test the feasibility of using aerial photographs to census populations of seabirds. The size of each colony must be determined. At present the size of colonies of seabirds nesting at Heron Island and One Tree Island are known. Some colonies at Masthead Island have been censused but otherwise there are no published accounts of the actual size of any colonies on the other nine islands in the area.

4.3.3 Features of a habitat to which seabirds primarily respond when selecting a nest-area need to be determined. For example, does the type of vegetation, the height of the vegetation, the presence of conspecifics and the presence of other species affect where a species nests?

Secondly, the following data are needed to determine how to manage populations of seabirds.

4.3.4 The breeding success of each species at their major colonies should be measured. This is needed to determine if sufficient protection has been afforded colonies to allow their long-term survival in the region.

4.3.5 Data about the diet of each species of seabird and where each species forages should be collected. This will enable one to determine if their food supply is adequate to support the populations of each species in the region. Also what area around a colony is needed to supply the food of seabirds.

4.3.6 The movement of individuals between colonies and/or islands should be determined. This can be done by recoveries and sightings of colour banded birds. Banding will also enable one to collect data on the rate of recruitment to the breeding population, the fidelity of birds to a colony, mortality of various age groups and dispersal patterns of the birds during the non-breeding season.

Thirdly, studies of the effects of various human activities on the breeding success and hence the viability of seabird colonies should be done.

4.3.7 The levels of human activities in the region that are incompatable with viable colonies of seabird should be determined. Then the level of each activity/use compatable with viable colonies should be determined.

Fourthly, studies of the ecology of Silver Gulls should be done because predation on eggs and clucks of terns by Silver Gulls is one of the major causes of mortality of several species of tern.

4.3.8 The role of garbage dumps as refuges for Silver Gulls during the year, especially winter.

4.3.9 Methods of disposing of garbage so as to reduce the effectiveness of garbage dumps as refuges for gulls.

4.3.10 The movement of gulls between the mainland and off-shore islands.

Data in points 4.3.1 to 4.3.6 can be collected by the same research group (minimum size 2). The data mentioned in points 4.3.1, 4.3.2 and 4.3.5 can be collected during one breeding season. Colonies of each species could be censused during two visits of 3 days each to an island. At the same time data about the diet of each species could be gathered by collecting regurgitations and/or by observing what prey are fed to young.

Data in points 4.3.3 and 4.3.4 would need to be collected over two breeding seasons. For 4.3.3 field experiments may be required and as with 4.3.4 comparative data from two breeding seasons are needed. During the first season one can determine which features may be important and then manipulate these features during the second season to determine the effects. Breeding success should be collected over two seasons because of the great variability from year to year.

Data in 4.3.6 can be collected over a number of years only. However, after two breeding seasons during which the most intensive work has been done i.e. 4.3.1 to 4.3.5 data from birds banded in previous work in the region and during the two breeding seasons will require less intensive work and could be collected by GBRMPA or Queensland NPWS personnel.

Some information needed for 4.3.7 could be collected by the research group collecting data for 4.3.1 to 4.3.5. However, the research group would need to be expanded to three or four people to collect data on 4.3.7. Alternatively another research group could collect the data needed for 4.3.7.

Studies of Silver Gulls would require, a different research group from the one studying the seabirds. Such a study would need a minimum of two years. The first year the number of gulls using garbage dumps of Gladstone and Rockhampton throughout the year could be determined. Some banding possibly colour banding, would be needed to determine movemment of gulls between the mainland and off-shore islands. One would need to rely on sightings of banded gulls to determine their movements to and from the islands. Therefore, it would need advertising to bring to the general public's notice that marked gulls are in the area and would they please report whereand when they saw marked gulls. During the second year different methods of disposing of garbage could be assessed in affecting the numbers of gulls in the area of a garbage dump.

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