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GULLS AND TERNS *(LARIDAE)* OFF WOLLONGONG, NEW SOUTH WALES: SEASONAL ABUNDANCE, SCAVENGING BEHAVIOUR AND DEPTH ZONATION

K. A. WOOD

7 Eastern Avenue, Mangerton, New South Wales 2500

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During 23 monthly pelagic cruises off Wollongong, Silver Gulls *Larus novaehollandiae* comprised about 90 per cent of 11 483 larids counted and were the most dominant scavengers. Gulls were mainly inshore whereas terns were mostly offshore and pelagic. Five tern species were seen irregularly. Crested Terns were consistently more pelagic than neritic while not breeding and consistently more neritic than pelagic while breeding. Numbers of Silver Gulls increased markedly in winter (before breeding) when zonal distribution changed to partly neritic, partly pelagic. At peak abundance in June 1985, their rates of encounter in pelagic and neritic zones were equal. It is suggested that the Silver Gulls in the pelagic zone were mainly adults, scavenging for nutritious food before breeding.

INTRODUCTION

Sixteen species of gulls and terns (family Laridae) have been recorded from the Wollongong area (Gibson 1977; Corben 1988). Silver Gulls *Larus novaehollandiae*, Kelp Gulls *Larus dominicanus* and Crested Terns *Sterna bergii* are resident breeders; White-fronted Terns *Sterna striata* are winter migrants from New Zealand. The remaining 12 species are irregular visitors. Local breeding colonies occur on the Five Islands, 7 km SSE of Wollongong (34°25′S, 150°54′E). These colonies consist of about 50 000 pairs of Silver Gulls, 2 500 pairs of Crested Terns and 15 pairs of Kelp Gulls (Gibson 1979; Lane 1979). Little has been reported on monthly patterns of abundance in the area or depth zonation off the coast.

The purpose of this study was to quantify temporal abundance and zonal distribution of larids at sea off Wollongong. Between April 1985 and March 1987, 23 ocean transects were conducted perpendicular to the coast. Cruises were made in every month except September 1986 and February 1987. The average transect distance was 66 km seawards (depth 2 500 m). Time spent in pelagic and neritic habitats was almost equal as the shelf break (depth 200 m) is 34 km east.

STUDY AREA AND METHODS

The study area and methods have been described previously (Wood 1990). Briefly, censuses were conducted from the *Sandra K*, a 14-metre converted trawler which was chartered regularly to view seabirds. Fish remains and pieces of animal fat were chopped on board and cast astern to attract the birds.

Watches were continuous from the stern deck (eye height 2.6 m above water). Gulls and terns within a radius of 200 m were counted during 360 degree scans at about eight minute intervals. Identification was aided with 8 × 40 binoculars.

Sample data are based on successive periods of approximately 20 minutes. Within each period, the highest number of individuals of each species seen together while boat-following or sitting on the water was counted together with the cumulative number of discrete individuals of each species seen passing by. Twenty minute counts for species which followed, sat on the water and passed by were added. Count durations used by researchers range from ten minutes to one hour but the ten-minute count has recently gained most favour, particularly if the boat is not discharging offal (Tasker *et al.* 1984). A 20-minute duration was selected because it reduced the number of individuals recounted when offal was tossed overboard.

Throughout this paper, 'c' refers to the number of 20-minute censuses. Seasons of the year are as defined in Blakers *et al.* (1984); foraging terms are as in Harper *et al.* (1985). Marine zones are classified as inshore, offshore and pelagic. Inshore refers to the area within 8 km of the mainland, offshore is eastwards to the shelf break (but not inshore) and pelagic is at depths >200 m. Neritic is at depths <200 m.

RESULTS AND DISCUSSION

Altogether I counted 11 483 individuals of nine species. Regularly occurring species and corresponding abundances were Silver Gull 90 per cent, Crested Tern 9 per cent, Kelp Gull 1 per cent and White-fronted Tern <1 per cent (Table 1). The relative abundance of the three former species

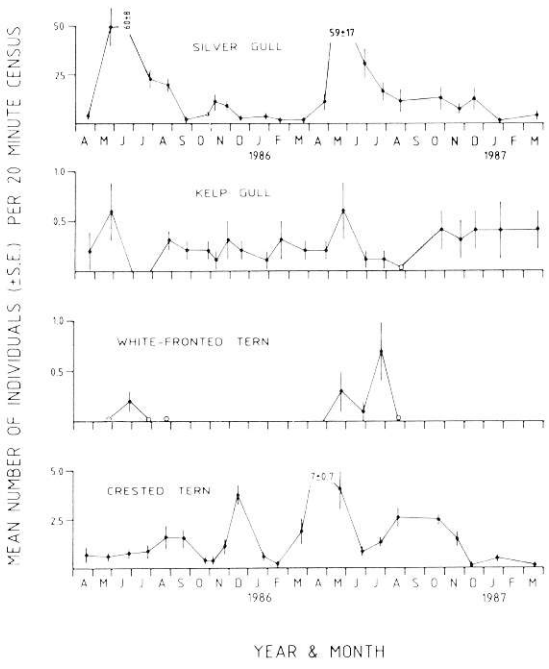

Figure 1. *Monthly abundance of gulls and terns seen regularly off Wollongong from April 1985 to March 1987. Open circles represent a total of one or two individuals.*

mirrors the size of their breeding colonies on the Five Islands. During the first and second 12-month periods respectively, 6 285 and 5 198 individuals (all species combined) were observed, of which 5 748 and 4 532 were Silver Gulls. The

TABLE 1

Distribution of 11 483 gulls and terns in marine habitats off Wollongong from April 1985 to March 1987 (23 cruises). Total number of birds of each species is shown in parenthesis; n — number of individuals; c — number of 20-minute censuses; P* — percentage of individuals per 20-minute census in each marine zone.

	Inshore				Offshore				Pelagic			
Species	n	c	$\frac{n}{c}$	P*	n	c	$\frac{n}{c}$	P*	n	c	$\frac{n}{c}$	P*
Silver Gull (10 280)	3 629	74	49.04	67	4 332	244	17.75	24	2 319	329	7.05	9
Kelp Gull (159)	98	67	1.46	84	57	223	0.26	15	4	296	0.01	1
Crested Tern (975)	87	74	1.18	27	393	244	1.61	37	495	329	1.50	36
White-fronted Tern (38)	2	24	0.08	19	21	87	0.24	54	15	124	0.12	27

corresponding number of 20-minute census periods was 371 and 277 respectively. Figures 1 and 2 respectively show monthly abundance and depth zonation in 10 km increments. Distribution in various marine habitats is quantified in Table 1.

Thirty-one individuals of five other species were observed irregularly (Table 2). Caspian Terns *Hydroprogne caspia* and Little Terns *Sterna albifrons* are not rare locally (Gibson 1977; Wood 1985), yet neither species was seen.

Silver Gull *Larus novaehollandiae*

Silver Gulls followed persistently and foraged close to the boat (<40 m) on both types of offal. Some birds may have followed for an hour or more. They successfully competed against all other scavengers by contact dipping or catching

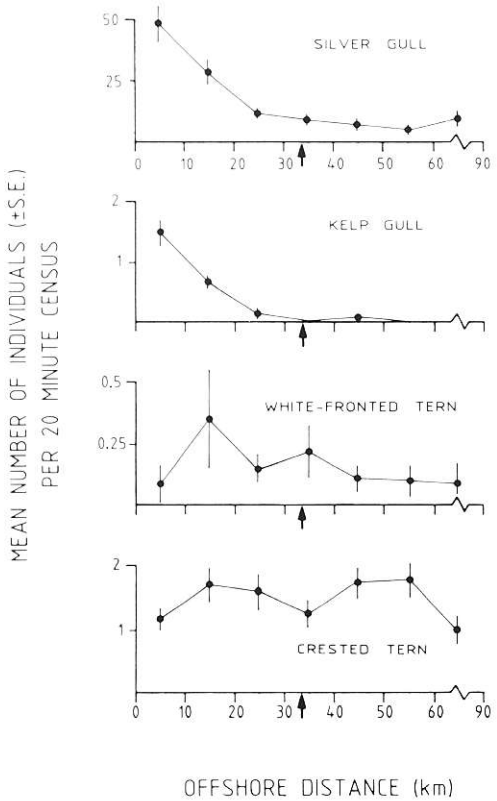

Figure 2. *Depth zonation of gulls and terns seen regularly off Wollongong during 23 cruises from April 1985 to March 1987. Arrows indicate approximate position of 200 m isobath.*

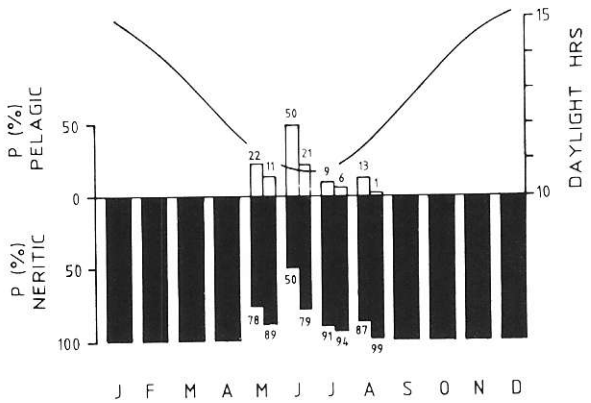

Figure 3. *Monthly distribution of 10 280 Silver Gulls in neritic and pelagic zones from April 1985 to March 1987. P is percentage of individuals per 20-minute census calculated as in Table 1 with values for 1985 and 1986 listed left and right respectively.*

food in air but did not dive. Occasionally they rested on the surface but were not observed feeding on live prey. This species was present on every cruise, but from May to August each year, numbers increased markedly (Fig. 1). Whereas in other months the average number of birds per cruise was 160, from May to August it was 990. Seventy-seven per cent of individuals was counted during these four months (both years combined). Adults and immatures were not counted separately but very few first-year birds (<5%) were observed.

Silver Gulls occurred mainly in the inshore zone (Fig. 2, Table 1) where flocks of 50–100 birds were encountered throughout spring, summer and autumn. Inshore winter flocks were much larger (200–300) and were attracted to the returning vessel about 20 km from shore compared with about 10 km in other months. The species was absent from the pelagic zone except from May to August each year (Fig. 3) when their zonal distribution changed from being totally neritic to partly neritic, partly pelagic (Fig. 3). The highest overall abundance and the highest rate of encounter in the pelagic zone were both recorded in the 89 km cruise on 29 June 1985. During that cruise, Silver Gulls followed and foraged to the turning point and were counted in every 20-minute period but one (count range 20–200 neritic,

0–200 pelagic). Of 1 780 birds, 515 were in the neritic zone (c = 9, n/c = 57.2) and 1 265 were over pelagic waters (c = 22, n/c = 57.5). The rates of encounter in neritic and pelagic zones were almost equal. These data suggest a winter influx into the study area and a concurrent change in zonal distribution. About 60 km north of Wollongong, Milledge (1977) surveyed only the offshore zone and found that 'Silver Gull numbers were fairly constant throughout the year'. In Annual Bird Reports of the New South Wales Field Ornithologists Club from 1974 to 1986, Silver Gulls have been reported at sea only once. 'Large numbers' were seen out to the continental shelf (turning point) off Sydney on 29 June 1985 (Cooper 1989). Reports by Milledge (1977) and Cooper (1989) are not inconsistent with the temporal changes in zonation determined in the present study. Month-by-month census results presented in Figure 1 over-emphasized the relative abundance of Silver Gulls in winter because only then did they follow in the pelagic zone and substantially increase in numbers behind the returning vessel about 20 km from shore.

Murray and Carrick (1964) found that Silver Gulls in south-eastern Australia nested from August to February. More recently, G. C. Smith (unpubl. data) determined that peak egg laying at the Five Island colonies was in August. As in Western Australia (Wooller and Dunlop 1979), Smith found that a second brood of chicks was hatched in December, but mainly from different adult pairs. The large influx of gulls in the study area from May to August immediately preceded the first peak egg-laying period on the Five Islands. A corresponding rise in numbers before the second brood of chicks was not detected.

Gibson (1979) reported a spectacular increase in the Silver Gull population on the Five Islands from about 1 000 pairs in 1940 to over 50 000

TABLE 2

Details of 31 terns observed irregularly off Wollongong from April 1985 to March 1987.

Species	No. of individuals	Time (E.S.T.)	Date	Distance from shore (km)	Depth (m)	Beaufort wind speed and direction	Surface water temperature (°C)
Common Tern	1	14:23	14 Dec. 1985	20	130	Force 4 S	21.0
	2	06:53	26 Apr. 1985	11	60	Force 4 WSW	21.5
	1	07:29	26 Apr. 1985	21	140	Force 4 WSW	21.7
	4	07:37	26 Apr. 1985	24	150	Force 4 WSW	21.7
	2	07:50	26 Apr. 1985	27	160	Force 4 WSW	21.8
	4	08:01	26 Apr. 1985	30	170	Force 4 WSW	21.8
	1	08:12	26 Apr. 1985	33	200	Force 4 WSW	21.9
	1	09:28	26 Apr. 1985	55	1660	Force 4 WSW	22.2
	1	08:31	24 May 1986	37	300	Force 4 WSW	21.0
	1	05:55	23 Nov. 1986	9	44	Force 0	16.9
	2	07:24	13 Dec. 1986	40	480	Force 5 W	20.4
Arctic Tern	2	12:45–13:02	21 Sep. 1985	22–25	150–160	Force 6 S	18.8
Sooty Tern	2	07:56	14 Dec. 1985	45	1030	Force 4 SSE	22.7
	1*	08:24–12:40	14 Dec. 1985	55–77	1500–2600	Force 4 SSE	22.8–23.0
	2	10:22	25 Jan. 1987	57	2000	Force 4 NE	21.3
Grey Ternlet	1	08:18	15 Feb. 1986	46	1100	Force 2 SE	21.9
	1	13:20	15 Feb. 1986	25	160	Force 4 E	21.6
White Tern	1	10:42	14 Dec. 1985	77	3700	Force 4 SSE	23.2
	1†	11:45	14 Dec. 1985	63	2600	Force 4 SE	23.0
	1	09:00	22 Mar. 1986	44	900	Force 4 NE	22.0

*One individual seen repeatedly between 08:24 and 12:40; †Probably the same individual as seen at 10:42 on same day.

pairs in 1978. Such growth was attributed mainly to a corresponding increase in scraps and garbage provided by an expanding human population. The breeding population has plateaued somewhat in recent years (Smith, unpubl. data) as has the human population of the Greater City of Wollongong.

Kelp Gull *Larus dominicanus*

Kelp Gulls were present in small numbers on 21 cruises (Fig. 1). Five or fewer individuals were counted in 69 census periods and more than five birds only twice. In May 1986 and January 1987, eight were seen together foraging behind the boat. Although this species was present in both inshore and offshore habitats, it was predominantly inshore (Fig. 2, Table 1). Almost twice as many individuals were seen in the 0–10 km zone as in all other zones combined. Only once did Kelp Gulls occur beyond the shelf: on 26 May 1986 two immatures followed for about 30 minutes (depth 380–580 m). Silver Gulls and Kelp Gulls occurred together inshore but Kelp Gulls scavenged more distant from the boat (40–80 m).

Common Tern *Sterna hirundo*

All Common Terns came into view and disappeared after a few minutes. Some were temporarily attracted to the vessel but none took offal or attempted to catch prey. On 26 April 1986, 15 birds were encountered in seven discrete flocks between 11 and 55 km eastwards (weighted av. 29 km, Table 2). I could not detect their direction of movement. Milledge (1977) observed a flock of 60 birds feeding over water about 60 m deep in January 1974. Large flocks of Common Terns (500–1 000) have been reported from the New South Wales coast near Sydney in summer (Rogers 1976, 1977; Rogers and Lindsey 1978; Lindsey 1982), but the type of movement observed in the study area in late April was consistent with migration. Flocks were small and mobile and were regularly intercepted across a 44 km front. In Eastern Canada, Common Terns feed inshore and 'are seldom seen from ships except while migrating' (Brown 1986). Peak northward migration of the nominate race is in late April (Dunn 1985).

Arctic Tern *Sterna paradisaea*

Two birds followed the *Sandra K* closely for about 17 minutes and provided clear views of the underwings. Primaries showed a well-defined black trailing edge of constant width. In ventral aspect, secondaries and inner primaries were translucent. The webs of the tail streamers were black. These features typify the Arctic Tern in flight (Carter *et al.* 1979).

These terns were seen after 13 days of adverse weather in the western Tasman Sea (Wood 1990) and may have been forced northward after following the southern coasts of Australia in migration to Antarctica (Serventy *et al.* 1971). However, recent New South Wales reports of Arctic Terns in good weather suggest that some individuals may migrate via the east Australian coast. Of 22 birds reported between 1975 and 1985 (Rogers 1976; Rogers and Lindsey 1978; Lindsey 1981, 1982, 1984, 1985, 1986; Cooper 1989, this study), ten were observed in each of the northward and southward migration periods, April to July and August to November respectively. Increased sightings off New South Wales since 1974 may be due to improved identification and greater coverage in pelagic habitat. Blakers *et al.* (1984) in compiling the Atlas of Australian Birds, reported Arctic Terns from 1977 to 1981, in only three one-degree 'squares' on the eastern coast compared with 13 one-degree 'squares' on the southern and western coasts.

White-fronted Tern *Sterna striata*

Of the regularly occurring larids, White-fronted Terns were least abundant. Most birds foraged behind the boat for about ten minutes then departed. Adults and immatures were not distinguished separately. Nine birds were counted from May to August 1985 and 29 from May to August 1986. The average flock size was 1.8 ± 1.3 (mean ± SD, range 1–6, n = 21). A majority of individuals per census period was found in the offshore zone (54%, Table 1). Blakers *et al.* (1984) also reported the species more common offshore than inshore around Tasmania and in Bass Strait. Data presented supports an abundance status of a regular winter migrant in variable numbers (Serventy *et al.* 1971; Blakers *et al.* 1984). Variability in abundance is typified by a sighting of

1 000+ birds at Windang (near Five Islands) in August 1959 (McKean 1960) yet an absence of the species off Sydney in the 12 month period May 1973 to April 1974 (Milledge 1977).

Sooty Tern *Sterna fuscata*

Two adult Sooty Terns were observed on 14 December 1985; a single adult and juvenile on 25 January 1987. On the former cruise, one bird followed in the distant wake for almost four hours whereas on the latter, both birds were attracted to within 30 m for only a few minutes. None of the Sooty Terns attempted to take offal. All four individuals were over pelagic waters in summer when about 50 000 pairs breed on Lord Howe Island, 850 km ENE of the study area (Fullagar *et al.* 1974). The sighting of an adult and juvenile together in January 1987 supports the finding that post-fledging parental care is exercised at considerable distances from breeding colonies (Feare 1975).

Crested Tern *Sterna bergii*

This species was present on every cruise with an average flock size of 3.6 ± 3.0 (mean ± S.D., range 1–20, c = 272) but there was no obvious seasonal abundance pattern (Fig. 1). The following corresponding monthly counts reflect the variability in their abundance: 19 birds in April 1985 but 183 (highest count) in April 1986, 21 in May 1985 but 110 in May 1986, 114 in December 1985 yet 4 (second lowest) in December 1986. Crested Terns lay eggs on New South Wales marine islands from October to January (Gibson 1977; Morris *et al.* 1981). On the Five Islands, about 2 000 pairs produced chicks in 1984 and 1985 seasons and about 1 000 pairs in the 1986 season (H. Battam, pers. comm.). There was no obvious relationship between the irregular pattern of abundance observed in the study area and the numbers of birds which bred on the Five Islands.

Zonal distribution ranged from 1.8 birds per census period in the 50–60 km zone to 1.2 birds per census period inshore (Fig. 2). Statistical difference between the number of birds observed in each of the seven 10 km incremental zones was higher ($\chi^2 = 35.2$, df = 6, $P < 0.001$) than the difference between the number of birds observed in the five incremental zones 10 to 60 km from shore ($\chi^2 = 11.5$, df = 4, $P < 0.05$). By comparison with the inshore zone, the overall rate of encounter in the offshore zone was 33 per cent higher (1.6 vs 1.2 birds per census period, Table 1) and in the pelagic zone was 25 per cent higher (1.5 vs 1.2 birds per census period).

Monthly variations in zonal distribution were analysed by comparing neritic and pelagic encounter rates (Fig. 4). From April to September each year, the species was consistently more pelagic than neritic but in other months it was consistently more neritic than pelagic. Overall, the pelagic to neritic encounter rates were 61:39 per cent while not breeding and 34:66 per cent in the breeding season (Fig. 4). Crested Terns avidly followed the boat and scavenged for fish and fat by contact dipping. Most birds were adults (>80%). They were only moderately successful in foraging bouts with other seabirds. No birds were seen resting on the water although four individuals rested on the bow handrail for about 20 minutes, 60–70 km east of Wollongong in December 1985.

Grey Ternlet *Procelsterna albivittata*

Both Grey Ternlets were alone when initially seen about 250 m from the boat on 15 February 1986. They approached to within 60 m, inspected the scavenging by other seabirds and departed. The closest breeding colony of about 1 000 pairs is at Lord Howe Island. Some of this population disperses soon after breeding in summer (Fullagar *et al.* 1974). The present sightings, together with some 11 others reported recently by Lindsey (1979), Blakers *et al.* (1984) and Cooper (1989) between December and March, support the suggestion that dispersal from Lord Howe Island after breeding is partly towards the east coast of Australia (Holmes 1976).

White Tern *Gygis alba*

On 14 December 1985 and 22 March 1986, White Terns were viewed in the pelagic zone at about 150 m (Table 2). Both birds showed no apparent interest in the foraging activity behind the *Sandra K.* The nearest breeding colony is also at Lord Howe Island where in 1971–72 about 10 pairs were breeding each summer. The Lord Howe Island population is estimated at about 300 birds (Fullagar *et al.* 1974). At least 16 individuals

have now been reported from the New South Wales coast of which some 13 were present between December and April (Lane 1986; Cooper 1989). As with the Grey Ternlet, some White Terns may disperse westwards from Lord Howe Island into New South Wales waters at the end of their breeding season. Although colonies of both species exist at Norfolk Island (van Tets and Fullagar 1984) the likelihood of birds from Norfolk Island is low because it is more than twice the distance of Lord Howe Island from Wollongong.

GENERAL DISCUSSION

The census method, like all others proposed to study seabirds at sea, has unavoidable biases (Tasker *et al.* 1984). The tossing of offal has caused scavenging species to be over-estimated in comparison with others. Nevertheless, a standard method free from observer variability has been used and the results may be compared with other shipboard surveys if similar methods are adopted. After allowing for respective biases, Silver Gulls were clearly the most abundant species. They outnumbered all other species combined by 8.5 to 1. Thirty-one individuals of five species, irregular in their presence, were recorded (Table 2). Almost half of these sea terns were over pelagic waters suggesting that they may be more abundant off Wollongong than previously reported. The apparent rarity of sea terns may reflect a lack of coverage in the pelagic zone rather than absence of the species because marine habitats covered in New South Wales Annual Bird Reports (1974–1985) and in studies by Milledge (1977), Morris *et al.* (1981) and Blakers *et al.* (1984) have been largely confined to the neritic zone.

Silver Gulls may consume appreciable quantities of discarded marine food at sea off Wollongong. They were not only avid scavengers of fish and fat tossed from the *Sandra K* but also of fish, cephalopods and crustacea discarded from trawlers. The port of Wollongong has 19 trawlers (>10-metre) which land an average of 1 800 tonnes of commercial fish annually (Anon 1985). These trawlers regularly operated in the study area and were pursued by Silver Gulls (max. 400) as discards were released. The number of scavenging

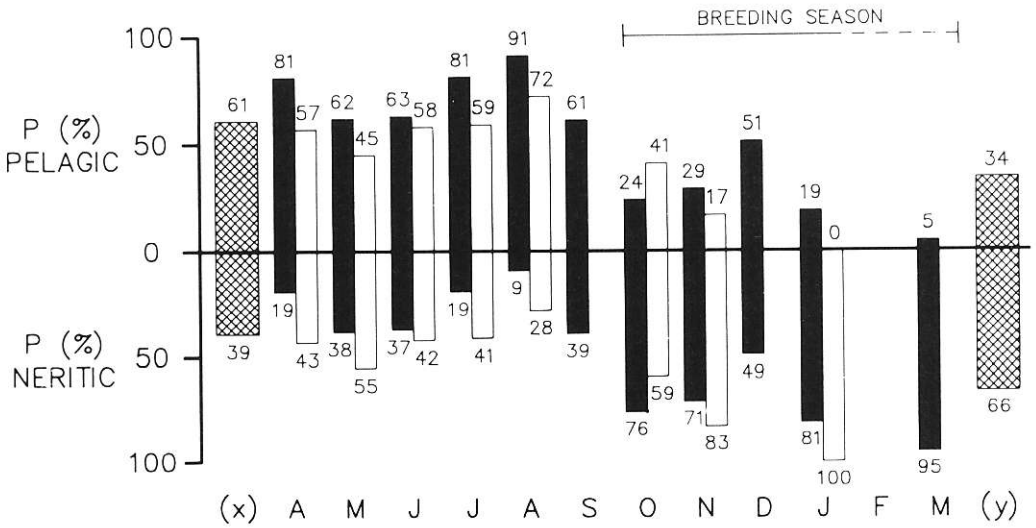

Figure 4. *Monthly distribution of Crested Terns in neritic and pelagic zones from April 1985 to March 1987. P is percentage of individuals per 20-minute census calculated as in Table 1 with first and second 12-month periods listed left and right respectively. Months with fewer than 10 birds omitted. Combined percentages are shown from April to September (x) and October to March (y).*

birds was approximately proportional to the quantity of offal being discharged. In the pelagic zone in winter, large flocks moved between trawlers in synchrony with the release of discards while smaller flocks followed the *Sandra K*. The sizes of following flocks varied markedly each 10–15 minutes, indicating that population turnover was occurring. Sated individuals probably returned to shore, hungry birds probably joined the scavenging population at sea.

As in the seas around the Shetland Islands (Hudson and Furness 1989), an interspecific foraging hierarchy was evident behind the *Sandra K*. Silver Gulls were clearly the most dominant larid. Of all the seabirds which followed, only Wedge-tailed Shearwaters *Puffinus pacificus* were able to share discards in comparable proportions. Kelp Gulls and *Sterna* spp. terns took much less food, foraging mostly in the distant wake where scraps were less abundant. When foraging more closely, they were out-numbered and out-manoeuvred by Silver Gulls or Wedge-tailed Shearwaters.

Terns were generally more abundant in offshore and pelagic zones than inshore but gulls were predominantly inshore. These generic groups appear to have different foraging niches in the study area. Zonal distribution of Silver Gulls and Crested Terns changed temporally in a regular but different pattern (Figs 3 and 4). Silver Gulls were entirely neritic, except in winter (immediately before breeding) when a significant proportion of the population in the study area (max. 50%) foraged over pelagic water. Crested Terns were predominantly pelagic except in spring and summer (during the breeding season) when they were predominantly neritic. These different but regular zonal shifts in distribution appear to be linked to the respective breeding cycles.

The shift in zonal distribution of Silver Gulls coincided with a minimum of daylight hours (Fig. 3) and an influx of the species prior to breeding (Fig. 2). Presumably, a considerable number of birds foraged over pelagic waters in winter because the required quantity or quality of food could not be obtained elsewhere. It is suggested that most of these birds were adults, scavenging for the nutritious food required before eggs are laid. They certainly had well-developed foraging skills, known to be necessary for successful breeding in other *Larus* species (Burger and Gochfeld 1981). The basis for this suggestion is circumstantial but other workers have shown that breeding success in some seabirds is dependent on food ingested before egg-laying. In Common Terns, Nisbet (1978) found that reproduction was dependent on the composition and quantity of food before egg-laying and concluded that the protein content of egg albumen was the critical nutritional factor involved. In Audubon's Shearwater *Puffinus lherminieri*, Harris (1969) concluded that the ultimate factor which controlled breeding was the availability of food for egg formation. Other studies have not been quite so definitive. Safina *et al.* (1988) determined that breeding success of Common and Roseate Terns *S. dougallii* was dependent on the quantity of fish prey in egg-laying and chick-raising periods. In a 26-year study in New Zealand, Mills (1990) concluded that reproductive success in the Silver Gull sub-species *L. n. scopulinus* was affected by the availability of the planktonic euphausiid *Nyctiphanes australis*. Neither Safina *et al.* nor Mills mentioned the relative dependence of each breeding phase. Consequently, the results of their studies do not conflict with the above suggestion. In south-eastern Australia, Carrick and Murray (1964) considered that food supply within the foraging range of breeding birds was the factor most responsible for regulating colony size in the Silver Gull. The quality and quantity of food taken in winter before eggs are laid may also be a regulatory factor.

In recent years, late breeders on the Five Islands have produced considerably fewer young than early breeders (pers. obs.). In November–December 1988 about half as many pairs attempted to breed as in August–September and the breeding success to fledging was less than one chick from every ten nests (G. C. Smith, unpubl. data). Although they have longer daylight hours in which to forage (Fig. 3), late breeders may not ingest satisfactory food either before laying eggs, while feeding chicks or in both breeding stages. Absence of Silver Gulls from the pelagic zone before the second breeding each year, but not before the first, is consistent with this possibility.

Comparative measurement of hatching and fledging success rates would identify the breeding phase responsible for low reproduction in late breeders.

The zonal shift in distribution of Crested Terns coincided with the commencement of the breeding cycle in October. While courting, egg-laying and chick-raising, this species probably acquired suitable food closer to the coast than at other times. The energy cost of flight itself is trivial (Ricklefs 1983) but reproductive performance is enhanced if foraging times are reduced. Crested Terns counted in the neritic zone while not breeding comprised about 40 per cent of the total, compared with 66 per cent while breeding (Fig. 4). It seems reasonable to suggest that a majority of the 2 500 breeding pairs on the Five Islands obtained their food from the surrounding neritic zone during the breeding season. The sporadic nature of abundance (Fig. 1 and species account) probably reflects patchiness in prey. Coarse scale ocean features (0–100 km) often produce localized patches of nekton and zooplankton which in turn concentrates prey for piscivourous birds (Hunt and Schneider 1987). Concentrations of suitable prey in the study area would account for abundance peaks; remote concentrations would account for a paucity of birds. The ability of Crested Terns to prey on localized schools of fish on the Great Barrier Reef has been reported by Hulsman *et al.* (1989) but the limit of their feeding range, beyond which success is impaired, has not been studied.

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BOOK REVIEW

The Petrels. Their Ecology and Breeding Systems.
John Warham. 1990. Academic Press.
440 pp., numerous photographic illustrations and line drawings etc., 250 × 170 mm, rrp. $104.45.

This is a truly magnificent compendium about one of the most fascinating of the several groups of seabirds. The book deals with members of the order Procellariiformes, the highly distinctive group of oceanic birds, which includes the albatrosses, fulmars, gadfly petrels, prions, shearwaters, storm-petrels and diving-petrels. The quality of production is excellent.

The first chapter is a brief summary of the general characters of the group stressing special features like the unique formation of the nostrils (the 'tubenoses') and the unusual structure of the bill. The review covers many other matters concerning external morphology, anatomy, body size, allometry, general ecology, breeding ecology, global distribution, populations, systematics and nomenclature. The first half of the book continues in the form of a series of reviews which deal briefly with what is known about the biology of living species in a family by family treatment. The fossil record is mentioned in the opening section to each of these chapters and the body of the text covers in a most competent manner the wide range of topics that constitute the accumulating body of knowledge available from the group as a whole. Furthermore, these reviews help to point out the lack of information on some topics and the imperfect understanding about the biology of certain species.

The remainder of the book deals with breeding biology and is presented in the from of a sequence of chapters on the pre-egg stage, the egg, incubation, and finally the chick. This is the real meat of the book and reflects many of the lifelong interests of the author.

In a work of this type it would be easy to quibble over details but I noted, for example, that the book is short on matters concerning important questions about olfaction and it was pointed out to me that there is not very much attention given to the interesting matter of polymorphism in the Southern Giant-Petrel, *Macronectes giganteus*. The taxonomy and systematic treatment adopted for the work is essentially conventional with some minor modifications and novelties derived from special knowledge, mostly based on work by fellow New Zealanders. It is revealed that a companion volume is in preparation that will look in detail at subjects such as behaviour and vocalizations, energetics and physiology, populations, food and feeding, distribution, human use, and conservation and management. It might therefore be premature to carp at presumed omissions from this book for they may have been deliberately deferred to a later more extensive discussion.

Personally, I have great admiration for the courage required of a single author to undertake a work of this type in the scientific world of today. The sheer energy and thoroughness of purpose which must go into such compilations must be very demanding. Nothing the least bit comparable has been attempted with respect to petrels since the publication in 1936 of Robert Cushman Murphy's classic *Oceanic birds of South America*.

There are many excellent line drawings scattered throughout the book and a sprinkling of well-chosen and delightful photographs, mostly by the author, all of which illustrate various points or portray certain species. There is an extensive list of references and an Appendix giving an abbreviated checklist of the order showing the genera, species and subspecies names (without synonymy and not always giving authority) alongside a brief description of breeding ranges. There is an index to species and to subject.

It may seem to be an expensive book but it will prove to be indispensable for anyone seriously interested in these magnificent birds. Deserved attention to the delights and fascination of petrels have been well served by John Warham in this the first part of his proposed two work *magnum opus*. The expectation of that companion volume must hold us in suspense for the while.

P. J. Fullagar
Lyneham, ACT