Vol. 45: 1–11, 1988 | MARINE ECOLOGY – PROGRESS SERIES Mar. Ecol. Prog. Ser. | Published June 20

Effect of trawling on bird and seal distributions in the southern Benguela region

P. G. Ryan, C. L. Moloney

Percy FitzPatrick Institute of African Ornithology and Marine Biology Research Institute, University of Cape Town, Rondebosch 7700, South Africa

ABSTRACT: Attendance patterns of seabirds and Cape fur-seals *Arctocephalus pusillus pusillus* at research trawls in the southern Benguela region during the austral winter are analysed to infer the importance of trawl fisheries to different seabird and seal species. Three specific responses to trawlers are recognized: (1) species that avoid feeding assemblages at trawlers (jackass penguin *Spheniscus demersus*, soft-plumaged petrel *Pterodroma mollis*, Cape cormorant *Phalacrocorax capensis*); (2) species that consistently are attracted to trawlers and whose distributions are influenced by trawlers (black-browed albatross *Diomedea melanophris*, shy albatross *D. cauta*, pintado petrel *Daption capense*, white-chinned petrel *Procellaria aequinoctialis*); (3) species that only forage at trawlers in deep, offshore waters (Cape gannet *Sula capensis*, kelp gull *Larus dominicanus*, Cape fur-seal). Other species lie between these extremes. These variations in response indicate the importance of trawler discards in each species' diet. The divisions do not follow the guild classification used for the region to date. Reported increases in seabird populations as a result of trawling activity should be interpreted with caution.

INTRODUCTION

The importance of parasitic and commensal relationships between marine predators and fisheries are poorly understood (Watson 1981, Burger & Cooper 1984, Abrams 1985). Many marine predators steal food from fishing nets and scavenge fishery wastes (Brown 1970, Bartle 1974, Wahl & Heinemann 1979, Shaughnessy et al. 1981, Watson 1981, Abrams 1983), and this may be responsible for increases in seabird populations (Fisher 1952, 1966), but the evidence is equivocal (Salomonsen 1965, Brown 1970, Bailey & Hislop 1978).

The shelf waters off the west and south coasts of southern Africa, the southern Benguela region, support a large demersal trawl-fishery, aimed primarily at hake *Merluccius* spp. (Crawford et al. 1987). The region also supports a diverse seabird community (Brooke 1981), many individuals of which forage at trawlers, as do Cape fur-seals *Arctocephalus pusillus pusillus* (Rodriguez 1972, Shaughnessy et al. 1981, Abrams 1983). Abrams (1983, 1985) described trawler attendance by seabirds in different dietary guilds off the west coast of southern Africa, and attempted to show changes in community structure brought about by the trawl-fishery. However, he did not establish the importance of trawler waste in seabird diets, and failed to consider species-specific differences (e.g. Wahl & Heinemann 1979) because of a simplistic guild approach.

This study examines the influence of the southern Benguela demersal trawl-fishery on seabird and seal distributions by (1) identifying the principal factors determining the spatial attendance patterns of scavenging birds and seals at trawls, and (2) by estimating the relative attraction of trawlers to different species. Work was conducted during the austral winter because this is the period when the largest numbers of migrant seabirds from the Southern Ocean are present (Ryan & Rose in press), and trawler attendance is greatest (Abrams 1985). The importance of the fishery to different species is inferred from the impact of the fishery on species distributions. Some of the assumptions made by Abrams (1983, 1985) to infer recent changes in seabird populations are examined in the light of our data.

METHODS

Data collection. The numbers of seabirds and seals attending 82 research trawls were counted between 4 and 27 July 1984. Trawls were conducted during the day from the R. S. 'Africana' using a 60 m trawl net to

0171-8630/88/0045/0001/$ 03.00

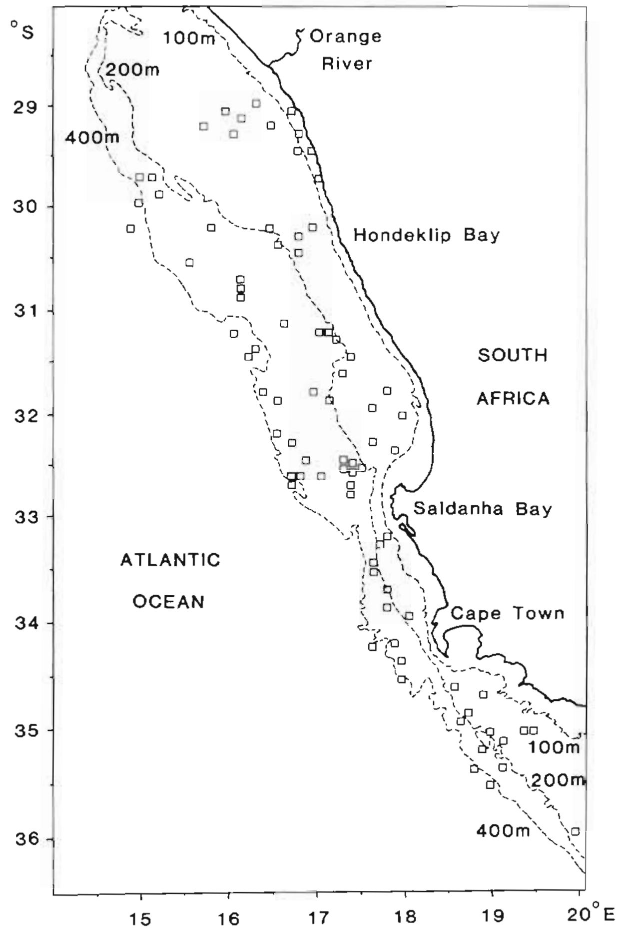

Fig. 1. Study area with the positions of 82 research trawl stations and 3 isobaths

assess demersal fish stocks, at stations selected by random stratified sampling (by water depth) in the southern Benguela region, between the Orange River Estuary and Cape Agulhas (Fig. 1). The duration of each trawl varied with water depth, because all drags (= bottom time) lasted 30 min. The fishing operation differed from those of commercial trawlers operating in the area; a pilchard net-liner (27.5 mm mesh diameter) in the cod-end retained small fish, drags were shorter than commercial trawls (usually 3 h), and most fish were discarded after sampling. However, these differences should not affect the survey results because they were consistent for all research trawls.

Counts of attendant seabirds and seals were made during 20 min following the net surfacing, from an 8 m vantage overlooking the stern. The maximum number of individuals of each species within a 500 m radius of the ship was recorded by the same observer throughout. Northern and southern giant-petrels, and common and Arctic ('commic') terns were lumped because not all individuals could be identified to the species level (scientific names of all species are listed in Table 2). The majority of prions were Antarctic prions *Pachyptila desolata*, but other species may have been overlooked.

An index of recent commercial trawling activity (I) in the vicinity of each station was derived from industry returns for June and July 1984, which record the number of trawls made in 35 × 35 km grid blocks, such that:

2I = No. of trawls in a station's grid block +
(Total no. of trawls in 4 adjacent grid blocks) / 4

where adjacent blocks were those with a common side with the station's grid block. The index smoothed the data to weight grids according to their position in the trawling area. A truncated index of recent trawling activity (T) was obtained by imposing an arbitrary maximum value for (I) of 100. This further smoothed the trawling intensity data by reducing geographical variation around the coast (resulting from concentrations of effort near fishing ports). The following variables also were recorded for each station: water depth (m), distance offshore (to nearest land, km), sea surface temperature (°C), time of day, time since the previous trawl, the mass of fish and squid caught (kg), and the mass of fish and squid potentially available to birds (i.e. all fish/squid <2 kg).

Density estimates (number km^{-2}) of seabirds and seals at sea were made using census techniques modified from Tasker et al. (1984). All seabirds and seals passing within 200 m of the ship were counted while the ship steamed at approximately 20 km h^{-1} between trawl stations. Observations were made from the bridge wing (elevation 11 m), and scanned a 90° arc between the bow and beam. No observations were made within 30 min of leaving a station to reduce the effects of bird/mammal aggregations at trawl stations.

Data analysis. Stepwise multiple correlations were performed using Statpro (Imhof et al. 1983) to test for the environmental variables and fishery statistics best correlated with the distributions of the 12 most abundant species attending trawls. This technique allows for the interdependence of variables (Draper & Smith 1981), many of which are correlated here (Table 1). Analysis was terminated when no additional variable was correlated at below the 5 % significance level.

Classification and ordination analyses (Field et al. 1982) were performed on the numbers of the 12 most abundant bird and mammal species attending trawls to identify spatial differences in the composition of the trawl assemblage. Classifications were performed using a Bray-Curtis measure of similarity and group average sorting. Ordination analysis was by non-metric multidimensional scaling of the Bray-Curtis similarity matrix. Groups of similar trawl stations identified by classification analyses were analysed in terms of the following environmental variables and fishery statis-

Table 1. Linear correlation *(r)* matrix for variables describing research trawl stations. Significance level is denoted by the number of symbols, 1 to 3 equivalent to $p < 0.05$, 0.01 and 0.001 respectively

Parameter	Water depth	Distance offshore	Surface temp.	Trawl index (I)	Trawl index (T)	Total catch	Bird-avail. catch
Water depth	1.00	0.69	0.59	0.18	0.52	0.08	0.18
Distance offshore	+++	1.00	0.43	−0.06	0.09	−0.03	−0.08
Surface temperature	+++	+++	1.00	0.29	0.49	0.01	−0.19
Trawl index (I)			++	1.00	0.70	0.24	0.07
Trawl index (T)	+++		+++	+++	1.00	0.24	0.18
Total catch				+	+	1.00	0.45
Bird-available catch						+++	1.00

tics: water depth, distance offshore, sea surface temperature, total catch, bird-available catch, and indices of recent trawling activity. A mean value was calculated for each variable in each group. Significant differences between means were tested using ANOVA. If a significant difference occurred, a Newman-Keuls Multiple Range Test was used to identify which groups differed. This test is less powerful than ANOVA, and Type II errors occurred if a significant difference identified by ANOVA could not be detected by the range test (Zar 1984).

Estimates of seabird and seal densities at sea derived from census transects were lumped into 3 major faunal areas identified by the classification analyses of trawl attendance patterns. The mean density of each species in each of the 3 areas was used to calculate the theoretical radius of attraction (R) which would supply the mean number of individuals observed to attend trawls

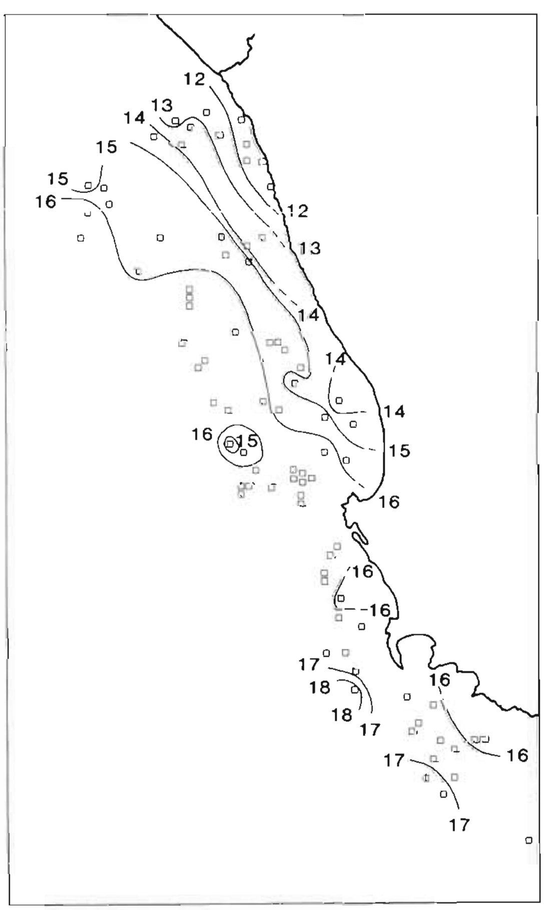

Fig. 2. Sea surface isotherms (°C) during July 1984

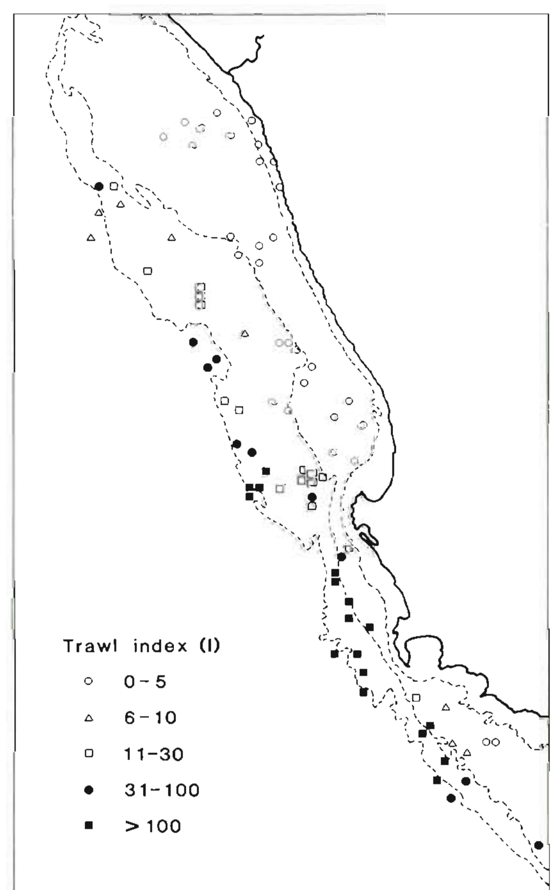

Fig. 3. Index of commercial trawling activity (I) during June to July 1984

in that area, assuming that all individuals within the radius of attraction would be attracted to a trawl. This provides a convenient index of the importance of point attractants such as fishing vessels, other ships, predatory fish, cetaceans, etc. (Wahl & Heinemann 1979).

RESULTS

Research trawls sampled the shelf waters of the southern Benguela region between 5 and 210 km offshore, and in water between 80 and 540 m deep (Fig. 1). Sea surface temperatures generally were greater farther offshore, with a minimum of 11.0 °C inshore in the north, and a maximum of 18.4 °C over the shelf edge off Cape Town (Fig. 2). There were significant correlations between water depth, distance offshore and sea surface temperature (Table 1).

Research trawls took place in areas of both great and little commercial trawling activity, the index (I) ranging between 0 and 630. Most commercial trawling activity occurred in water between 200 and 500 m deep and effort was most concentrated near the ports of Saldanha Bay and Cape Town (Figs. 1 & 3). The trawl index (I) was poorly correlated with environmental variables (water depth, distance offshore and sea surface temperature), due to regional differences in fishing effort. This variability was reduced using the truncated index (T), which was significantly correlated with both water depth and sea surface temperature (Table 1).

The mass of fish caught by research trawls ranged from 2 to 3500 kg, of which between 1 and 1600 kg comprised fish small enough to be handled by seabirds. There was no clear spatial pattern in the magnitude of fish catches, other than a tendency for larger total catches in areas with more commercial trawling activity (Table 1).

Specific patterns of attendance

A total of 25 species of seabirds and a marine mammal, the Cape fur-seal, were observed attending research trawls (Table 2). An additional 6 species of seabird were seen during the cruise, but were not observed to attend trawls: jackass penguin *Spheniscus demersus* (N = 43), great-winged petrel *Pterodroma macroptera* (10), Kerguelen petrel *P. brevirostris* (25), soft-plumaged petrel *P. mollis* (186), grey petrel *Procellaria cineria* (1), and little shearwater *Puffinus*

Table 2. Frequency of occurrence and numbers of seabirds and seals attending 82 standardized research trawls conducted off the west coast of South Africa during July 1984. B: a species which breeds in the Benguela Current region; M: a migrant to the area

Species	Frequency of occurrence (%)	Mean number per trawl	N
White-chinned petrel *Procellaria aequinoctialis* (M)	100	79.7	6533
Black-browed albatross *Diomedea melanophris* (M)	68	59.5	4875
Pintado petrel *Daption capense* (M)	87	58.2	4770
Shy albatross *Diomedea cauta* (M)	85	21.0	1721
Sooty shearwater *Puffinus griseus* (M)	91	20.4	1671
Cape gannet *Sula capensis* (B)	90	17.2	1407
Cape fur-seal *Arctocephalus p. pusillus* (B)	82	7.7	634
Prions *Pachyptila* spp. (M)	83	6.2	508
Wilson's storm-petrel *Oceanites oceanicus* (M)	68	5.6	457
Kelp gull *Larus dominicanus* (B)	27	5.4	442
Subantarctic skua *Catharacta antarctica* (M)	82	4.1	336
Yellow-nosed albatross *Diomedea chlororhynchos* (M)	51	1.2	101
Swift tern *Sterna bergii* (B)	5	0.7	54
Antarctic tern *Sterna vittata* (M)	10	0.5	42
Giant-petrels *Macronectes halli/giganteus* (M)	18	0.2	19
Common/Arctic terns *Sterna hirundo/paradisaea* (M)	15	0.2	18
Blue petrel *Halobaena caerulea* (M)	17	0.2	16
Grey-headed albatross *Diomedea chrysostoma* (M)	16	0.2	15
Wandering albatross *Diomedea exulans* (M)	10	0.1	10
Cape cormorant *Phalacrocorax capensis* (B)	4	0.1	6
Antarctic fulmar *Fulmarus glacialoides* (M)	5	< 0.1	4
Hartlaub's gull *Larus hartlaubii* (B)	1	< 0.1	3
South polar skua *Catharacta maccormicki* (M)	2	< 0.1	2
Royal albatross *Diomedea epomophora* (M)	1	< 0.1	1
Great shearwater *Puffinus gravis* (M)	1	< 0.1	1
Sabine's gull *Larus sabini* (M)	1	< 0.1	1

assimilis (2). Twelve species occurred at more than 25 % of trawl stations, with a mean attendance of more than one individual per station (Table 2). Nine of these 12 species are non-breeding migrants to the Benguela region, all breeding farther south in the Southern Ocean. The remaining 3 species breed in southern Africa (Table 2).

The spatial distribution of trawler attendance differed between species. Black-browed albatrosses were most abundant at trawls near the shelf edge (Fig. 4), as were pintado petrels and white-chinned petrels. The numbers of these species attending research trawls were positively correlated with the truncated index of recent trawling activity (T), although black-browed albatrosses were better correlated with water depth (Table 3). These variables accounted for more than 40 % of variance in trawler attendance for all 3 species. Shy albatrosses, yellow-nosed albatrosses, Wilson's storm-petrels and sub-antarctic skuas also were most abundant at trawls near the shelf edge, but were present in larger numbers north of Saldanha Bay, and were best correlated with distance offshore (Table 3). The proportion of variance accounted for by distance offshore was relatively small for all these species, except shy albatross, probably as a result of small abundances and patchy distributions. The distribution of shy albatross attendance also was positively correlated with the trawling index (T).

Prions showed no clear spatial pattern to their attendance at trawls (Fig. 5). The attendance pattern of

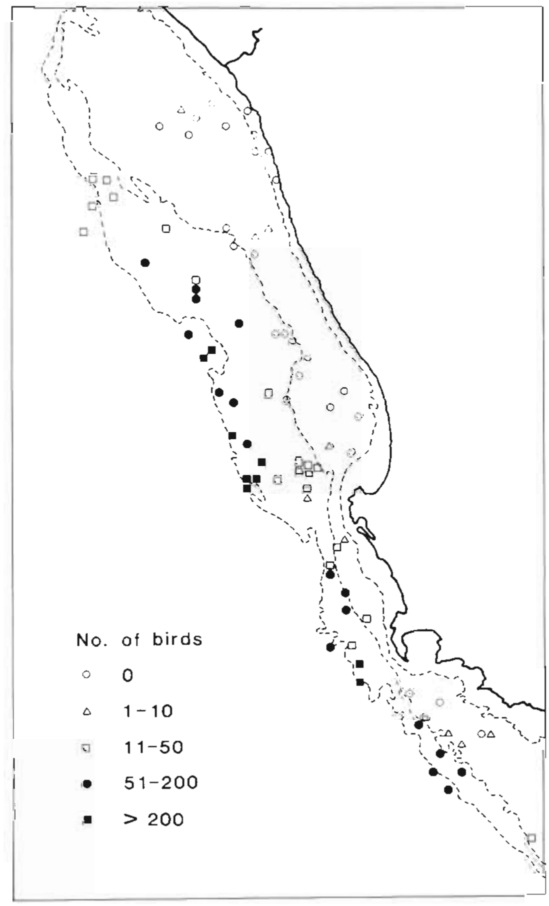

Fig. 4. Numbers of black-browed albatrosses attending trawls

Table 3. Independent variables influencing the patterns of trawler attendance by the 12 most abundant species at trawls, as calculated by stepwise multiple correlation analyses (N = 82)

Species	Independent variable	Sign	Cumulative r^2
White-chinned petrel	Trawl index (T)	+	0.479
Black-browed albatross	Water depth	+	0.422
	Trawl index (T)	+	0.448
	Sea surface temperature	−	0.477
Pintado petrel	Trawl index (T)	+	0.503
	Distance offshore	+	0.529
	Water depth	−	0.566
Shy albatross	Distance offshore	+	0.460
	Trawl index (T)	+	0.552
	Total catch	+	0.572
Sooty shearwater	Water depth	+	0.231
Cape gannet	Trawl index (T)	+	0.049
	Water depth	−	0.080
Cape fur-seal	Trawl index (T)	+	0.330
	Distance offshore	−	0.461
Prion spp.	Sea surface temperature	+	0.175
Wilson's storm-petrel	Distance offshore	+	0.169
Kelp gull	Trawl index (I)	+	0.207
	Distance offshore	−	0.289
	Bird-available catch	+	0.341
Sub-antarctic skua	Distance offshore	+	0.162
Yellow-nosed albatross	Distance offshore	+	0.258

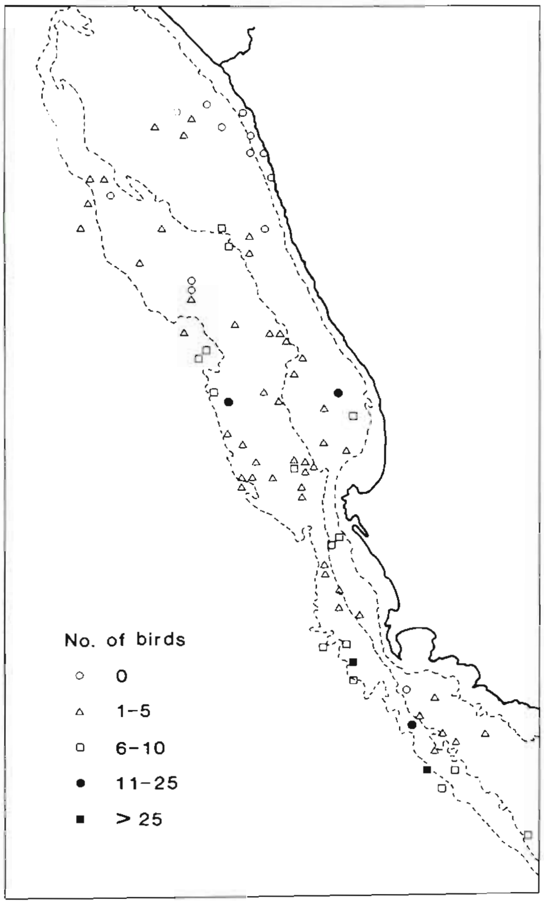

Fig. 5. Numbers of prions attending trawls

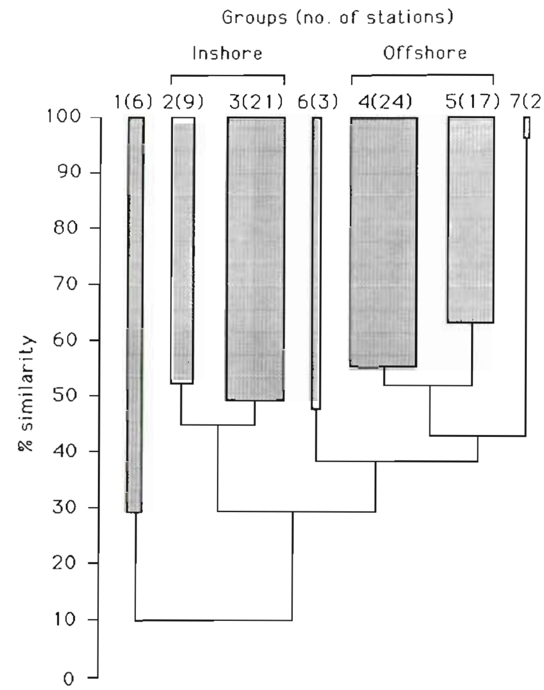

Fig. 6. Simplified dendrogram of trawl groups, based on numbers of the 12 most abundant species attending trawls. Number of stations in each group given in parentheses after group number

prions was positively correlated with sea-surface temperature, but the amount of variance accounted for was small (Table 3). Sooty shearwaters also were seldom attracted to trawls in large numbers, and their distribution at trawls was only poorly correlated with water depth (Table 3).

The 3 locally-breeding species which were abundant at trawls, Cape gannet, kelp gull and Cape fur-seal, all were positively correlated with indices of trawling activity (either I or T) (Table 3). When this factor has been accounted for, the numbers of all 3 species attending trawls were negatively correlated with either distance offshore or water depth. The numbers of Cape gannets and Cape fur-seals attending trawls were best correlated with (T) because they were more dispersed over the trawling grounds than were kelp gulls (best correlated with I), which were abundant only on grounds close to fishing harbours.

Time of day and the interval since the previous trawl had no effect on the overall distributions of seabirds and seals. However, large numbers of seabirds and some seals occasionally followed the ship between trawl stations.

Classification of trawl stations

Bird/mammal abundances were used to produce a classification dendrogram of trawl stations. Six stations close inshore in the north were split off in a discrete, if poorly inter-related group (1) (Figs. 6 & 7). The remaining stations were separated into 2 major faunal areas, one characterized by inshore, shallow water stations, the other by offshore, deeper water stations. The inshore and offshore areas were each subdivided into 2 large groups (called 2 and 3 for the inshore group, and 4 and 5 for the offshore group). Three anomalous stations in the mouth of Saldanha Bay (Group 6) were only distantly linked to the offshore groups. They were characterized by large numbers of seals, gannets and kelp gulls, and were not considered further. Two very similar stations near the shelf break off Hondeklip Bay formed a distinct group (7) only distantly related to the other offshore groups (4 & 5) as a result of unusually large numbers of Wilson's storm-petrels and black-browed and yellow-nosed albatrosses. The 2 stations were very close together and the feeding assemblage stayed with the ship, allowing exceptional numbers to gather. These stations were also excluded from further analyses. The ordination plot of trawl stations showed a clear gradation between Groups 1 and 5 identified by classification analysis (Fig. 8).

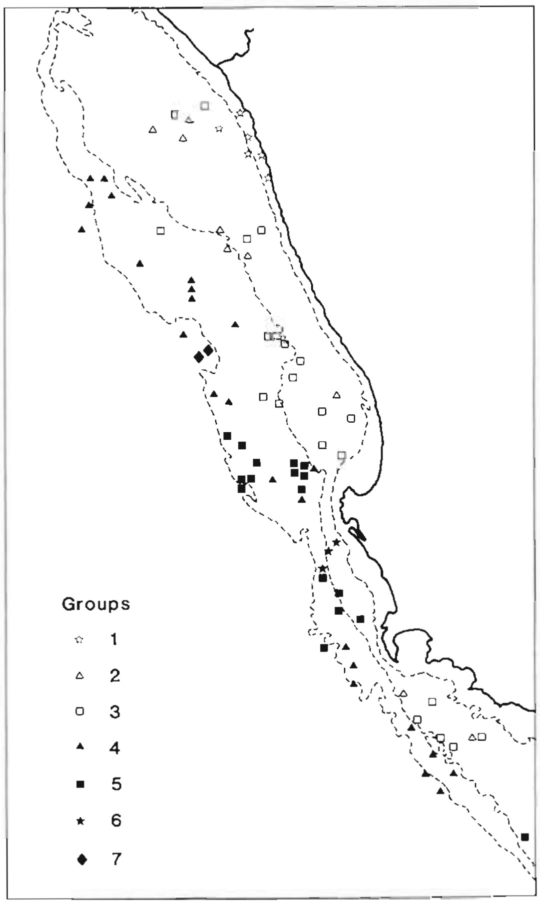

Fig. 7. Spatial pattern of research trawls classified into 6 groups on the numbers of attendant seabirds and seals

The mean total number of birds and seals attending trawls increased from Groups 1 through 5, as did the mean number of species (Table 4). The mean number of each of the 12 most abundant species at trawls also increased from Groups 1 through 5, except for prions, Wilson's storm-petrels and kelp gulls (Table 4). Indices of commercial trawling activity also increased from Groups 1 through 5. Mean water depth, distance offshore and sea-surface temperature increased from Groups 1 through 4, but were greater in Group 4 than in Group 5 (Table 4). The trawl index (T) was the only variable that differed significantly between Groups 4 and 5, with Group 5 distinct (Table 5), suggesting that in the offshore region trawling activity is the major determinant of bird distribution patterns.

Comparison with density at sea

The total density of birds and seals at sea based on transects was similar in each of the 3 areas considered, but the species composition differed markedly (Table 6). Prions were the most abundant species in the mid- and offshore areas (Groups 2 & 3 and 4 & 5), followed by sooty shearwaters and white-chinned petrels (Table 6). Cape fur-seals, Cape cormorants and swift terns were most abundant in the inshore zone (Group 1). The offshore area (Groups 4 & 5) had higher densities of albatrosses and pintado petrels than the midshelf area (Groups 2 & 3).

Although sample sizes for some species were small, approximate radii of attraction were consistent

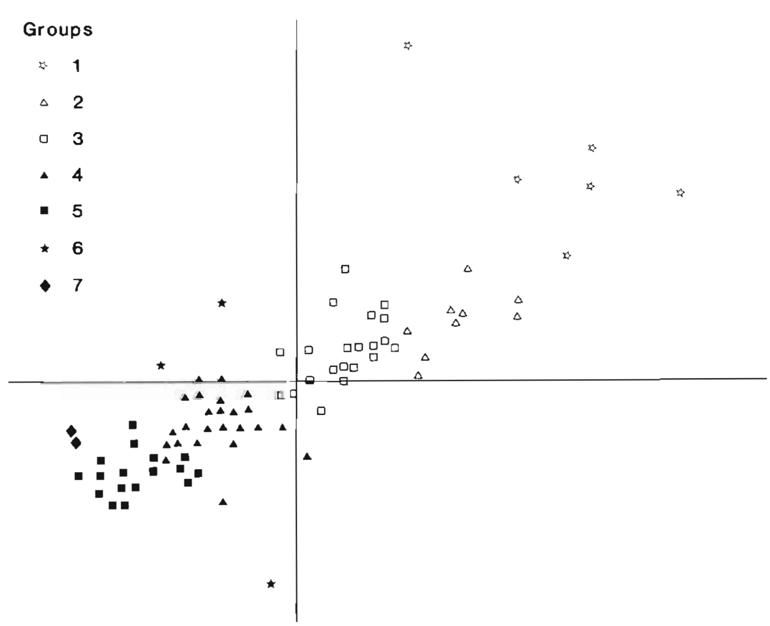

Fig. 8. Ordination of research trawls based on numbers of the 12 most abundant seabird and seal species attending trawls

Table 4. Means and standard deviations of the numbers of birds and seals attending trawls and the values of environmental variables and fishery statistics for the 5 groups of trawl stations identified by classification analyses

Species/variable	Group number (N trawls)									
	1 (6)		2 (9)		3 (21)		4 (24)		5 (17)	
	mean	(SD)	mean	(SD)	mean	(SD)	mean	(SD)	mean	(SD)
White-chinned petrel	6.2	(3.7)	17.9	(4.8)	47.4	(16.6)	69.8	(26.2)	198.3	(58.5)
Black-browed albatross					2.9	(7.0)	77.1	(54.3)	111.5	(110.3)
Pintado petrel	0.2	(0.4)	1.8	(2.1)	4.1	(4.2)	57.8	(38.5)	181.2	(87.5)
Shy albatross			2.9	(3.8)	4.7	(5.4)	35.2	(28.4)	36.5	(27.4)
Sooty shearwater	0.2	(0.4)	5.1	(2.9)	22.0	(17.5)	25.3	(15.1)	22.4	(13.3)
Cape gannet	0.7	(0.8)	2.7	(2.7)	6.4	(7.1)	8.7	(6.9)	22.2	(23.4)
Cape fur-seal	1.2	(1.0)	1.2	(1.7)	3.1	(3.1)	7.3	(7.7)	17.2	(6.8)
Prion spp.			4.8	(5.2)	2.9	(2.5)	11.2	(20.8)	5.3	(2.5)
Wilson's storm-petrel			8.3	(8.7)	4.2	(5.3)	5.2	(3.7)	4.7	(4.3)
Kelp gull	7.8	(11.3)	0.3	(1.0)	1.5	(4.7)	0.5	(1.7)	4.0	(7.6)
Sub-antarctic skua			1.6	(1.2)	2.2	(1.5)	6.9	(9.2)	4.4	(3.1)
Yellow-nosed albatross			0.3	(0.7)	0.6	(1.1)	1.9	(1.6)	1.3	(1.3)
Total no. birds + seals	22.2	(13.7)	47.2	(22.5)	102.6	(39.5)	308.2	(96.7)	611.1	(182.0)
Number of species	4.7	(0.5)	7.3	(2.1)	9.1	(2.0)	11.7	(1.6)	12.8	(1.7)
Water depth	98.8	(20.6)	171.3	(25.0)	172.0	(34.1)	320.8	(91.2)	299.9	(101.1)
Distance offshore	12.5	(10.9)	56.1	(19.5)	57.3	(24.6)	112.8	(51.1)	77.1	(34.8)
Surface temperature	11.5	(0.6)	14.6	(1.1)	15.0	(1.2)	16.3	(0.8)	15.8	(0.6)
Trawl index (I)	0.1	(0.0)	2.3	(4.2)	3.8	(9.9)	83.9	(171.6)	101.8	(90.9)
Trawl index (T)	0.1	(0.0)	2.3	(4.2)	3.8	(9.9)	43.2	(38.6)	68.7	(35.7)
Total catch	428.0	(306.1)	164.6	(187.7)	198.6	(171.7)	376.5	(358.9)	633.1	(862.5)
Bird-available catch	410.3	(296.2)	66.8	(58.0)	144.2	(151.3)	190.5	(170.1)	370.8	(441.1)

between areas, at least for migrant species (Table 6). Pintado and white-chinned petrels, black-browed and shy albatrosses, sub-antarctic skuas and Wilson's storm-petrels were present in relatively large concentrations at research trawls (radius of attraction, R >3 km). Giant-petrels, blue petrels, and sooty shearwaters were concentrated to an intermediate extent (1 < R < 3 km), whereas terns, prions and Cape cormorants were not concentrated at research trawls (R < 1 km). Yellow-nosed albatrosses were frequent at trawls but were not recorded during transects, whereas jackass penguins and soft-plumaged petrels were seen during transects, but did not attend trawls.

The radii of attraction of the 3 local breeding species increased with increasing distance from shore. In the offshore area, Cape gannets, kelp gulls and Cape fur-seals had large radii of attraction characteristic of species strongly attracted to research trawls, but in the mid- and inshore areas, they had relatively small radii of attraction (Table 6). Cape fur-seals were not only less attracted to inshore trawls, but those which were attracted to inshore trawls were more frequently

Table 5. Tests of the significance of differences (ANOVA and Newman-Keuls Multiple Range Test) between mean values of variables describing trawl stations of the 5 major groups identified by classification analyses. Significant differences occur between sets of groups in parentheses

Variable	ANOVA *F*	ANOVA significance	Newman-Keuls Test of group differences
Total no. birds + seals	78.71	$p < 0.001$	(1 = 2 = 3) (4) (5)
Number of species	35.16	$p < 0.001$	(1) (2) (3) (4) (5)
Water depth	22.24	$p < 0.001$	(1 = 2 = 3) (4 = 5)
Distance offshore	13.05	$p < 0.001$	(1) (2 = 3 = 5) (4)
Surface temperature	33.74	$p < 0.001$	(1) (2 = 3) (4 = 5)
Trawl index (I)	3.80	$p < 0.05$	Type II error*
Trawl index (T)	31.48	$p < 0.001$	(1 = 2 = 3) (4) (5)
Total catch	2.44	NS	
Bird-available catch	3.57	$p < 0.05$	Type II error

* See Methods for explanation

Table 6. Density (number km^{-2}) of seabirds and seals at sea as determined by transects in each of the 3 major faunal areas, and the radius of attraction (R) necessary to attract the mean number of individuals of a species to a trawl in each area. *N*: number of birds seen during transects; +: presence in trawl assemblages when none was recorded during transects

Species	Group 1 (7.8 km^2)			Groups 2 & 3 (51.8 km^2)			Groups 4 & 5 (49.1 km^2)			Mean *R* (km)
	density	*N*	*R* (km)	density	*N*	*R* (km)	density	*N*	*R* (km)	
Pintado petrel			+	0.04	2	5.3	1.49	73	4.8	5.0
Black-browed albatross						+	1.69	83	4.6	4.6
Sub-antarctic skua				0.08	4	2.9	0.10	5	4.5	3.7
Shy albatross				0.12	6	3.4	0.79	39	3.8	3.6
White-chinned petrel	0.13	1	3.8	1.91	99	2.5	2.32	114	4.1	3.5
Wilson's storm-petrel				0.10	5	4.2	0.31	15	2.6	3.4
Kelp gull	1.03	8	1.4	0.15	8	1.0	0.02	1	5.4	2.6
Giant-petrel spp.							0.02	1	2.4	2.4
Blue petrel			+			+	0.02	1	2.1	2.1
Cape fur-seal	8.72	68	0.2	0.91	47	0.9	0.16	8	4.6	1.9
Cape gannet	0.13	1	1.3	1.08	56	1.3	0.71	35	2.6	1.7
Sooty shearwater	0.13	1	0.6	1.95	101	1.7	2.42	119	1.8	1.4
'Commic' tern spp.			+	0.42	22	0.6			+	0.6
Prion spp.				8.03	416	0.4	9.19	451	0.6	0.5
Swift tern	4.49	35	0.7	0.10	5	0.0				0.4
Cape cormorant	8.97	70	0.2	1.70	88	0.0				0.1
Soft-plumaged petrel							0.22	11	0.0	0.0
Jackass penguin				0.46	24	0.0				0.0
Total no. birds + seals	23.60	184	0.6	17.05	883	1.3	19.46	956	2.7	

drowned in the net than were seals attending trawls farther offshore; 2 of the 7 seals attending trawls in Group 1 drowned, compared with 1 of 76 in Groups 2 & 3, and 0 of 551 in Groups 4 & 5 (G = 19.08, d.f. = 2, $p > 0.001$, Zar 1984).

DISCUSSION

The diets of many seabird species in the southern Benguela region are little known (Jackson 1988). It is not possible to infer the importance of food derived from trawlers in the diets of seabirds and seals from numbers feeding at and away from trawlers, because estimates of seabird population sizes in the area are crude and there are no published estimates of seabird numbers attending commercial trawlers. However, we suggest that the importance of trawlers as a source of food can be inferred by comparing the distributions of seabirds and seals with that of commercial trawlers, and by estimating the relative attraction of trawlers. The effect of trawlers on seabird and seal distributions in the southern Benguela region is likely to be most marked in mid-winter (the period of this survey) when numbers of migrant seabirds (many of which attend trawlers) are greatest (Ryan & Rose in press) and trawler catches of hake are smallest (ICSEAF Division 1.6, Crawford & De Villiers 1984), resulting in the greatest aggregations at trawlers (Abrams 1985).

Both the correlation and classification analyses of seabird and seal attendance at trawls suggest that the distributions of black-browed and shy albatrosses, pintado and white-chinned petrels, Cape gannets and Cape fur-seals are influenced significantly by commercial trawling activity. Trawling probably also has a major influence on the distributions of yellow-nosed albatrosses and sub-antarctic skuas, but their numbers are too few or attendance too patchy for significant relationships. By comparison, the distributions of prions, sooty shearwaters and Wilson's storm-petrels apparently are little affected by trawling activity, despite opportunistic foraging at trawlers.

Species seldom seen at trawls such as jackass penguins, soft-plumaged petrels and Cape cormorants were characterized by very small radii of attraction. The mean radii of attraction of species which attended trawls varied considerably, but species identified as being influenced by trawling activity generally had large radii of attraction, whereas species less influenced by trawling activity had small radii of attraction. This supports the hypothesis that commercial trawling activity is an important determinant of the distributions of certain seabird and seal species.

Dietary data from seabirds collected at sea in the southern Benguela Current region support these findings; trawler offal comprises more than half the diet of white-chinned petrels, but less than 5 % of the diet of sooty shearwaters (Jackson 1988).

We have assumed that the specific response to trawlers is approximately constant, and thus that the counts of birds attending trawlers reflect the distribution of birds at sea. This is a reasonable assumption for most species, but is invalid for the 3 local breeding species which frequent trawlers: Cape gannets, kelp gulls and Cape fur-seals. These species vary their reaction to trawlers largely as a function of water depth and distance from shore. They probably forage almost exclusively at trawlers in deep waters offshore, but are much less dependent on scavenged food inshore. The relatively small attraction exerted by research trawls to these species inshore, and the poor ability of at least fur-seals to exploit trawler discards at inshore stations, suggest that foraging at trawlers is individual-specific or perhaps age-specific in these species. The importance of trawlers as a food source to these species is presumably less than that for petrels and albatrosses which have consistently large radii of attraction.

The variation in specific responses to trawlers does not follow supposed feeding guilds used by Abrams & Griffiths (1981) and Abrams (1983, 1985). This demonstrates a major draw-back to the guild-level approach where the foraging ecology of species is poorly understood.

Commercial trawling has had an impact on seabirds in the Benguela Current region; the distributions of some species have expanded, apparently to exploit trawler discards, resulting in an increase in co-occurrence of different species (Abrams 1983, Cooper 1984, Abrams 1985). However, it is less clear whether the population sizes of species which feed at trawlers have increased, as inferred by Abrams (1983, 1985). Abrams compared counts of birds from a research vessel on oceanographic stations during the early 1950s, prior to extensive trawling activity, with recent density estimates from commercial trawlers, and from ship and aircraft transects. The experience of the observers varied greatly and the techniques used are not compatible. It was assumed that the point censuses from a stationary vessel censused 57 km^2 (Abrams 1985). This represents a radius of 4.3 km, the derivation of which is obscure; it is well beyond the range at which seabirds can be counted adequately (Tasker et al. 1984), and almost certainly is too great a radius of attraction (cf. Table 6) for an oceanographic vessel with less attraction to birds than trawlers (Wahl & Heinemann 1979, pers. obs.). These biases result in underestimates of seabird populations in the pre-trawling period, and may account for the population increases reported to have taken place as a result of trawling activity. Further work is required to assess the impact of fishery discards on seabird populations in view of likely reductions in the amount of discards in future (Furness 1984).

Acknowledgements. We are grateful for the co-operation and support of the South African Sea Fisheries Research Institute and the officers and crew of the R.S. 'Africana'. Barrie Rose assisted with the collection of data. Financial support was received from the Benguela Ecology Programme of the South African National Committee for Oceanographic Research, and the South African Scientific Committee for Antarctic Research.

LITERATURE CITED

Abrams, R. W. (1983). Pelagic seabirds and trawl-fisheries in the southern Benguela Current region. Mar. Ecol. Prog. Ser. 11: 151–156

Abrams, R. W. (1985). Pelagic seabird community structure in the southern Benguela region: changes in response to man's activities? Biol. Conserv. 32: 33–49

Abrams, R. W., Griffiths, A. M. (1981). Ecological structure of the pelagic seabird community in the Benguela Current region. Mar. Ecol. Prog. Ser. 5: 269–277

Bailey, R. S., Hislop, J. R. G. (1978). The effects of fisheries on seabirds in the northeast Atlantic. Ibis 120: 104–105

Bartle, J. A. (1974). Seabirds of eastern Cook Strait, New Zealand, in autumn. Notornis 21: 135–166

Brooke, R. K. (1981). The place of South Africans in the world of seabirds. In: Cooper, J. (ed.) Proceedings of the Symposium on Birds of the Sea and Shore, 1979. African Seabird Group, Cape Town, p. 135–147

Brown, R. G. B. (1970). Fulmar distribution: a Canadian perspective. Ibis 112: 44–51

Burger, A. E., Cooper, J. (1984). The effects of fisheries on seabirds in South Africa and Namibia. In: Nettleship, D. N., Sanger, G. A., Springer, P. F. (eds.) Marine birds: their feeding ecology and commercial fisheries relationships. Pacific Seabird Group, Seattle, p. 150–160

Cooper, J. (1984). Changes in resource division among four breeding seabirds in the Benguela upwelling system, 1953–1978. Proc. V. Pan-Afr. orn. Congr., Southern African Ornithological Society, Johannesburg, p. 217–230

Crawford, R. J. M., De Villiers, G. (1984). Chub mackerel *Scomber japonicus* in the south-east Atlantic – its seasonal distribution and evidence of a powerful 1977 year-class. S. Afr. J. mar. Sci. 2: 49–61

Crawford, R. J. M., Shannon, L. V., Pollock, D. E. (1987). The Benguela ecosystem. Part IV. The major fish and invertebrate resources. Oceanogr. mar. Biol. A. Rev. 25: 353–505

Draper, N. R., Smith, H. (1981). Applied regression analysis. 2nd edn. Wiley & Sons, New York

Field, J. G., Clarke, K. R., Warwick, R. M. (1982). A practical strategy for analysing multispecies distribution patterns. Mar. Ecol. Prog. Ser. 8: 37–52

Fisher, J. (1952). The Fulmar. Collins, London

Fisher, J. (1966). The Fulmar population of Britain and Ireland, 1959. Bird Study 13: 5–76

Furness, R. W. (1984). Seabird-fisheries relationships in the northeast Atlantic and North Sea. In: Nettleship, D. N., Sanger, G. A., Springer, G. F. (eds.) Marine birds: their feeding ecology and commercial fisheries relationships. Pacific Seabird Group, Seattle, p. 162–169

Imhof, M., Hewett, S., Imhof, K. (1983). Statpro: the statistics and graphics database workstation. Wadsworth, Boston

Jackson, S. (1988). Diets of the white-chinned petrel and sooty shearwater in the southern Benguela region, South Africa. Condor 90: 20–28

Rodriguez, L. G. (1972). Observaciones sobre aves marinas en las pesquerias del Atlantico Sudafricano. Ardeola 16: 159–192

Ryan, P. G., Rose, B. (in press). Migrant seabirds. In: Payne, A. I. L., Crawford, R. J. M. (eds.) Oceans of life off southern Africa. Vlaeberg, Cape Town

Salomonsen, F. (1965). The geographical variation of the Fulmar *(Fulmarus glacialis)* and the zones of marine environment in the North Atlantic. Auk 82: 327–355

Shaughnessy, P. D., Semmelink, A., Cooper, J., Frost, P. G. H. (1981). Attempts to develop acoustic methods of keeping Cape Fur Seals *Arctocephalus pusillus* from fishing nets. Biol. Conserv. 21 141–158

Tasker, M. L., Jones, P. H., Dixon, T., Blake, B. F. (1984). Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567–577

Wahl, T R., Heinemann, D. (1979). Seabirds and fishing vessels: co-occurrence and attraction. Condor 81. 390–396

Watson, P. S. (1981). Seabird observations from commercial trawlers in the Irish Sea. Br Birds 74: 82–90

Zar, J. H. (1984). Biostatistical Analysis, 2nd edn. Prentice-Hall, Englewood Cliffs, New Jersey

This article was presented by Professor J. G. Field; it was accepted for printing on April 1, 1988