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Front cover photo: Crested Terns feed on small fish such as Southern Anchovy *Engraulis australis* (Photo: Peter Menkhorst).

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Summary

- Numbers of piscivorous (fish-eating) waterbirds have been documented in Western Port since 1974 and in West Corner Inlet since 1987. This project analyses data from counts at both locations in late summer (February) and winter (June–July) for the 38 years from 1974 to 2012 (Western Port) and the 25 years from 1987 to 2012 (West Corner Inlet).

- The study has identified opposing population trends for each location (terns, cormorants and the Australian Pelican decreasing at Western Port, but increasing at West Corner Inlet).

- Most of the decline in piscivorous birds in Western Port could be attributed to declines in tern numbers. About 70% of the decline in tern numbers in Western Port was due to a decline in the Crested Tern, with the remainder mostly due to a decline in Fairy Tern numbers.

- The decline in numbers of Crested Terns in Western Port was most likely due to their reduced use of Western Port for feeding, since breeding numbers increased substantially at the western entrance to Western Port during the period of study.

- The results suggest that feeding conditions for terns (and to a lesser extent for cormorants and pelicans) in Western Port have deteriorated in comparison to feeding conditions in West Corner Inlet.

- No obvious cause is apparent for the increases in numbers of terns, cormorants and the Australian Pelican at West Corner Inlet, but the increasing success of commercial fishing (as measured by catch per unit effort) suggests that fish stocks may have increased there, providing improved foraging conditions.

- Resolving the causes of these changes requires further understanding of the factors affecting the productivity and availability of populations of the prey species consumed by piscivorous birds. For the Crested Tern, the Southern Anchovy (*Engraulis australis*) is a particularly important prey species.

- We postulate that changes in fish trophic relationships in Western Port have resulted in a reduction in food availability for the Crested Tern. Specifically, a reduction in the abundance of a predatory fish, Australian Salmon (*Arripis trutta*), has reduced the time that schools of small fish spend in surface waters, thereby reducing their accessibility to bird species that capture small fish by shallow plunge diving, such as terns.

- Understanding the factors affecting the productivity and availability of species of small, schooling fish is a key information gap identified by this study.

- Another information gap is the lack of knowledge about the population status and ecology of the Fairy Tern in Western Port and adjacent waters.

1   Introduction

Western Port is a large tidal embayment in central Victoria (Figure 1). It has a diverse and abundant aquatic avifauna, a reflection of the diversity, extent and productivity of its habitats (Dann 2011). There have been a suite of studies on aquatic birds in Western Port over the past 40 years (Loyn 1978, Corrick 1981, Lowe 1982a,b, 1983, Lane 1987, Dann 1993, 1994, Dann et al. 1994, Loyn et al. 1994, Dann 2000, Dann et al. 2001, Loyn et al. 2001, Dann et al. 2003, Chambers and Loyn 2006, Dennett and Loyn 2009, Dann 2011, Hansen et al. 2011, 2015), many of which are based on the BOCA (Bird Observers Club of Australia, now BirdLife Australia) waterbird surveys, which began in 1973.

Three of these studies have shown that the numbers of some piscivorous birds in Western Port have declined (Loyn et al. 1994, Hansen et al. 2011, 2015). Loyn et al. (1994) recorded declines in abundance of Australian Pelican, White-faced Heron and four species of cormorant between 1973 and 1984. They suggested that this may have been due to the major reduction in seagrass that occurred during that period. In a recent review of long-term trends in waterbird abundance in Western Port, Hansen et al. (2015) demonstrated significant declines in 24 of 39 (61.5%) waterbird species in Western Port over the 35 years from 1974 to 2009. The declining species included eight piscivores: Great Cormorant, Pied Cormorant, Little Black Cormorant, Little Pied Cormorant, Australian Pelican, White-faced Heron, Crested Tern, Fairy Tern). Three other piscivorous species (Great Egret, Royal Spoonbill and Caspian Tern) showed no decline over that period.

In a wide-ranging review, Dann (2011) identified three significant threats to the abundance and diversity of waterbirds in Western Port: (i) loss of habitat, (ii) disturbance caused by human recreational activity, and (iii) reductions in food supply due to commercial and recreational fishing, and to seagrass loss.

It is important to understand the causes of changes in numbers of top-order predators such as piscivorous birds, as they could indicate fundamental changes in the ecology of the bays. Management actions could then be devised and assessed to address such changes as appropriate.

During 2010, Melbourne Water commissioned a scientific review of Western Port ecosystems and threats to their functioning (Keough et al. 2011a). This review identified a number of potential threats to birds, and some research gaps (Dann 2011, Keough et al. 2011a). The review prioritised research needs and allocated 13 of the 43 recommendations made for future research into a Priority 1 category. One of these 13 Priority 1 research projects was to 'Examine the trend in the diversity and abundance of piscivorous birds in Western Port' (Keough et al. 2011b). Accordingly, Melbourne Water commissioned this study of long-term trends in the abundance of piscivorous birds in Western Port and in West Corner Inlet, a bay of similar size and complexity 100 km to the east, for which long-term waterbird monitoring data were also available. It aims to determine if the long-term trend in Western Port is mirrored by trends in piscivorous birds in West Corner Inlet, thereby indicating whether causal factors may be local or regional in origin and impact. Note that despite broad similarities, West Corner Inlet differs from Western Port in several crucial respects. For example, its catchment is less developed; it is less used by recreational fishers and boaters (as it is more remote from centres of human population, notably Melbourne), and it receives less input of fresh water from rivers. Both bays are sheltered by large islands near the entrance. However, West Corner Inlet faces south-east and is exposed to currents and weather from the Tasman Sea, whereas Western Port faces south-west into Bass Strait. Each site also has distinct geological and bathymetric features.

2   Methods

2.1   General approach

The approach involved three key steps:

1. An analysis of trends in abundance of piscivorous birds over the 38 years to 2012 for Western Port and the 25 years to 2012 for West Corner Inlet. Since most of the species occur in both bays, a comparison between the bays should provide an indication of whether any changes are specific to Western Port or part of a broader trend for piscivorous birds in coastal Victoria.

2. An analysis of the changed abundances in relation to the foraging strategies of the bird species concerned, and the timing of any observed changes. Comparing the trends between groups of species was expected to reveal if any changes are trophically related, e.g. bird species (terns) feeding on clupeoid fishes compared to bird species (some cormorants) mostly feeding on benthic species of fish. This would provide insight into whether any changes are general or specific to particular foraging guilds or habitats. Analysis of the timing of any change could allow correlation with the timing of environmental events that may have influenced the ecology of the bays.

3. A comparison of trends in piscivorous bird species and guilds with the trends in commercial fishing effort in the two bays. Commercial fishing is one potential driver of changes to piscivorous bird populations for which trend data were available across the years of this study.

2.2   Site descriptions

The surveys in both Western Port and West Corner Inlet focus on the sheltered parts of the bays where extensive mudflats are exposed at low tide. The surveys do not include high-energy beaches such as the barrier islands of West Corner Inlet or the ocean shores of Phillip Island, which are known to attract a different mix of bird species and to be subject to different ecological processes.

2.2.1   Western Port

Western Port is located on the southern coast of Victoria (Figure 1) and covers about 680 km^2, including 270 km^2 of tidal mudflats. It contains two large islands (Figure 2) and has a coastline of 263 km, of which 107 km are lined with mangroves (Shapiro 1975). The BOCA Western Port survey is conducted at 20 sites, including all the major known high-tide roosts for waterbirds in the sheltered part of the bay (Figure 2). Approximately one-third of sites fall within national parks (both terrestrial and marine), with the majority of these occurring on French Island. Phillip Island is heavily settled and is a popular summer tourist destination, attracting over 100,000 visitors in addition to its 12,000 residents. French Island covers twice the area of Phillip Island, but is much less settled, with a resident population of about 80 people (M. Johnston pers. comm.). The rest of the mainland coast supports several areas of high human use, including the towns of Hastings, Cannons Creek, Warneet, Blind Bight, Tooradin, Grantville and Bass. For a recent review of the biological and environmental attributes of Western Port, see Keough et al. (2011a).

2.2.2   Corner Inlet

Corner Inlet is a large, complex, intertidal area in South Gippsland, Victoria, and is situated to the north-east of Wilsons Promontory (Figure 1). The surveys of piscivorous birds used in this report covered the western side of the Inlet, west of Snake Island, also known as 'West Corner Inlet' (Figure 3). The tidal range in Corner Inlet is small, peaking at up to 2.6 m, but at neap tides it is only 0.8 m (annual Victorian Tide Tables; VRCA 2015). The total area of water is around 360 km^2 (Martindale 1982), reducing by about three-quarters at low spring tides. Seagrass, mainly *Posidonia australis*, covers some of the mudflats.
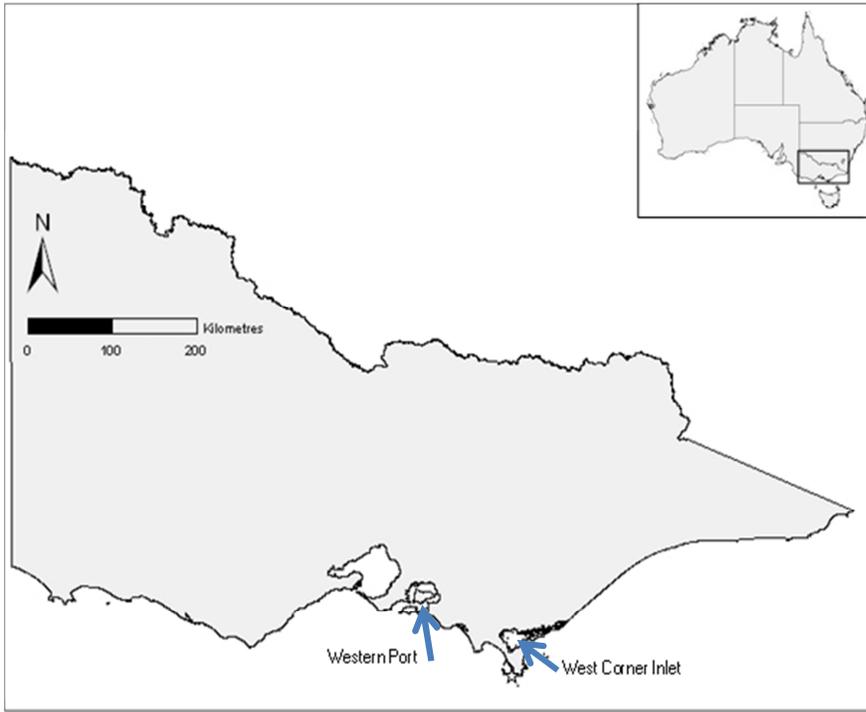
Figure 1. Locations of Western Port and West Corner Inlet in Victoria, Australia.

Figure 2. Map of Western Port, showing key waterbird roost sites (green stars) at which regular counts were made (from Hansen et al. 2011).
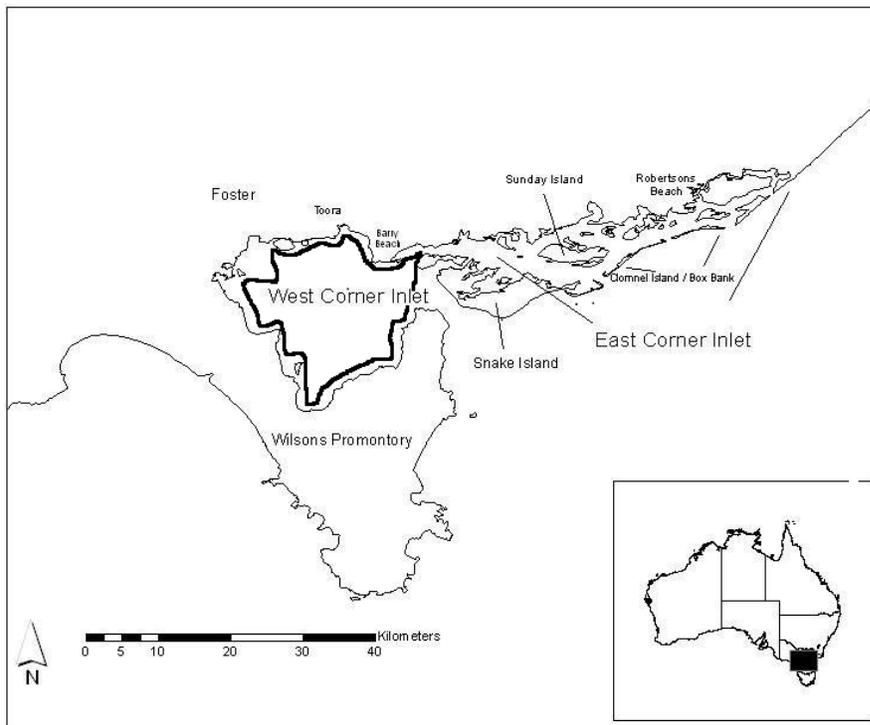
Figure 3. Location of Corner Inlet and 'West Corner Inlet' (adapted from Minton et al. (2012)). The black line shows the route taken (clockwise) by boat for the survey.

2.3 Survey methods

2.3.1 Western Port

Waterbirds have been monitored at 20 sites in Western Port since 1973 (Loyn 1978, Loyn et al. 1994, Loyn et al. 2001), although some sites were surveyed regularly in the early years and less regularly in later years. Waterbird numbers were surveyed at least thrice yearly by volunteers (Heislers et al. 2003). The summer (February) and winter (June–July) counts were used in this analysis because counts were made in corresponding months in West Corner Inlet. Surveys were conducted by teams of experienced volunteers who visited bird roosting sites on a single survey day in each season, close to high tide, and counted or estimated the number of birds present using binoculars and telescopes (Heislers et al. 2003). Survey dates coincided as closely as possible with the previous year's count date in the same season. Most sites were visited on foot, usually by walking through the site. Boats were used to access French Island and Barrallier Island, with some birds counted from the boat on small reefs near Barrallier Island. Hanns Inlet was counted from a boat in recent years. Further details on count methods can be found in Heislers et al. (2003) and Hansen et al. (2011).

High-tide roosts in Western Port are characterised by sandy shores, sandy spits, rocky platforms, or open areas of mudflat that remain exposed during low high tides (Loyn 1978, Hansen et al. 2011). Some species also roost on jetties and navigation beacons and in mangroves. Most roost sites are fringed by saltmarsh, mangroves or coastal scrub.

Analyses focused solely on 12 sites surveyed consistently from 1987 (with few counts missed for most of those sites). These 12 sites are Hanns Inlet (near Sandy Point); Warneet; Barrallier Island and the adjacent coast of north-west French Island; Tooradin; Bunyip River and Yallock Creek; Stockyard Point; Pioneer Bay and Red Bluff Creek; Reef Island and Bass Bay; Observation Point and nearby sites on Phillip Island; and three sites on French Island: Tortoise Head, Rams Island and Fairhaven.

2.3.2 West Corner Inlet

Boat-based counts at West Corner Inlet were carried out twice each year, in summer and winter, between 1987 and 2012, each count taking approximately five hours. The summer count was in late January or the first half of February and the winter count between mid-June and the end of July. In the winters of 1989, 1990, 1991 and 2005 and the summers of 1992 and 2011, scheduled counts of waterbirds in West Corner Inlet were repeatedly prevented by unsuitable weather conditions and, consequently, no counts are available for those periods. Counts were made (using binoculars) of all waterbirds encountered, whether resting or active. Medium to high tides were selected (>2.3 m) for boat access reasons and to ensure greater concentration of roosting birds.

West Corner Inlet was treated as one continuous count that started and finished in Port Welshpool and went around the West Corner Inlet basin in a clockwise direction, covering approximately 70 km (Figure 3). This included the northern shores of Wilsons Promontory, the eastern shores of the isthmus connecting the promontory to the mainland, and the northern and eastern shores of the inlet near Foster, Toora and Barry Beach. Piscivorous birds roosted in a variety of habitats, including small, low, mainly mangrove-fringed islands, rocky points, granite boulders, saltmarshes, beaches, jetties and navigation beacons. Each counting team consisted of two or three people, including one of us (Peter Dann), plus the coxswain.

2.3.3 Differences between the survey methods of the two areas

There are three essential differences between the counts in the two bays: the number of years of the surveys (38 years in Western Port and 25 years in West Corner Inlet), the number of counters (20+ per survey at the 12 sites in Western Port and 2–3 people per survey in West Corner Inlet), and the type of counting platform used (land-based or boat-based). The surveys in Western Port were largely shore-based counts of birds at high-tide roosts by different counters at different sites, but fairly consistently the same counters at the same sites. In contrast, West Corner Inlet counts were boat-based (also at high tide) by the same counters (Peter Dann usually present). The first difference is overcome by only comparing data from the period in which both regions were surveyed (1987–2012). The two methodological differences are considered unlikely to bias our comparison of trends in population numbers because the methods and effort were consistent within each survey area.

2.4 Piscivorous birds

In this study we have defined piscivorous birds as those land-based species that are physically adapted for taking fish as the major part of their diet, and which spend most of their time foraging in tidal waters rather than freshwater wetlands when they are in the Western Port and West Corner Inlet areas (Loyn 1978, Lowe 1982a, Dann et al. 1994, Loyn et al. 1994). Fifteen species were considered to meet those criteria: four terns, five cormorants, two egrets and one each of grebe, pelican, heron and spoonbill (Table 1). Hence, we excluded a number of species that feed mainly in freshwater wetlands (e.g. Australasian Grebe *Tachybaptus novaehollandiae*, White-necked Heron *Ardea pacifica* and Yellow-billed Spoonbill *Platalea flavipes*). We also excluded truly marine species (e.g. penguins, shearwaters and gannets), as our regular counts did not provide useful data for them. Of the 15 species, we considered 13 to be primarily dependent on fish (>40% of diet by weight), while two were less dependent (White-faced Heron and Royal Spoonbill), relying also on other foods such as crustaceans (Table 1).

In our analyses, we also considered various combinations of species, such as all terns, all cormorants or cormorants and pelicans, to reflect dominant patterns in foraging behaviour. In addition, wading fishers (egrets, herons and spoonbills) were considered separately from diving or up-ending fishers (terns, cormorants and pelicans) because the first group forage only from shallow waters, while the second group forage in a variety of water depths, and therefore over a greater proportion of each region.

2.5 Fish catch data

The Fisheries Research Branch of Fisheries Victoria provided data on the monthly commercial fishing effort (monthly number of net shots) (hereafter referred to as catch per unit effort (CPUE)) for the periods of our study. Total CPUE (in kilogram of fish taken per net shot) for all fish species combined, and for one individual species (Australian Salmon) were modelled. Australian Salmon was of particular interest because

it is a predator of small clupeoid fish and may play an important role in driving schools of clupeoids into surface waters—where they are available to piscivorous birds) (P. Dann pers. obs.).

2.6   Statistical analyses

Generalized additive mixed models (GAMMs) using a quasi-poisson distribution and AR(1) autocorrelation structures were built to characterise the relationships between bird abundance and time. The function gamm in the R package mgcv was used to build the models. Models were developed for individual bird species and for bird taxonomic groupings for summer and winter at both Western Port and West Corner Inlet. We also examined the relationship between fish CPUE and time, and between bird abundance and CPUE for both embayments.

3 Results

3.1 Diversity of piscivorous birds in Western Port and West Corner Inlet

A total of 15 piscivorous species of bird (as defined above) were recorded often enough to be included in analyses (Table 1). One of the 15 species, Black-faced Cormorant, was relatively abundant in West Corner Inlet, but uncommon in the sites surveyed in Western Port, and so was not included in the analyses. The Little Egret was scarce in both bays, but recorded often enough to warrant inclusion. Fairy Tern and Little Tern occur in both bays and are similar in appearance, making accurate identification a challenge, especially when viewing conditions are suboptimal. Furthermore, hybrids between these two species have been recorded in Corner Inlet, so both species were combined for the analyses.

Many of the piscivorous species considered in this analysis varied in abundance with time, location and season (Tables 2, 3 and Appendix 1). However, our main purpose here was to examine the trends with time and the interactions between time and region, i.e. do the trends in abundance of piscivorous birds differ between Western Port and West Corner Inlet?

Table 1. Piscivorous bird species (>40% fish in diet) recorded regularly in Western Port and West Corner Inlet between 1987 and 2012, and information on their diet

Piscivorous bird species	Main fish prey	Proportion of fish in diet	Source
Great Crested Grebe *Podiceps cristatus*	No Australian marine studies	Mostly fish	Marchant and Higgins (1990)
Great Cormorant *Phalacrocorax carbo*	Southern Anchovy *Engraulis australis*, Flathead *Platycephalidae* spp., Bridled Goby *Arenigobius bifrenatus*, Western River Garfish *Hyporhamphus regularis,* Small-mouthed Hardyhead *Atherina microstoma,* Cobbler *Gymnapistes marmoratus*, Australian Salmon *Arripis trutta*, Yellow-eyed Mullet *Aldrichetta forsteri*, Sandy Sprat *Hypolophus vittatus*	Predominantly fish	Marchant and Higgins (1990)
Pied Cormorant *Phalacrocorax varius*	Pilchard *Sardinops sagax*, Cobbler, Australian Salmon, Yellow-eyed Mullet, Flathead, Bridled Goby, Hardyhead *Pranesus endrachtensis*, Sandy Sprat	90% wet weight of identifiable prey	Trayler et al. (1989)
Little Black Cormorant *Phalacrocorax sulcirostris*	Atherinidae, Sandy Sprat	~96% wet weight of identifiable prey	Trayler et al. (1989)
Little Pied Cormorant *Microcarbo melanoleucos*	Atherinidae, Apongonidae, Gobiidae	~66% wet weight identifiable prey	Trayler *et al* (1989)

Black-faced Cormorant *Phalacrocorax fuscescens*	Wrasse sp. (Labridae), Silver Trevally *Pseudocarynx dentex*, Melbourne Silverbelly *Parequula melbournensis*, Red Cod *Pseudophysis bachus*, Flathead, Snapper *Centroberyx* sp.	97% frequency of occurrence of identifiable prey from Notch Island, south of Corner Inlet	Taylor et al. (2013)
Australian Pelican *Pelecanus conspicillatus*	No Australian marine studies	Mostly fish (based on information from freshwater habitats)	Marchant and Higgins (1990)
Great Egret *Ardea alba*	No Australian marine studies	Mostly fish (based on information from freshwater habitats)	Marchant and Higgins (1990)
Little Egret *Egretta garzetta*	No Australian marine studies	Mostly fish (based on information from freshwater habitats)	Marchant and Higgins (1990)
White-faced Heron *Egretta novaehollandiae*	Gobiidae	13.2% of prey in Western Port	Lowe (1983)
Royal Spoonbill *Platalea regia*	Bridled Goby	23% wet weight of prey in Western Port	Lowe (1982b)
Caspian Tern *Hydroprogne caspia*	Unidentified teleosts	58% frequency of occurrence	Higgins and Davies (1996)
Crested Tern *Thalasseus bergii*	Southern Anchovy, Jack Mackerel *Trachurus declivis*, Barracouta *Thyrsites atun*	93% frequency of occurrence brought to chicks at The Nobbies, Phillip Island	Chiaradia et al. (2002)
Fairy/Little Tern *Sternula nereis/albifrons*	Pilchard, Southern Anchovy, Blue Sprat *Spratelloides robustus*	Mostly fish	Taylor and Roe (2004)

Table 2. Total counts (means, standard deviations and ranges) of piscivorous birds in summer and winter in Western Port between 1974 and 2012

Species	Summer			Winter		
	Mean (*n* = 24)	S.D.	Range	Mean (*n* = 20)	S.D.	Range
Great Crested Grebe	0.0	0.0	0	0.9	1.2	0–7
Great Cormorant	6.2	6.0	0–54	5.3	4.8	0–20
Pied Cormorant	50.5	25.1	11–155	49.8	28.6	0–152
Little Black Cormorant	7.3	6.9	0–57	14.0	9.4	0–57
Little Pied Cormorant	104.4	50.6	23–281	146.1	84.5	1–544
Black-faced Cormorant	0.1	0.2	0–4	0.6	1.22	0–15
Australian Pelican	68.4	80.5	0–184	44.1	33.6	2–224
Great Egret	14.2	11.8	0–70	6.0	4.3	0–30
Little Egret	0.1	0.1	0–1	0.2	0.4	0–5
White-faced Heron	162.8	64.5	48–636	136.7	58.9	19–319
Royal Spoonbill	81.4	34.4	15–195	107.6	59.3	3–261
Caspian Tern	18.0	8.3	4–61	11.7	5.6	0–26
Crested Tern	168.0	95.1	30–657	60.7	53.0	5–618
Little/Fairy Tern	23.7	24.1	0–122	3.3	4.4	0–39

Table 3. Total counts (means, standard deviations and ranges) of piscivorous birds in summer and winter in West Corner Inlet between 1987 and 2012

Species	Summer			Winter		
	Mean (*n* = 24)	**S.D.**	**Range**	**Mean** (*n* = 20)	**S.D.**	**Range**
Great Crested Grebe	0.1	2.8	0–6	14.9	20.9	0–147
Great Cormorant	50.7	4.9	6–228	47.7	50.9	0–276
Pied Cormorant	39.0	18.5	0–103	31.8	27.46	0–91
Little Black Cormorant	13.3	5.1	0–53	37.9	19.0	5–116
Little Pied Cormorant	273.8	126.6	9–710	662.8	273.9	199–1368
Black-faced Cormorant	56.2	66.4	0–339	156.1	112.7	0–450
Australian Pelican	19.1	3.9	3–31	20.9	9.69	5–45
Great Egret	4.9	1.0	0–26	5.8	4.0	0–19
Little Egret	1.0	0.02	0–4	2.9	2.3	0–9
White-faced Heron	270.7	29.9	80–639	313.7	126.8	86–578
Royal Spoonbill	56	22	2–154	89.7	46.1	0–187
Caspian Tern	3.2	0.6	0–8	2.1	2.7	0–27
Crested Tern	105.4	11.7	3–348	85.1	34.2	16–209
Little/Fairy Tern	42.8	3.6	0–270	3	4.1	0–42

3.2 Trends in abundance of piscivorous birds in Western Port and West Corner Inlet

There was a significant interaction between the trend in abundance of all bird species combined and region (Western Port and West Corner Inlet) for both summer and winter (Figures 4 and 5). In summer, there was a significant decline ($p = 0.0002$) in piscivorous birds in Western Port and a significant increase ($p < 0.0001$) in West Corner Inlet (Figure 4). In winter, there was a significant decline ($p = 0.0007$) in piscivorous birds in Western Port and a significant, though less strong, increase ($p = 0.025$) in West Corner Inlet (Figure 5).

Six species (Pied Cormorant, Little Pied Cormorant, Australian Pelican, White-faced Heron, Royal Spoonbill and Crested Tern) declined in Western Port relative to West Corner Inlet, while Black-faced Cormorant increased in West Corner Inlet but remained at low numbers in Western Port (Appendices 1 and 2). The trends in abundances of seven species (Great-crested Grebe, Great Cormorant, Little Black Cormorant, Great Egret, Little Egret, Caspian Tern and Fairy/Little Tern) did not vary significantly between the two bays during the survey period (Appendices 1 and 2).

Five of the species groupings (all species; cormorants, pelicans and terns; cormorants and pelicans; terns; herons and egrets) declined in Western Port relative to West Corner Inlet (Appendices 1 and 2). No species or group of species increased in Western Port in comparison to West Corner Inlet.
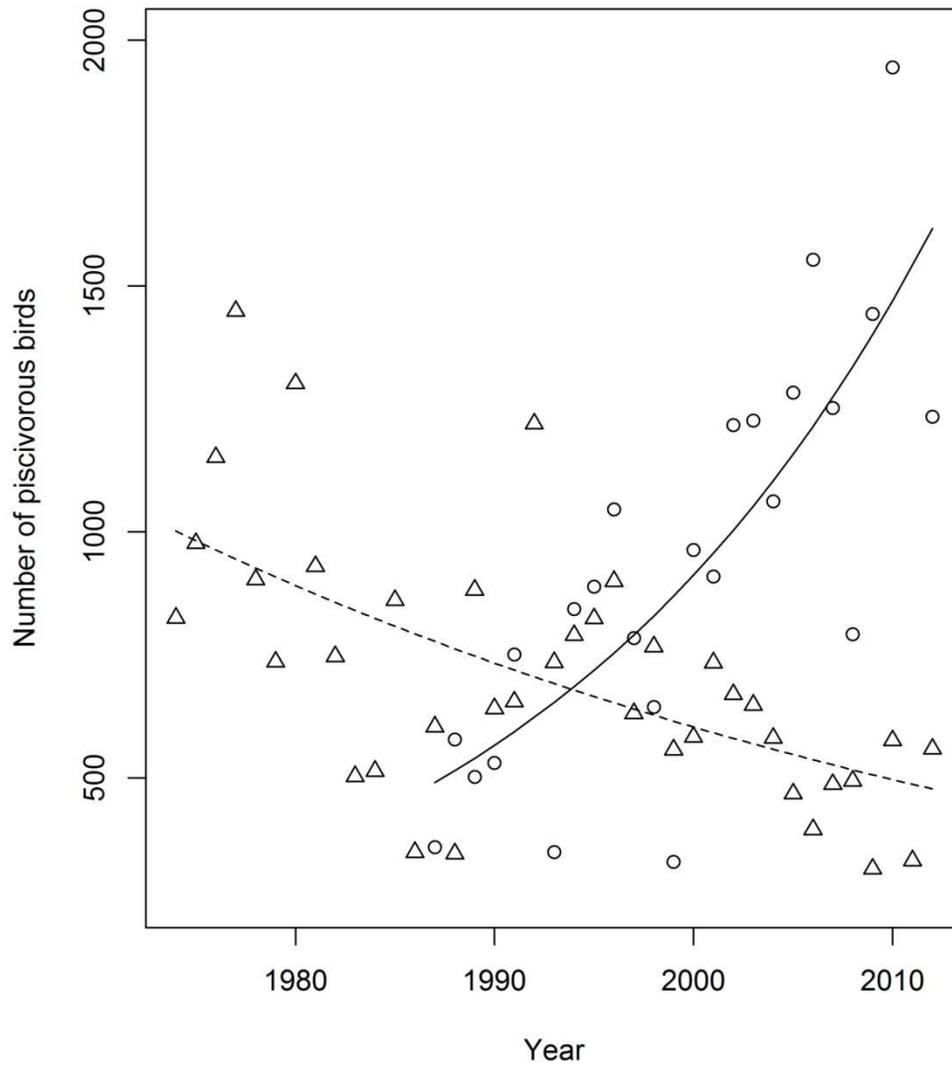
Figure 4. Annual counts of all piscivorous birds in Western Port (triangles, dashed line) and in West Corner Inlet (circles, solid line) in summer between 1974 and 2012.
Both time trends are significant (Western Port p = 0.0002, R^2 (adj) = 0.342; Corner Inlet p < 0.0001, R^2 (adj) = 0.596.

Figure 5. Annual counts of all piscivorous birds in Western Port (triangles, dashed line) and in West Corner Inlet (circles, solid line) in winter between 1974 and 2012.
Both time trends are significant (Western Port p = 0.0007, R^2 (adj) = 0.366; Corner Iinlet p = 0.025, R^2 (adj) = 0.0824).

Figure 6. The sum of the numbers of cormorants and pelicans in summer in Western Port (triangles, dashed line) and in West Corner Inlet (circles, solid line) between 1974 and 2012.
Both time trends are significant (Western Port $p < 0.0123$, R^2 (adj) = 0.172; Corner Inlet $p < 0.0001$, R^2 (adj) = 0.581).
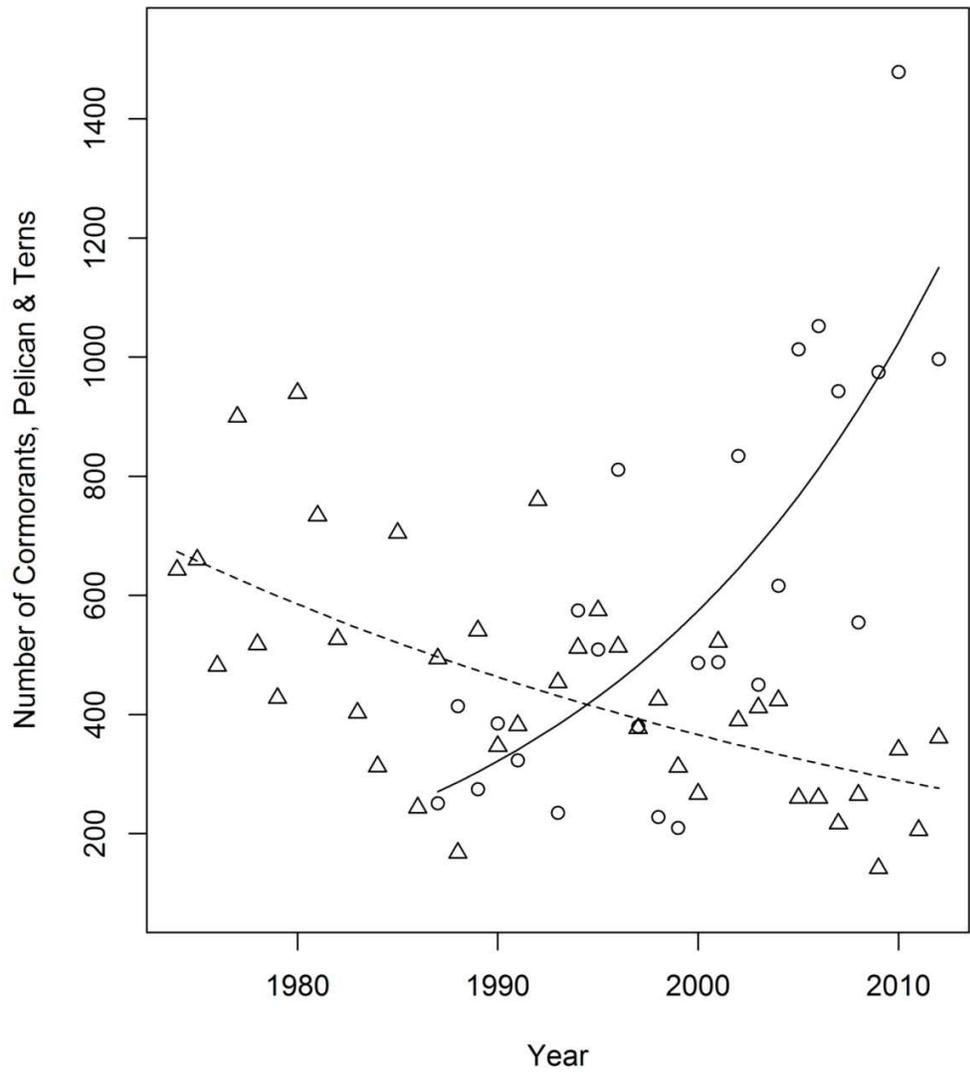
Figure 7. The sum of the numbers of cormorants, pelicans and terns in summer in Western Port (triangles, dashed line) and in West Corner Inlet (circles, solid line) between 1974 and 2012.
Both time trends are significant (Western Port $p < 0.0001$, R^2 (adj) = 0.362; Corner Inlet $p < 0.0001$, R^2 (adj) = 0.59).

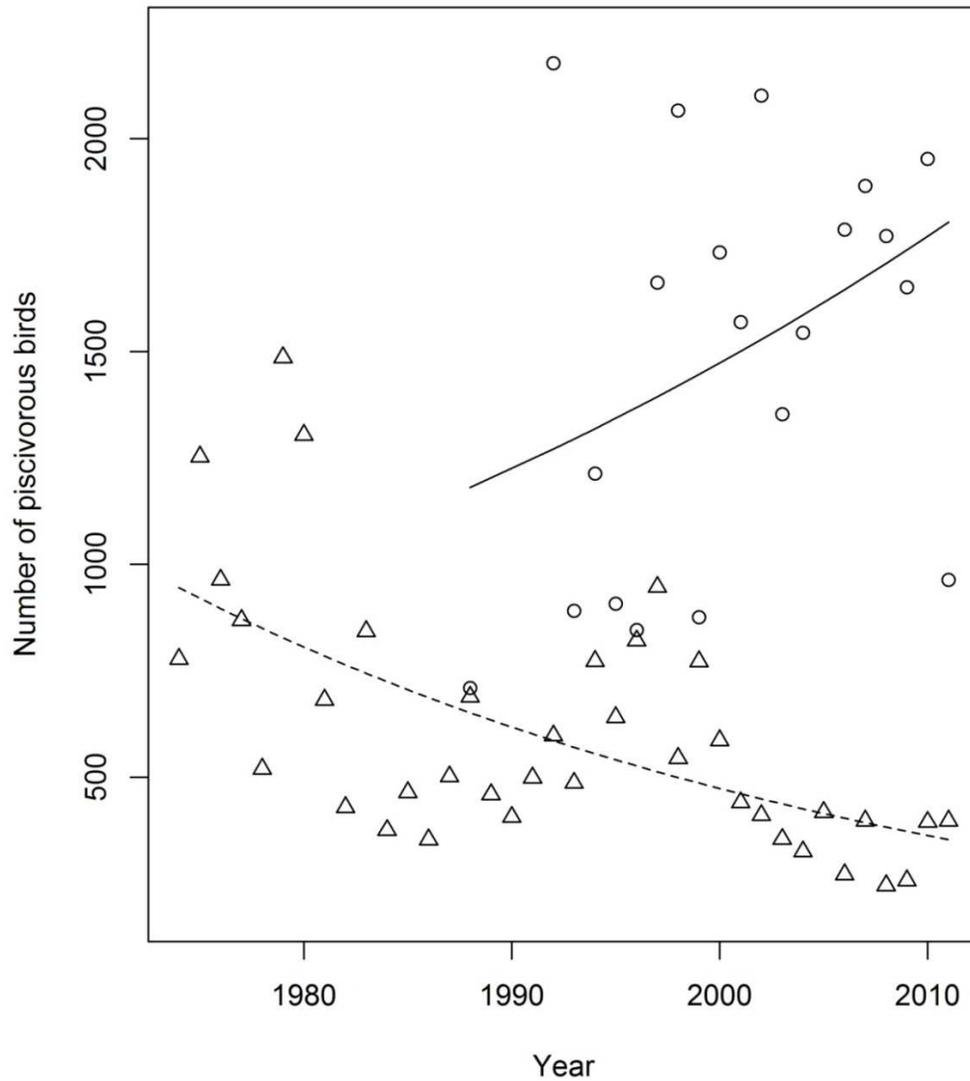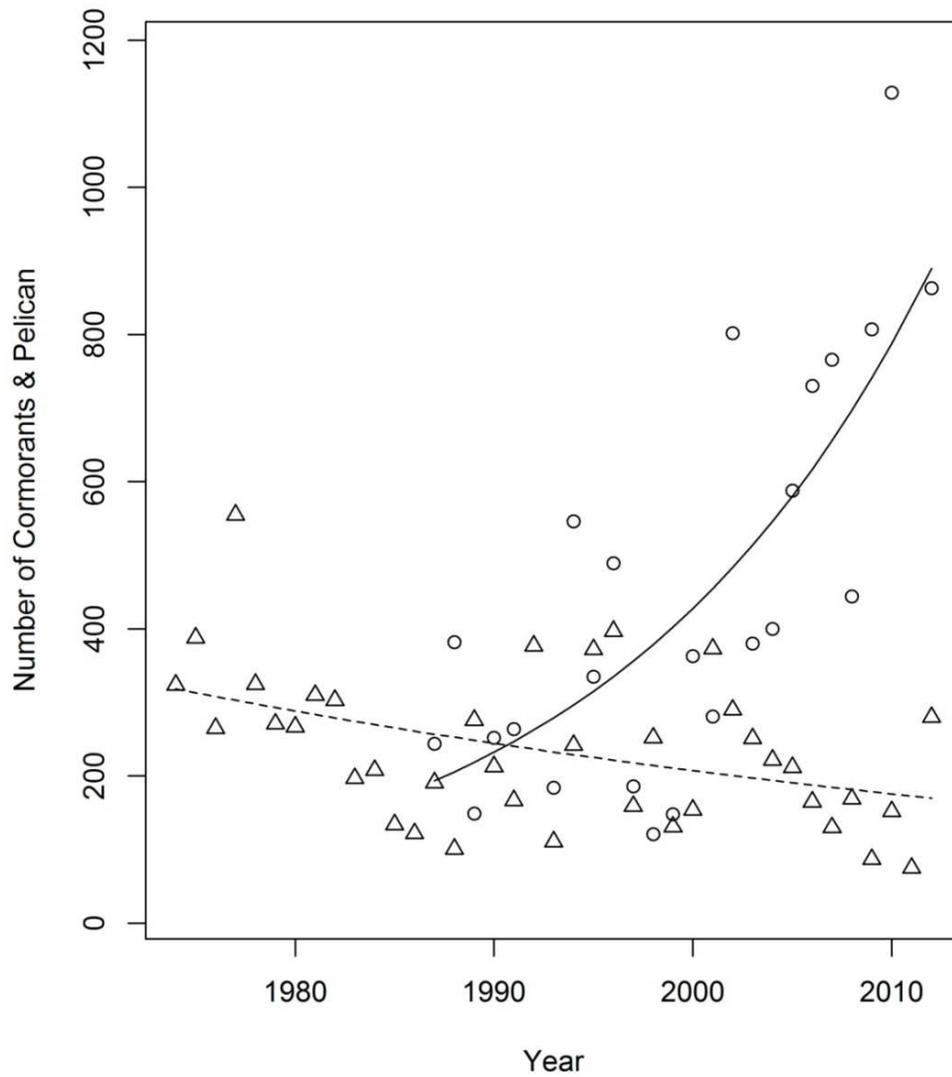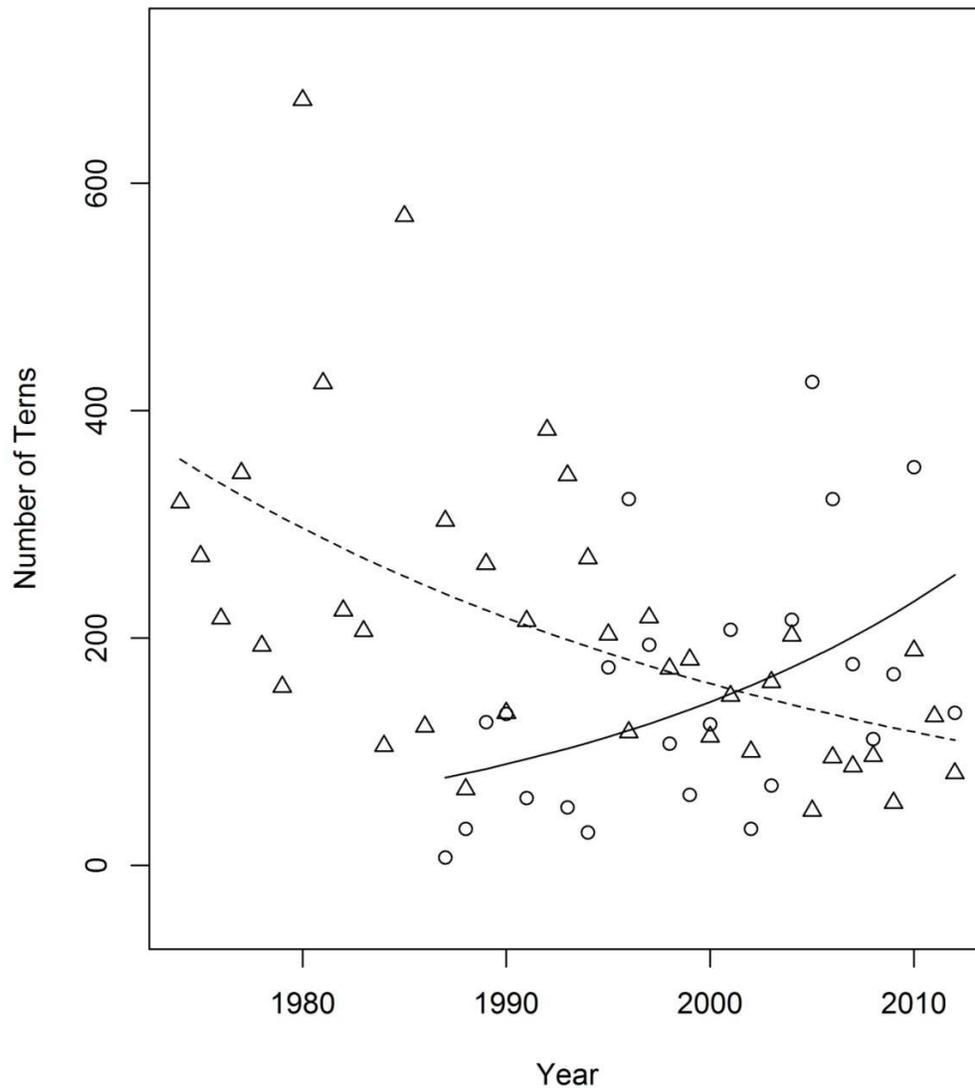**Figure 8. The sum of the numbers of all tern species in Western Port (triangles, dashed line) and in West Corner Inlet (circles, solid line) between 1974 and 2012.**
The trend for Western Port is significant ($p < 0.0001$, R^2 (adj) = 0.251); that for Corner Inlet is not ($p = 0.0663$, R^2 (adj) = 0.178).

Summer counts of three groups (terns; cormorants and pelicans; cormorants, pelicans and terns) produced significantly decreasing trends for Western Port. For West Corner Inlet, the two groups that included cormorants showed significant increases (Figures 6 and 7), while the trajectory for terns was upwards, but not significant (Figure 8). Of the declining groups in Western Port, terns showed the steepest decline, suggesting that terns contributed importantly to the overall declining trend there (Figure 8). In West Corner Inlet cormorants and pelicans contributed more to the overall increase in piscivorous birds than did terns.

The summer numbers of cormorants and pelicans combined showed divergent trends between the two bays, but the trend for Western Port (Figure 6) was not as strong ($p = 0.0123$) as that for West Corner Inlet ($p < 0.0001$). The annual combined summer counts of cormorants, pelicans and terns showed a significant interaction between bays, and both were highly significant (Figure 7), again suggesting that terns were responsible for much of the decline in Western Port. The increase in terns in West Corner Inlet in summer was of a similar magnitude to the decline in Western Port in summer (Figure 8). Of the three tern species

(Crested, Caspian and Fairy/Little), only the Crested Tern has changed dramatically in numbers (Figures 9 and 10), the other two species having remained in low numbers, or declined slightly, at both sites throughout the study period.
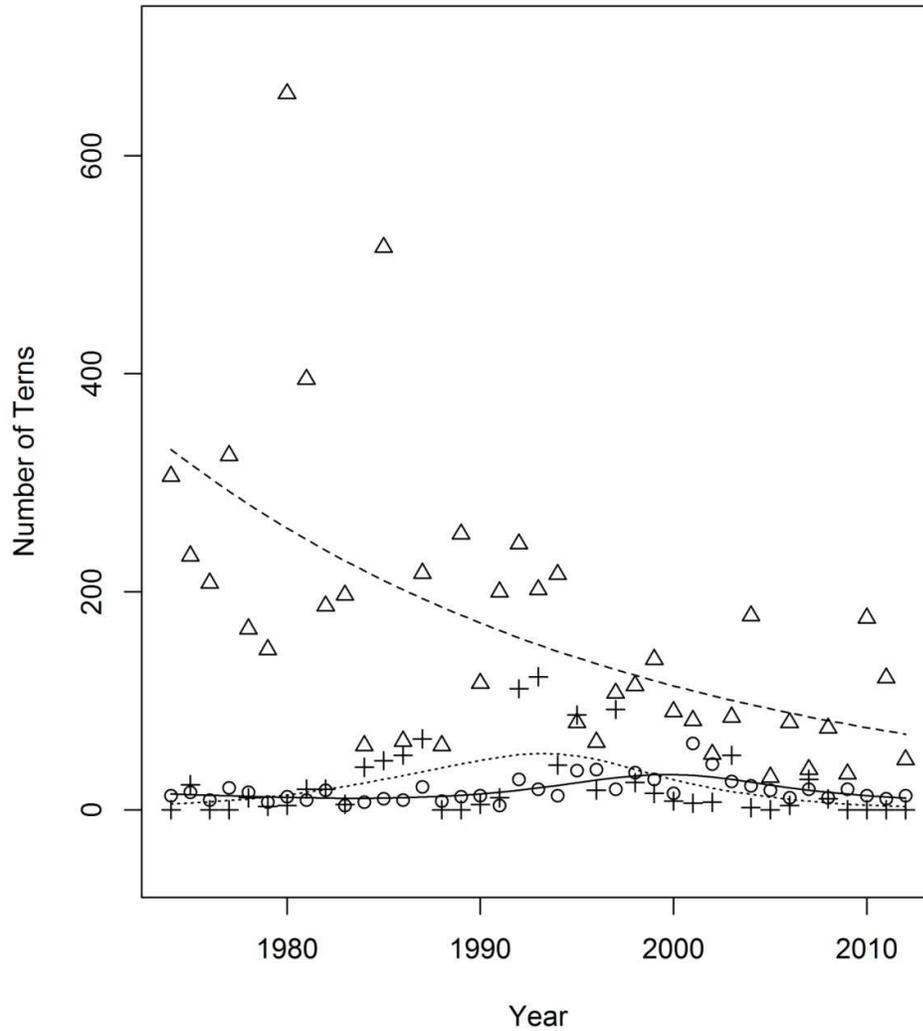
Figure 9. Numbers of the three tern species—Crested Tern (triangles, dashed line), Caspian Tern (circles, solid line) and Fairy/Little Tern (plus symbols, dotted line)—in Western Port in summer between 1974 and 2012.
The time trends are significant for all three species—Crested Tern (p < 0.0001, R^2 (adj) = 0.306); Caspian Tern (p < 0.0001, R^2 (adj) = 0.439) and Fairy/Little Tern (p < 0.0064, R^2 (adj) = 0.305).
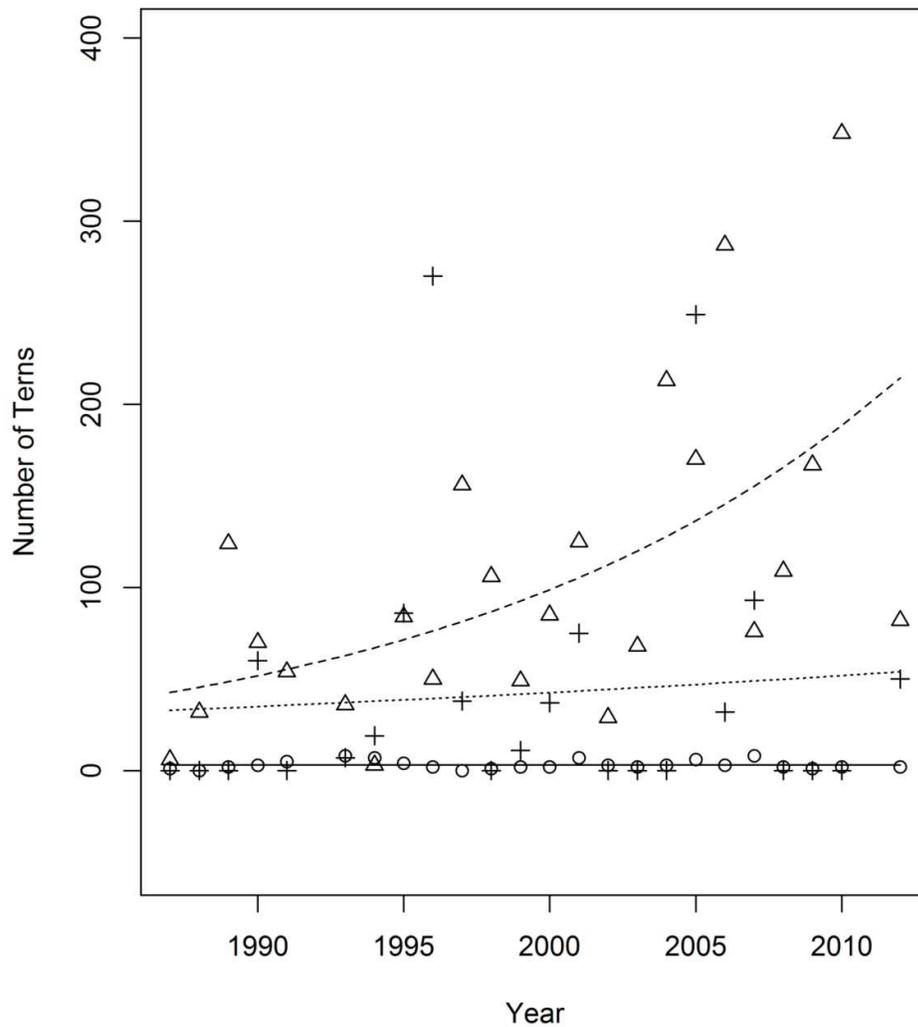
Figure 10. Numbers of the three tern species—Crested Tern (triangles, dashed line), Caspian Tern (circles, solid line) and Fairy/Little Tern (plus symbols, dotted line)—in in summer in West Corner Inlet between 1987 and 2012.
The time trends are significant for Crested Tern ($p < 0.0019$, R^2 (adj) = 0.289), but not for Caspian Tern ($p = 0.988$, R^2 (adj) = −0.458) or Fairy/Little Tern ($p = 0.698$, R^2 = −0.0409).

3.3 Relationships with commercial fish catches

3.3.1 Commercial fish CPUE over time

Commercial fish CPUE showed similar trends over time at both embayments—fluctuating throughout the 1980s and 1990s then increasing markedly in the 2000s (Figure 11). The last two datapoints for Western Port (lower right in Figure 11) were not included in the model because they are clear outliers, probably reflecting the winding down of commercial fishing in the late 2000s – presumably, the few remaining fishers had increased success in the last few years before commercial fishing effectively ceased in 2009.
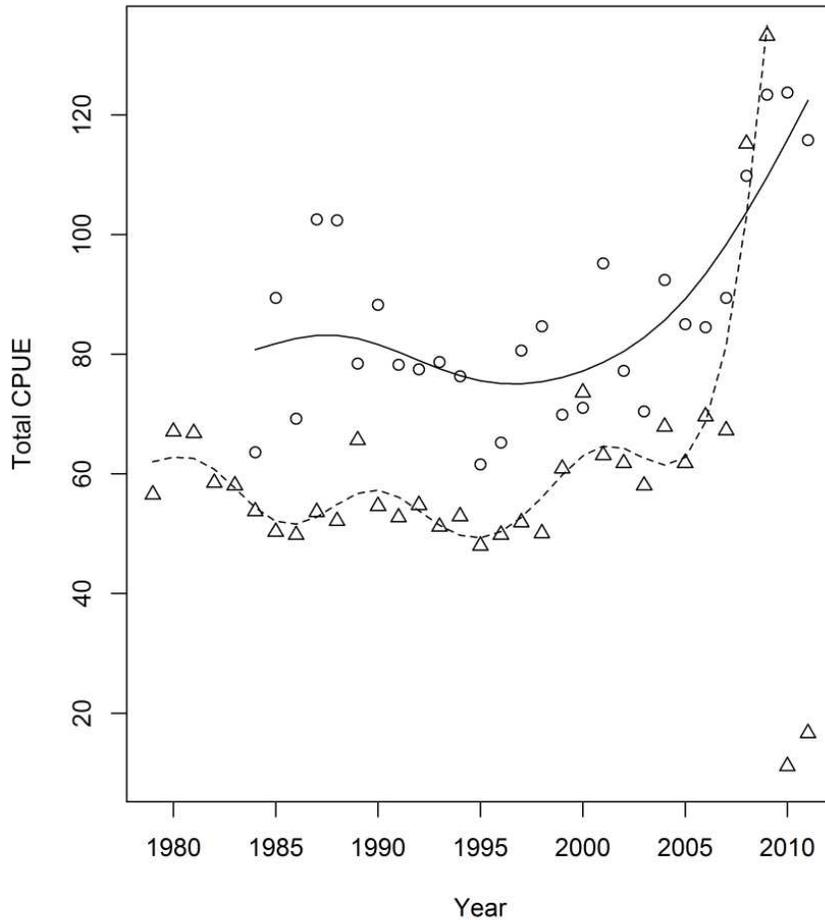
Figure 11. Relationship between commercial fish CPUE and time for Western Port (triangles, dotted line) and West Corner Inlet (circles, solid line).
Both relationships are significant—Western Port $p < 0.0001$, R^2 (adj) = 0.894; West Corner Inlet ($p < 0.0001$, R^2 (adj) = 0.598).

3.3.2 Relationships between CPUE and abundance of piscivorous birds

The relationship between CPUE for all fish species combined and the total number of piscivorous birds was not significant for either West Corner Inlet or Western Port (Figure 12).
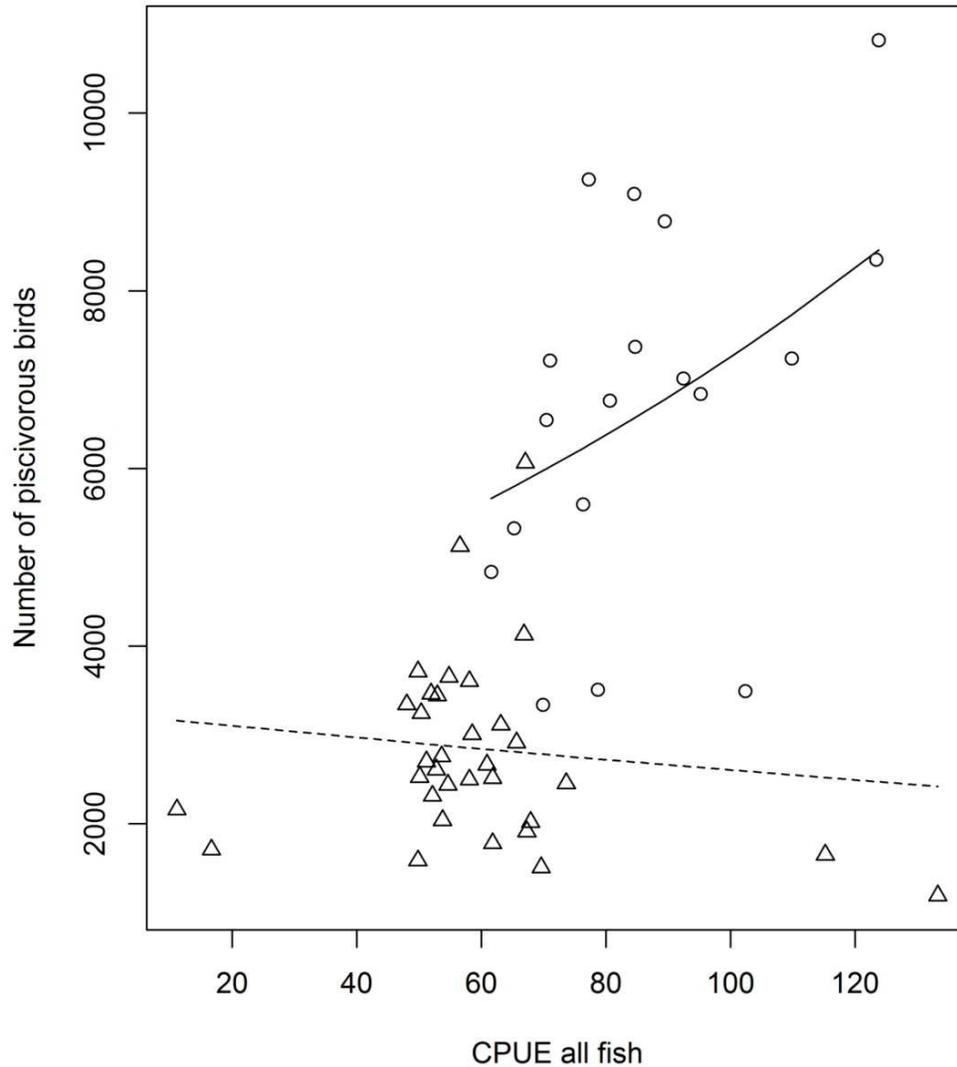
Figure 12. Relationship between CPUE for all fish species and number of piscivorous birds (sum of summer and winter counts) for Western Port (triangles, dotted line) and West Corner Inlet (circles, solid line).
There is no significant relationship for Western Port ($p = 0.354$, R^2 (adj) = −0.0101) or West Corner Inlet ($p = 0.128$, R^2 (adj) = 0.174).

3.3.3 Terns versus Australian Salmon CPUE

In both West Corner Inlet and Western Port, Crested Tern numbers were positively correlated with Australian Salmon CPUE (Figure 13). CPUE of Australian Salmon varied with time for both Western Port and West Corner Inlet (Figure 14). In Western Port, the salmon CPUE declined sharply during the 1980s, remained relatively low during the 1990s, and was effectively zero through the 2000s. In West Corner Inlet, CPUE of Australian Salmon increased steadily throughout the study period (Figure 14).
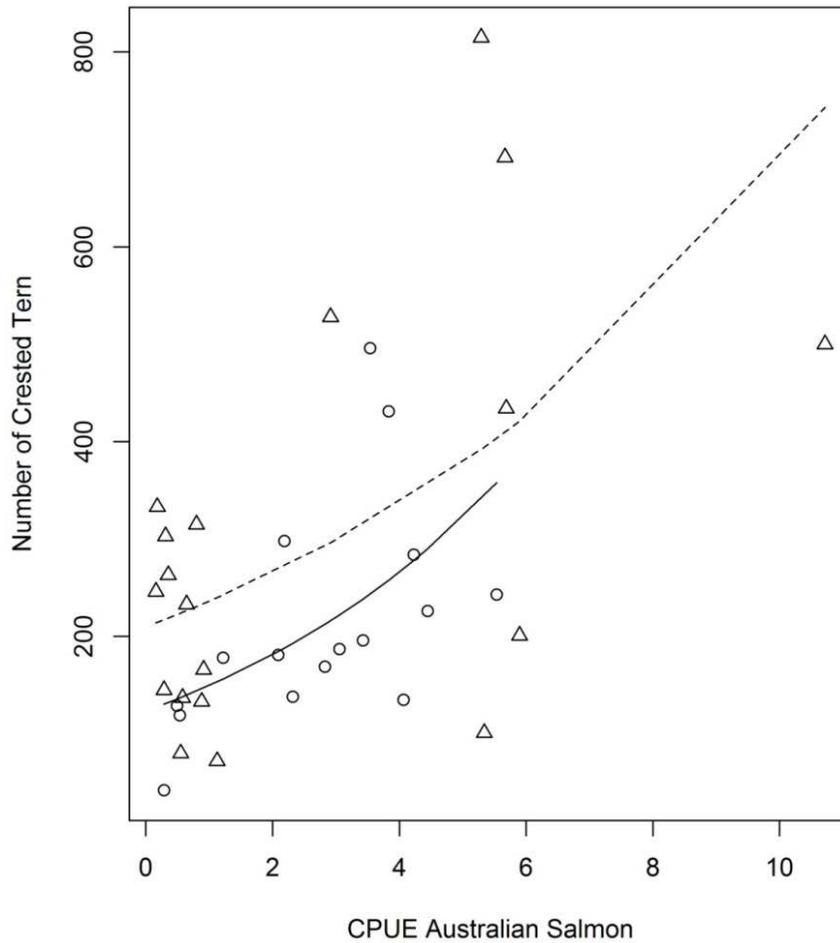
Figure 13. Relationship between CPUE for Australian Salmon and number of Crested Terns (sum of summer and winter counts) for Western Port (triangles, dotted line) and West Corner Inlet (circles, solid line).
Both relationships are significant—Western Port $p < 0.0001$, R^2 (adj) = 0.172; West Corner Inlet ($p = 0.0294$, R^2 (adj) = 0.167).
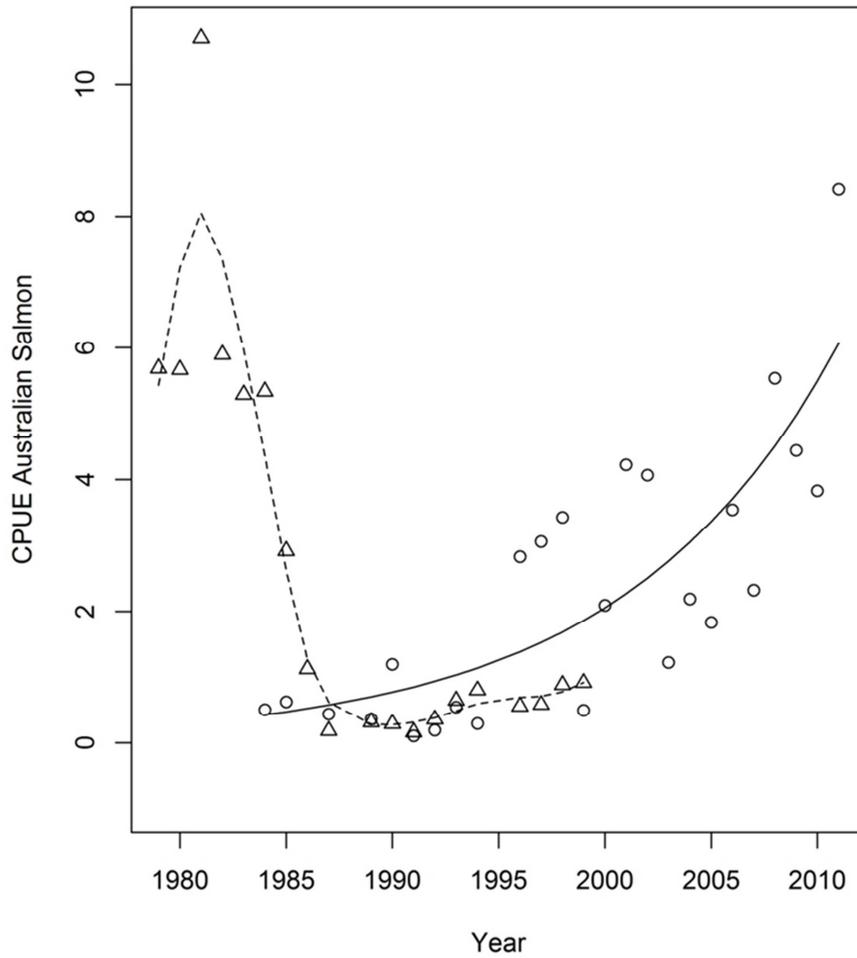
Figure 14. Relationship between CPUE for Australian Salmon and year for Western Port (triangles, dotted line) and West Corner Inlet (circles, solid line).
Both time trends are significant (Western Port $p < 0.0001$, R^2 (adj) = 0.874; Corner Inlet $p < 0.0001$, R^2 (adj) = 0.626).

4   Discussion

This analysis has shown a major difference in trends between the two bays, with piscivorous birds as a group declining over time in Western Port and increasing in West Corner Inlet. Some other groups of waterbirds that do not eat fish (notably shorebirds) have decreased at West Corner Inlet over the same period (Minton et al. 2012). Clearly, Western Port has been subject to different pressures than has West Corner Inlet in terms of suitability for piscivorous birds, particularly terns and cormorants. Declines have occurred across the piscivorous feeding guilds and include species that feed by plunge diving (terns), underwater pursuit (cormorants), surface snatching and up-ending (sometimes including cooperative herding) (Australian Pelican), wading pursuit (herons and egrets) and substrate sweeping (spoonbills). This ubiquity of decline suggests that the causes most likely relate to the availability of food and apply across a range of fish habitat niches. That is, they are likely to be driven by one or more degrading processes applying widely across the marine environment of Western Port. Such processes could include changes to habitat, particularly nursery habitat (e.g. seagrass loss), and they have probably resulted in changes to trophic structure and function. Unfortunately, our measures of these possible drivers are far from perfect. Seagrass dieback was documented in the 1970s for Western Port (Bulthuis 1981), but the seagrass beds seem to have recovered in the 1990s, except for the eastern arm of Western Port (Blake and Ball 2001). Although we found no relationship between commercial fish CPUE (all species) and numbers of piscivorous birds (Figure 12), commercial fish catches may be a poor surrogate measure of fish stocks, especially in Western Port, where commercial fishing has ceased and recreational fishing is increasingly popular. There are no data on recreational fish catches in Western Port or West Corner Inlet to incorporate into our models.

4.1   Trends in tern numbers

Most of the decline in piscivorous bird numbers in Western Port since 1987 can be attributed to decreases in terns, particularly the Crested Tern (by about 200 individuals) and, to a lesser extent, the Fairy Tern (by about 50 individuals). The decline in numbers of Crested Terns in Western Port is surprising, given the establishment of a breeding colony in 1994 at The Nobbies at the western entrance to Western Port (Chiaradia et al. 2002) and its expansion to a colony of approximately 5000 nests by 2011–2012 (far more than the numbers ever observed in the Western Port survey area) (PINP 2011). It has now become the largest Crested Tern colony in Victoria. Therefore, the decrease in numbers of Crested Terns is most likely due to their reduced use of Western Port for feeding. This decrease is most likely due to a reduction in the availability of food, and possible reasons for this include: reduced fish availability in the bay due to declines in seagrass; drought-affected estuarine production of some fish species; or increased sedimentation. These processes may not act directly on the terns. Rather, they could affect the availability of tern prey species, mostly small clupeoid fish (Chiaradia et al. 2002). This could occur through changes in behaviour of the fish, resulting from cascading effects caused by changing trophic relationships, such as a decline in predatory fish.

The decline in Crested Tern numbers could also be influenced by changes in the behaviour of Crested Terns. When birds are breeding, their foraging patterns change because they need to radiate from a central point (the nest or nesting colony): this is known as 'central place foraging' (Orians and Pearson 1979, Kacelnik 1984, Stephens and Krebs 1986). Hence, they may disappear from some potential habitats that are further from the breeding colony, such as the inner parts of Western Port. The establishment of the Crested Tern breeding colony at The Nobbies, in combination with central place foraging, raises the possibility that the decrease in Crested Terns in Western Port is a sign of good feeding conditions outside the survey area (e.g. inshore along the southern coastlines of Phillip Island and the Mornington Peninsula).

The increase in terns in West Corner Inlet (by about 250 individuals) was similar in scale to the decline in Western Port, which could be taken to indicate a shift of populations between the two bays. However, this seems most unlikely, because the breeding population at The Nobbies was established, and then increased substantially, during the period under analysis. That is, there appears to have been an overall movement of Crested Terns towards the ocean side of Western Port, rather than eastwards to Corner Inlet.

Conversely, the increase in Crested Terns in West Corner Inlet may reflect dispersal of birds from The Nobbies after successful spring breeding. These possibilities may be true, but they fail to explain why dispersing birds from The Nobbies would choose to go to West Corner Inlet in preference to formerly occupied habitat in Western Port. The most parsimonious explanation is that the relative habitat value of the Western Port survey area may have declined during the period under analysis, whereas the habitat value of West Corner Inlet (and the waters close to the breeding colony at The Nobbies) may have increased or, at least, not decreased.

4.2 A possible explanation for Crested Tern decline in Western Port

Crested Terns have been reported feeding in close association with other seabirds in Western Port, particularly Little Penguins *Eudyptula minor* and Silver Gulls *Chroicocephalus novaehollandiae* (Dann et al. 2001). These seabird feeding aggregations appeared to be associated with the presence of large schools of baitfish (Hoedt et al. 1995). Examination of the fish distribution below one of these seabird feeding aggregations using an echosounder revealed that the baitfish were concentrated in surface waters and appeared to be there because of the presence of predatory fish beneath them (Figure 15). Australian Salmon is one such predatory fish that appears to have declined in Western Port around the time that Crested Tern numbers declined, and to have increased steadily in West Corner Inlet in a similar manner to the Crested Tern (Figure 14). This relationship supports our hypothesis that Crested Terns were dependent on salmon to make baitfish available in the surface waters of Western Port and that, in the absence of salmon, the terns were forced to feed outside the bay. Feeding associations have been reported between shearwaters and dolphins (Martin 1986), and these may have functioned in much the same manner as terns and salmon in Western Port.

4.3 A bird species not captured in this analysis

The BOCA Western Port survey has collected data from spring, early summer and autumn in addition to the two seasons analysed here (late summer and winter). Unfortunately, the spring and autumn surveys were discontinued around 2000 (Heislers et al. 2003), but the early summer survey has continued annually. These other survey periods do not alter the picture greatly, with one notable exception. In the eastern part of Western Port, flocks of up to 200 Whiskered Terns (*Chlidonias hybrida*) were found feeding in the shallow bay between Stockyard Point and Grantville in early summer during the 2000s, whereas the species had previously been rare. The Whiskered Tern can be classed as partly piscivorous (up to 45% by volume of their diet), although they also take insects and crustaceans skimmed from the water surface (Dostine and Morton 1989, Higgins and Davies 1996). This contrasts with the trends for Crested and Fairy/Little Terns in that the Whiskered Tern has increased in Western Port. Whiskered Terns feed mainly in freshwater habitats (Higgins and Davies 1996), and it is possible that the Whiskered Terns in Western Port were feeding mostly on invertebrate prey.

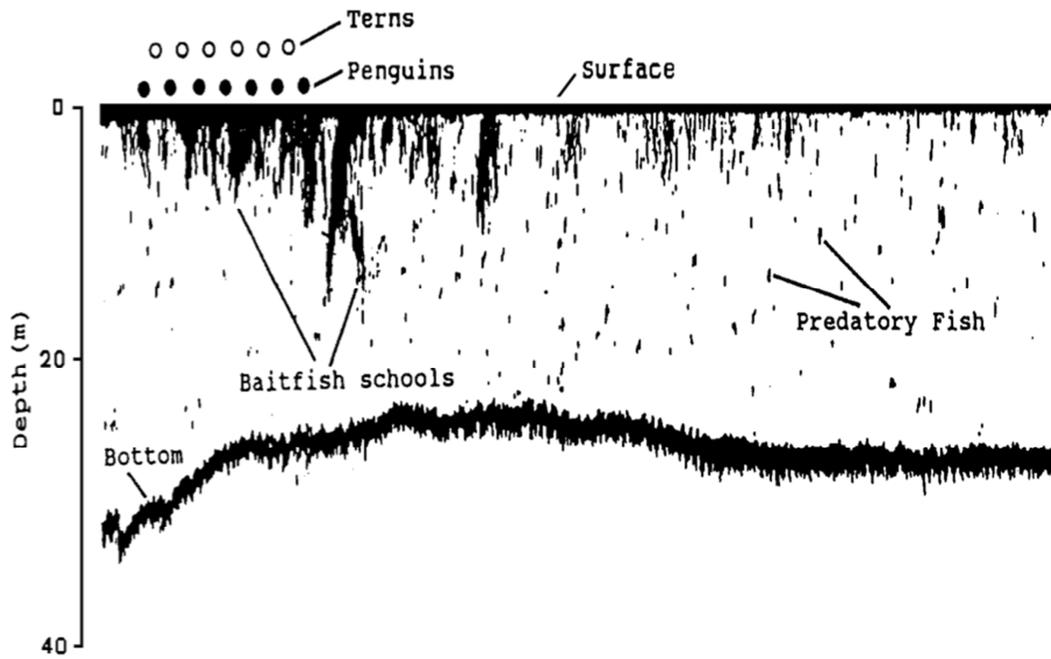**Figure 15. An echosounding trace of baitfish schools that have been driven to the surface by predatory fish in Western Port**
The open circles represent where Crested Terns were feeding in relation to the baitfish schools (Dann et al. 2001).

5   Conclusions

The data currently available have highlighted an unexpected contrast between the two bays, for which we have proposed some plausible (but untested) hypotheses. While many piscivorous bird species have declined in Western Port, the species that have undergone the most dramatic declines are the Crested Tern and the Fairy/Little Tern. The declines in tern use of Western Port are likely to be a consequence of:

• Loss of seagrass.

• Declining fish stocks (as indicated by declining commercial fish catches during the early 2000s); in particular declines in predatory fish such as the Australian Salmon.

• Expansion of breeding colonies outside the survey area.

• A combination of these variables.

Disentangling these hypotheses would require time-series information on seagrass distribution, and improved data on changes to fish stocks and the impacts of variables such as recreational fishing and freshwater inputs to the bays. However, there are few data of this sort available.

The management implications of this study are that feeding conditions for marine terns inside Western Port have deteriorated relative to outside the bay and in comparison to West Corner Inlet. This does indicate a change in the ecology of Western Port in recent times that may be influencing other aspects of the bay's ecosystem. The fish eaten by terns are also important food for some larger fish valued by recreational and commercial fishermen. We suggest that the reduced abundance of one of these larger fish, Australian Salmon, may have reduced the availability of small schooling fish for terns in Western Port. These changes may require management action to protect the integrity of the ecosystem and to maintain the populations of small fish, and of the birds and larger fish that feed upon them.

A critical information gap identified here that would allow increased resolution of the causes of the decline in tern use of Western Port is an understanding of the factors affecting the productivity (and availability) of populations of prey species consumed by marine terns (mostly small clupeoid fish). Southern Anchovy seems particularly important, as it is known to be a major prey species of Crested Terns breeding at the nearby colony at The Nobbies, Phillip Island (Chiaradia et al. 2002). Factors that are likely to affect the availability of small clupeoid fish include climate, seagrass productivity and water quality. There are sufficient data available for Western Port on climate and water quality that could be considered in relation to tern numbers. Analysis of these data would be a useful step in identifying management actions that may be needed.

The decline in fish-eating birds in Western Port was primarily due to decreases in counts of two species of tern (Crested and Fairy/Little). We believe that changes in Crested Tern numbers are due to a redistribution of feeding areas, not to a general decline in population. However, no such redistribution has been observed for Fairy Terns, and they now breed only intermittently in the adjacent Port Phillip. Their fate as a Victorian species may depend very much on conservation measures implemented in Western Port. Given our ignorance of the ecology of Fairy Terns in Western Port, we recommend that the more immediate management actions should relate to research to inform management of this species in Western Port.

We suggest that priorities in research and management of Fairy Terns in Western Port should be to:

1.   Measure the breeding success of Fairy Terns in Western Port.

2.   Identify management options for improving the potential value of breeding sites in Western Port.

3.   Examine historical data and document where Fairy Terns breed each year in Victoria (with numbers and breeding success if known) and what factors contribute to nesting failures.

4.   Determine seasonal patterns of Fairy Tern habitat use in Western Port.

5. Assess what is known of seasonal patterns of habitat use elsewhere in Victoria (especially Port Phillip) and identify any complementary patterns (e.g. is it possible that Fairy Terns breed in Western Port and then spend the winter in Port Phillip?).

6. Identify important gaps in knowledge, e.g. where doubt exists about the specific identity of small terns in the non-breeding season (when they are difficult to identify) and fill those gaps if possible.

7. Discover where Fairy Terns are fishing when they are breeding in Western Port, and if possible the species of fish that they are catching.

8. Discover where Fairy Terns are fishing in the non-breeding season, and if possible the species of fish that they are catching.

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7   Appendices

7.1   Details of GAMMs developed to examine trends in piscivorous bird populations

Region	Season	Response variable	Explanatory variable	p value explanatory variable	R^2 (adj)
WP	s	mean count Great Crested Grebe	time	too few data	–
WP	w	mean count Great Crested Grebe	time	0.445	0.0146
CI	s	mean count Great Crested Grebe	time	0.0847	−0.0169
CI	w	mean count Great Crested Grebe	time	0.281	−0.0474
WP	s	mean count Great Cormorant	time	0.0249	0.101
WP	w	mean count Great Cormorant	time	0.000316	0.167
CI	s	mean count Great Cormorant	time	0.99	−0.0455
CI	w	mean count Great Cormorant	time	<0.0001	0.0887
WP	s	mean count Pied Cormorant	time	0.0961	0.075
WP	w	mean count Pied Cormorant	time	0.201	0.0336
CI	s	mean count Pied Cormorant	time	0.00027	0.536
CI	w	mean count Pied Cormorant	time	0.00273	0.375
WP	s	mean count Little Black Cormorant	time	0.0525	0.0553
WP	w	mean count Little Black Cormorant	time	0.382	0.00752
CI	s	mean count Little Black Cormorant	time	0.00459	0.372
CI	w	mean count Little Black Cormorant	time	0.164	0.00125
WP	s	mean count Little Pied Cormorant	time	0.118	0.0258
WP	w	mean count Little Pied Cormorant	time	0.0268	0.166
CI	s	mean count Little Pied Cormorant	time	<0.0001	0.631
CI	w	mean count Little Pied Cormorant	time	0.258	−0.0153
WP	s	mean count Black-faced Cormorant	time	too few data	–
WP	w	mean count Black-faced Cormorant	time	<0.0001	−0.164
CI	s	mean count Black-faced Cormorant	time	0.0391	0.316
CI	w	mean count Black-faced Cormorant	time	0.0167	0.378
WP	s	mean count Australian Pelican	time	0.000174	0.668
WP	w	mean count Australian Pelican	time	<0.0001	0.484
CI	s	mean count Australian Pelican	time	0.000456	0.436
CI	w	mean count Australian Pelican	time	<0.0001	0.653

Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012

Region	Season	Response variable	Explanatory variable	p value explanatory variable	R^2 (adj)
WP	s	mean count Great Egret	time	0.142	0.0841
WP	w	mean count Great Egret	time	0.315	0.0407
CI	s	mean count Great Egret	time	0.066	0.17
CI	w	mean count Great Egret	time	0.748	−0.0523
WP	s	mean count Little Egret	time	0.229	0.0107
WP	w	mean count Little Egret	time	<0.0001	0.0745
CI	s	mean count Little Egret	time	0.0111	0.347
CI	w	mean count Little Egret	time	0.146	0.00555
WP	s	mean count White-faced Heron	time	0.0805	0.16
WP	w	mean count White-faced Heron	time	0.00127	0.231
CI	s	mean count White-faced Heron	time	0.0228	0.178
CI	w	mean count White-faced Heron	time	0.501	−0.0289
WP	s	mean count Royal Spoonbill	time	0.0161	0.208
WP	w	mean count Royal Spoonbill	time	0.668	0.045
CI	s	mean count Royal Spoonbill	time	<0.0001	0.272
CI	w	mean count Royal Spoonbill	time	0.869	−0.0548
WP	s	mean count Caspian Tern	time	0.0769	0.153
WP	w	mean count Caspian Tern	time	0.306	−0.009
CI	s	mean count Caspian Tern	time	0.854	−0.045
CI	w	mean count Caspian Tern	time	too few records	–
WP	s	mean count Crested Tern	time	<0.0001	0.306
WP	w	mean count Crested Tern	time	0.00197	0.0911
CI	s	mean count Crested Tern	time	0.000545	0.287
CI	w	mean count Crested Tern	time	0.000298	0.303
WP	s	mean count Fairy/Little Tern	time	0.00194	0.301
WP	w	mean count Fairy/Little Tern	time	0.0837	0.0388
CI	s	mean count Fairy/Little Tern	time	0.699	−0.041
CI	w	mean count Fairy/Little Tern	time	<0.0001	0.975
WP	s	mean count all grebes	time	0.128	0.0665
WP	w	mean count all grebes	time	0.235	0.0116
CI	s	mean count all grebes	time	<0.0001	0.654
CI	w	mean count all grebes	time	0.19	−0.031

Region	Season	Response variable	Explanatory variable	p value explanatory variable	R^2 (adj)
WP	s	mean count all cormorants plus Australian Pelicans	time	0.0123	0.172
WP	w	mean count all cormorants plus Australian Pelicans	time	0.0123	0.301
CI	s	mean count all cormorants plus Australian Pelicans	time	<0.0001	0.581
CI	w	mean count all cormorants plus Australian Pelicans	time	0.0598	0.0649
WP	s	mean count all cormorants plus Australian Pelicans plus all terns	time	<0.0001	0.362
WP	w	mean count all cormorants plus Australian Pelicans plus all terns	time	0.000136	0.391
CI	s	mean count all cormorants plus Australian Pelicans plus all terns	time	<0.0001	0.59
CI	w	mean count all cormorants plus Australian Pelicans plus all terns	time	0.0521	0.0707
WP	s	mean count all herons and egrets	time	0.207	0.115
WP	w	mean count all herons and egrets	time	0.00106	0.24
CI	s	mean count all herons and egrets	time	0.0209	0.191
CI	w	mean count all herons and egrets	time	0.538	−0.0325
WP	s	mean count all terns	time	<0.0001	0.251
WP	w	mean count all terns	time	0.00364	0.0807
CI	s	mean count all terns	time	0.0663	0.178
CI	w	mean count all terns	time	0.00231	0.207
WP	s + w	CPUE all fish	time	<0.0001	0.894
CI	s + w	CPUE all fish	time	<0.0001	0.598
WP	s + w	total piscivorous birds	CPUE all fish	0.354	0.0101
CI	s + w	total piscivorous birds	CPUE all fish	0.128	0.174
WP	s + w	mean number of Crested Tern	CPUE Australian Salmon	<0.0001	0.172
CI	s + w	mean number of Crested Tern	CPUE Australian Salmon	0.0294	0.167
WP	s + w	CPUE Australian Salmon	time	<0.0001	0.874
CI	s + w			<0.0001	0.626

7.2 Charts of GAMMs for bird species and bird groups (species in taxonomic sequence (see Table 1))
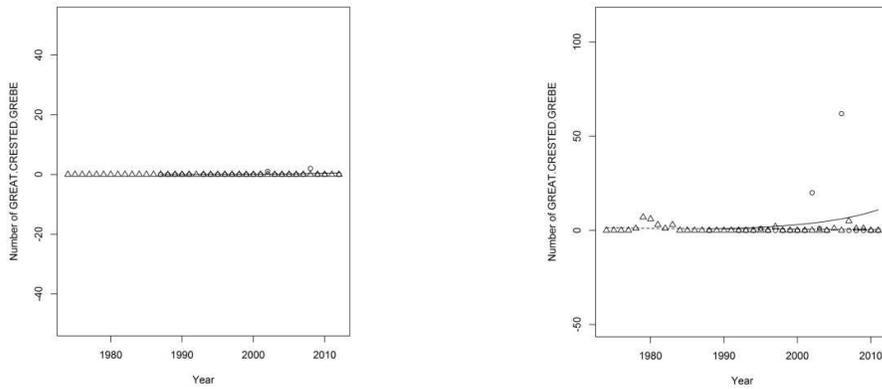
Figure A1. Relationship between numbers of Great Crested Grebe and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). None of the relationships are significant.
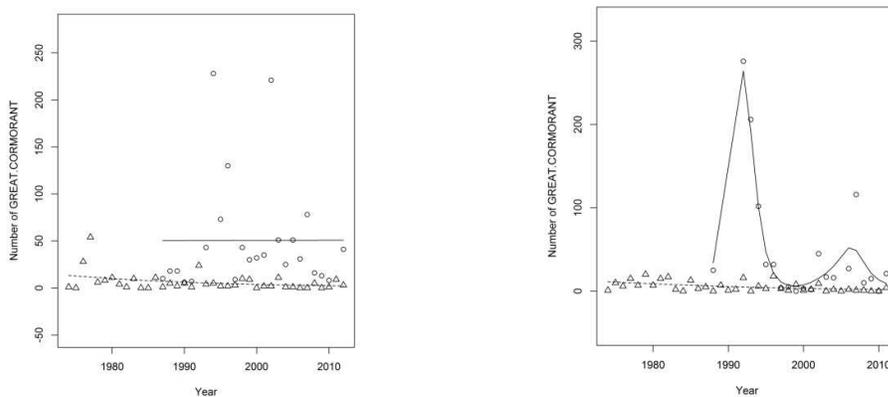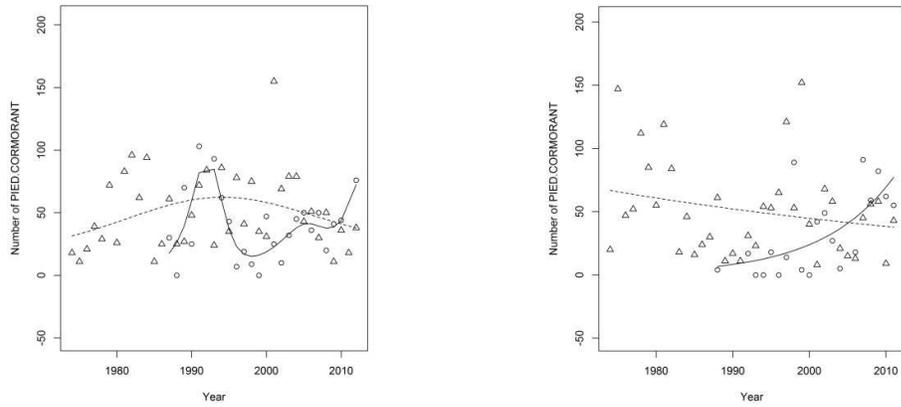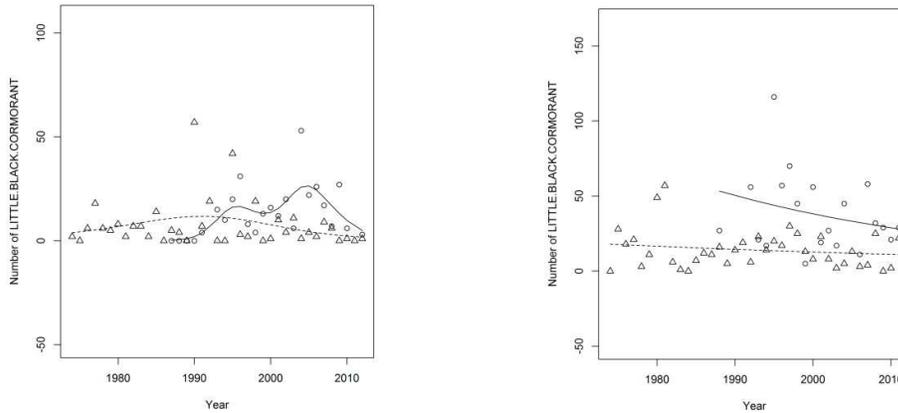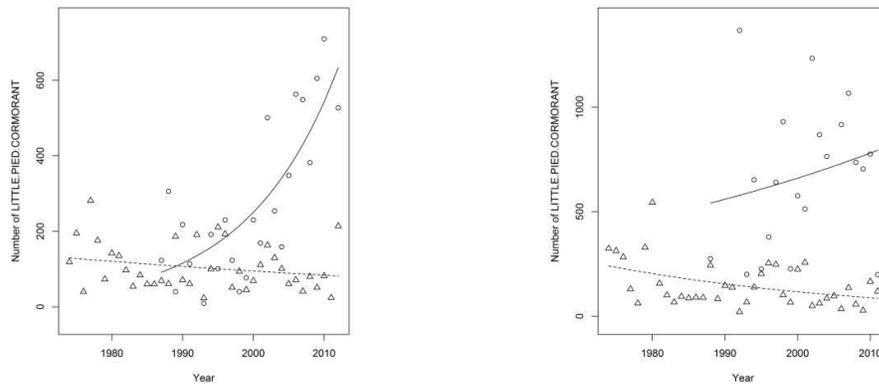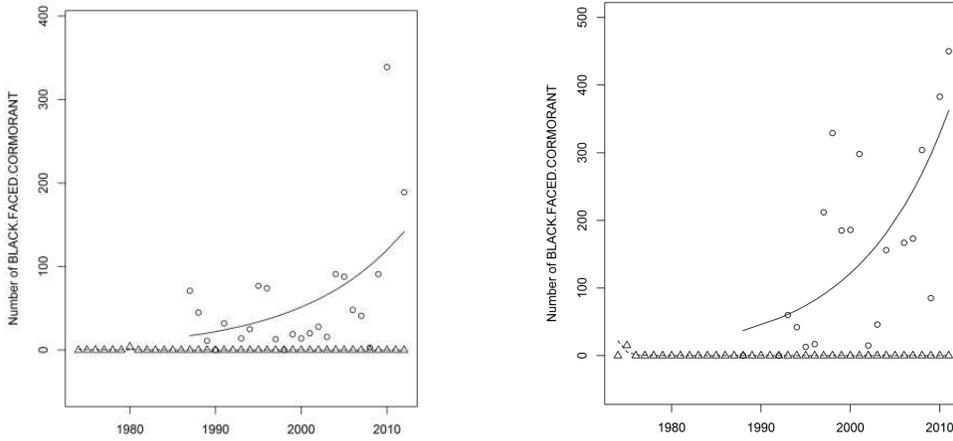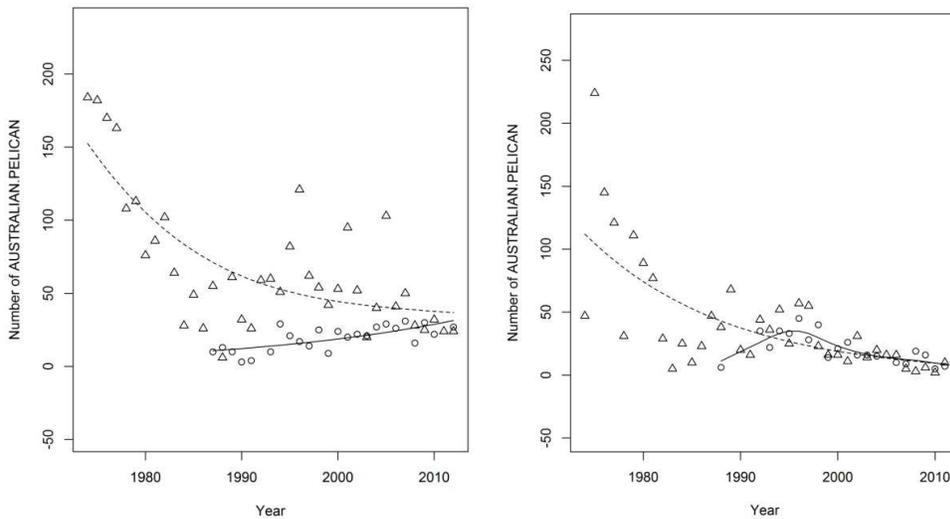

Figure A2. Relationship between numbers of Great Cormorant and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer (p = 0.0249, R^2= 0.101), Western Port in winter (p = 0.000316, R^2= 0.167), and for West Corner Inlet in winter (p < 0.0001, R^2= 0.887).
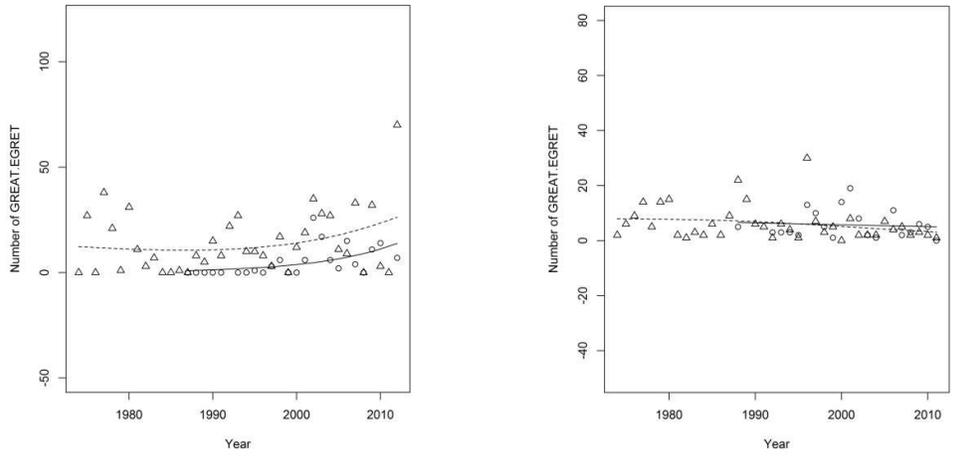
Figure A3. Relationship between numbers of Pied Cormorant and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for West Corner Inlet in summer (p = 0.000127, R^2 = 0.536) and in winter (p = 0.00273, R^2 = 0375.

Figure A4. Relationship between numbers of Little Black Cormorant and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for West Corner Inlet in summer (p = 0.00459, R^2 = 0.372).
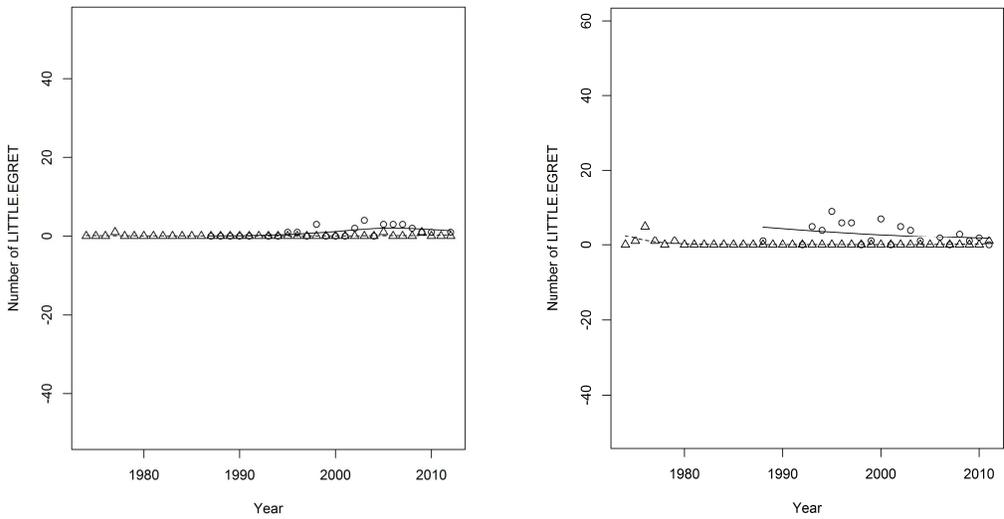

Figure A5. Relationship between numbers of Little Pied Cormorant and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in winter (p = 0.0268, R^2 = 0.166), and for West Corner Inlet in summer (p < 0.0001, R^2 = 0.631).

Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012
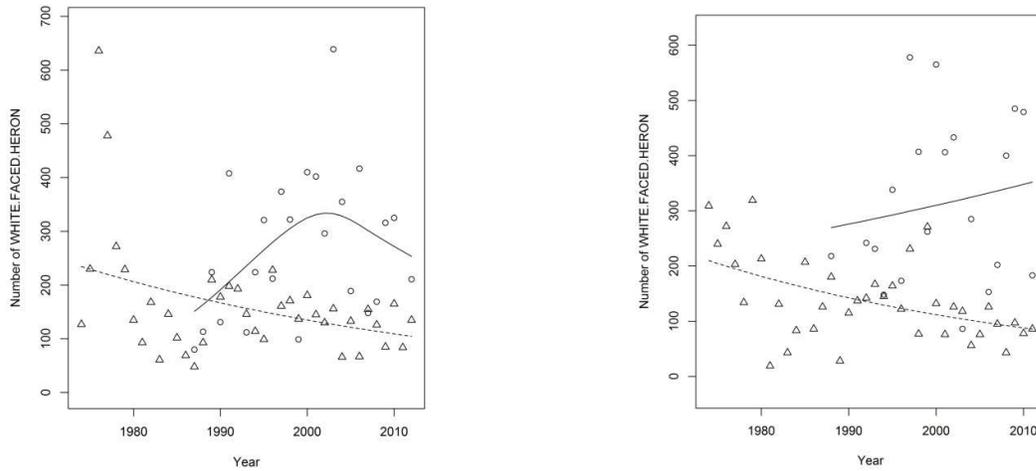
Figure A6. Relationship between numbers of Black-faced Cormorant and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in winter (p < 0.0001, R^2 = 0.164), and for West Corner Inlet in summer (p = 0.0391, R^2 = 0.316) and winter (p = 0.0167, R^2 = 0.378). Black-faced Cormorants gather in West Corner Inlet in summer to breed and disperse after breeding.
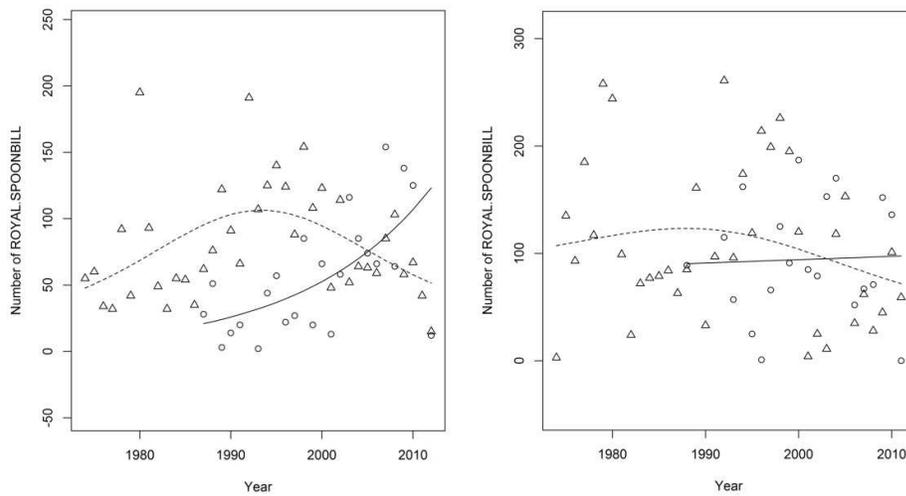

Figure A7. Relationship between numbers of Australian Pelican and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer (p = 0.000174, R^2 = 0.568) and winter (p ≤ 0.0001, R^2 = 0.0653).

Figure A8. Relationship between numbers of Great Egret and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). None of the relationships are significant.
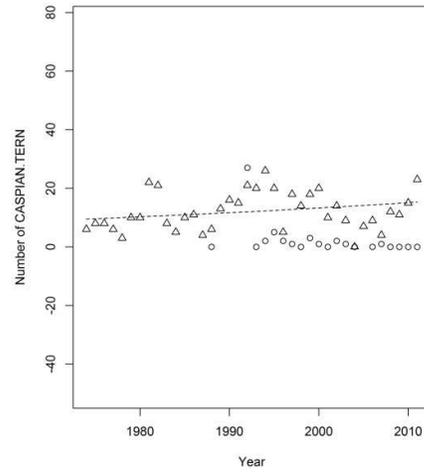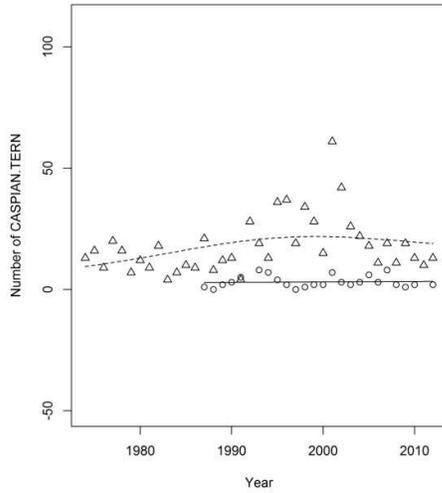

Figure A9. Relationship between numbers of Little Egret and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in winter ($p < 0.0001$, $R^2 = 0.0745$), and for West Corner Inlet in summer ($p = 0.0111$, $R^2 = 0.347$).

Figure A10. Relationship between numbers of White-faced Heron and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in winter (p = 0.00127, R^2 = 0.231), and for West Corner Inlet in summer (p = 0.0228, R^2 = 0.178).

Figure A11. Relationship between numbers of Royal Spoonbill and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer (p = 0.0161, R^2 = 0.208), and for West Corner Inlet in summer (p < 0.0001, R^2 = 0.272).

Figure A12. Relationship between numbers of Caspian Tern and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). None of the relationships are significant.
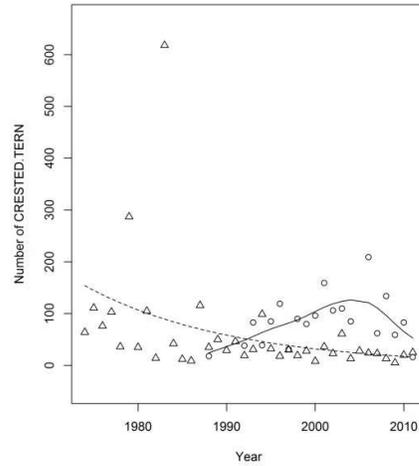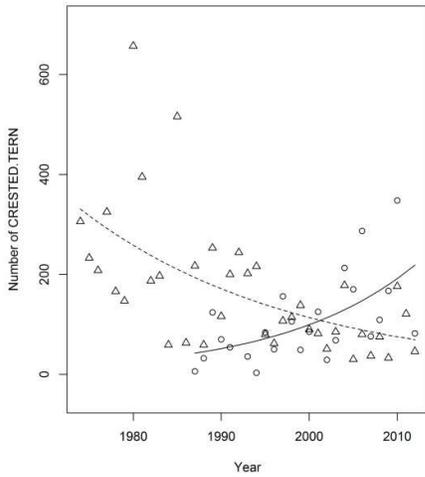

Figure A13. Relationship between numbers of Crested Tern and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer ($p < 0.0001$, $R^2 = 0.306$) and winter ($p = 0.00197$, $R^2 = 0.0911$), and for West Corner Inlet in summer ($p = 0.000545$, $R^2 = 0.287$) and winter ($p = 0.000298$, $R^2 = 0.303$).
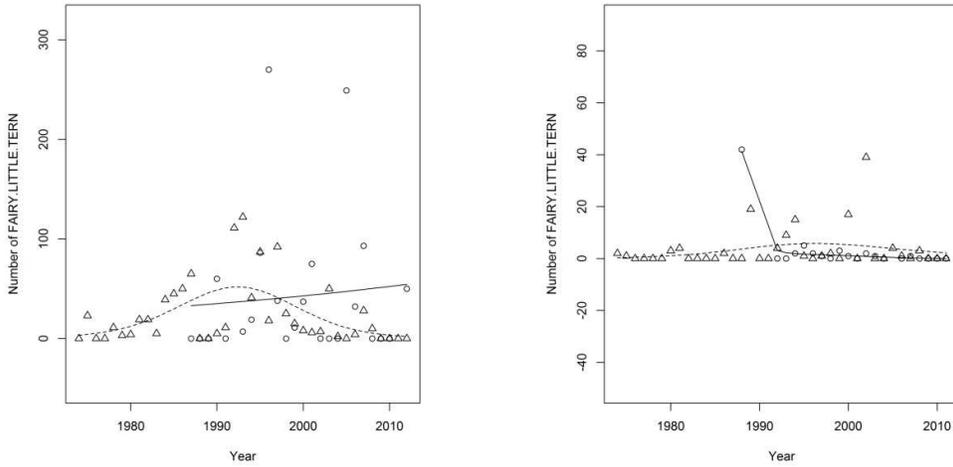
Figure A14. Relationship between numbers of Fairy/Little Tern and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer (p = 0.000194, R^2 = 0.301), and for West Corner Inlet in winter (p < 0.0001, R^2 = 0.975).
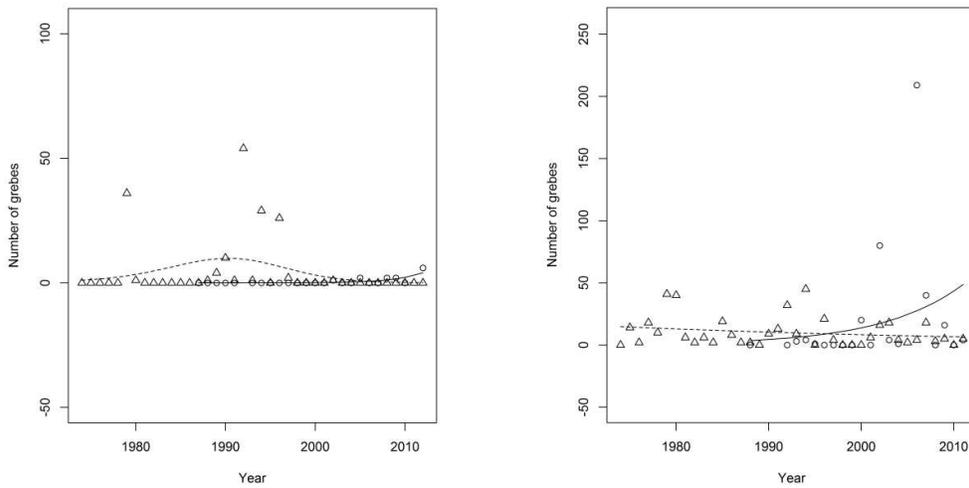

Figure A15. Relationship between numbers of all grebe species and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Only the relationship for West Corner Inlet in summer is significant (p < 0.0001, R^2 = 0.654).
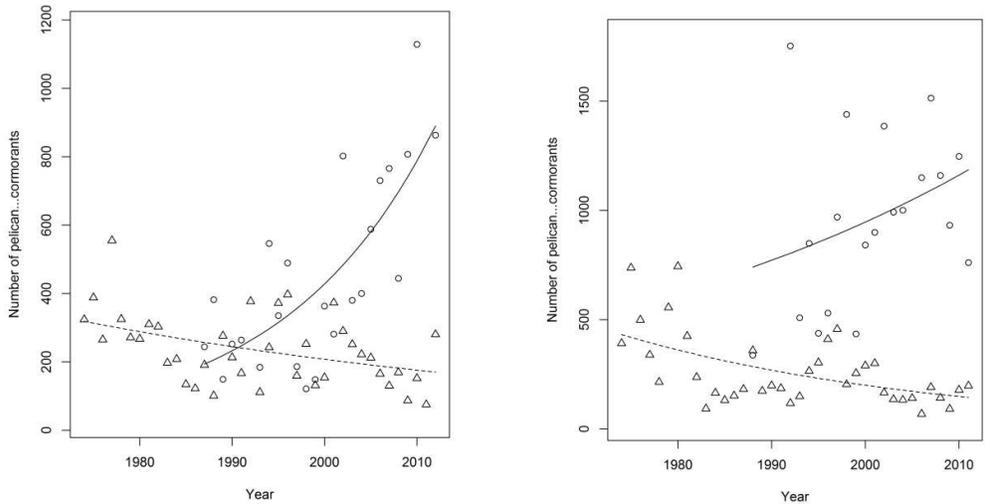
Figure A16. Relationship between numbers of all cormorants plus Australian Pelican and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and for West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer ($p = 0.0123$, $R^2 = 0.172$) and winter ($p = 0.0123$, $R^2 = 0.301$), and for West Corner Inlet in summer ($p < 0.0001$, $R^2 = 0.581$). Note that the summer graph is Figure 6 in the body of the report.
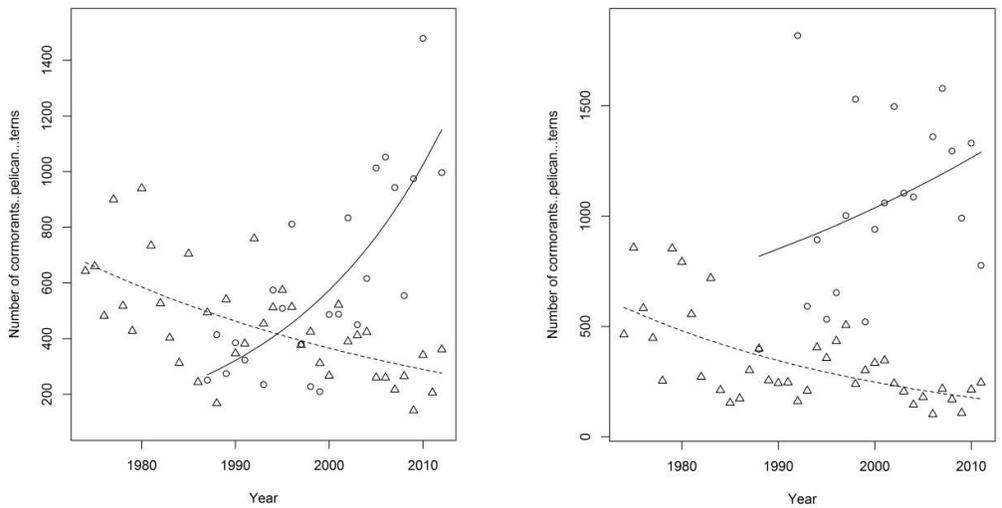

Figure A17. Relationship between numbers of all cormorants plus Australian Pelicans plus all terns and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer ($p < 0.0001$, $R^2 = 0.362$) and winter ($p = 0.000136$, $R^2 = 0.391$), and for West Corner Inlet in summer ($p < 0.0001$, $R^2 = 0.590$). Note that the summer graph is Figure 7 in the body of the report.
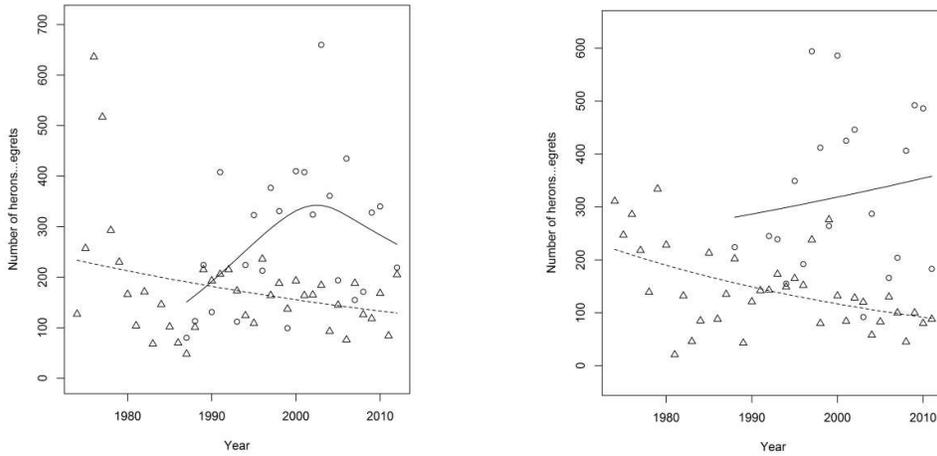
Figure A18. Relationship between numbers of all herons plus egrets and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in winter ($p = 0.00106$, $R^2 = 0.240$) and for West Corner Inlet in summer ($p = 0.0209$, $R^2 = 0.191$).
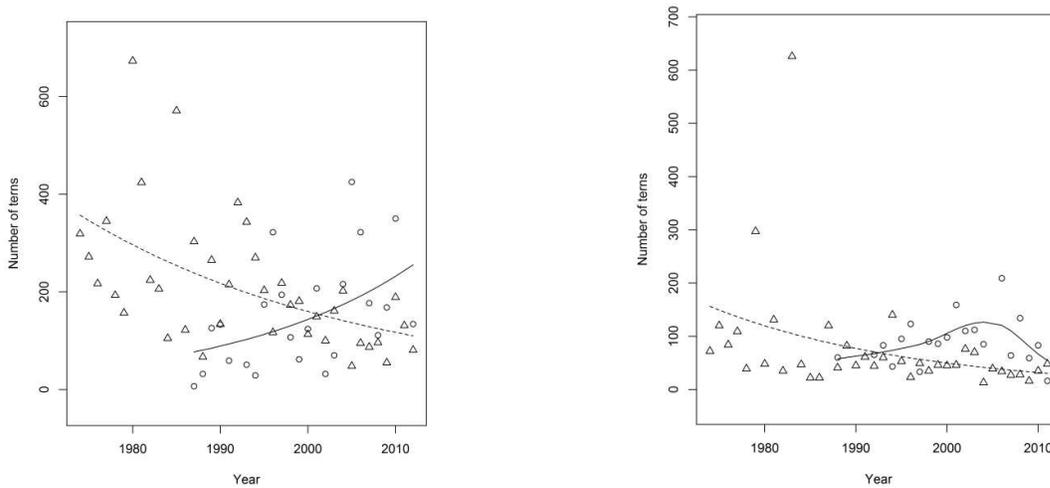

Figure A19. Relationship between numbers of all terns and time (year) in summer (left) and winter (right) for Western Port (triangles, dashed line) and West Corner Inlet (circles, solid line). Significant relationships are for Western Port in summer ($p < 0.0001$, $R^2 = 0.251$) and winter ($p = 0.00106$, $R^2 = 0.240$) and for West Corner Inlet in winter ($p = 0.00231$, $R^2 = 0.207$). Note that the summer graph is Figure 8 in the body of the report.

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