Chapter 16

Is predation on seabirds a new foraging behaviour for Great White Pelicans? History, foraging strategies and prey defensive responses

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Great White Pelicans *Pelecanus onocrotalus* feed mainly on fish and other aquatic organisms. In the Western Cape they display an unusual foraging behaviour: feeding on seabird chicks, with increasing extent and frequency since the mid 1990s. Seabird species targeted by pelicans include Cape Gannets *Morus capensis*, Cape *Phalacrocorax capensis* and Crowned *P. coronatus* Cormorants, Kelp Gulls *Larus dominicanus* and Swift Terns *Sterna bergii.* Bank Cormorants *P. neglectus* are occasionally disturbed by the activities of the pelicans. Pelicans use different hunting strategies for the diverse prey species, depending on their nesting characteristics and defensive behaviour of adults and chicks. The impact of predation on the breeding success of target species was assessed at four islands off the Western Cape in the summers of 2005/06 and 2006/07. A maximum of 200 pelicans was involved in predation events at the Saldanha Bay islands during peak predation by pelicans at the end of November. Pelican behaviour, time-budgets and all observed incidents of predation were recorded. The intensification of predatory interactions between pelicans and seabirds is linked to an increased population of pelicans and a diminished supply of artificial food sources for them. Pelican predation could have detrimental mid-term effects for local seabird populations. Proposed management actions are listed, providing a preliminary platform to discuss their effectiveness, pros and cons and other ethical considerations.

Keywords: Bank Cormorant, Cape Cormorant, Cape Gannet, Crowned Cormorant, Great White Pelican, foraging ecology, Kelp Gull, *Larus dominicanus*, *Morus capensis, Pelecanus onocrotalus*, *Phalacrocorax* spp., predation, seabird conservation, *Sterna bergii,* Swift Tern

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Introduction

As a consequence of global change, many organisms are exhibiting new or modified behavioural traits. A common response to human-altered ecosystems is the exploitation of novel food sources, which often result in population increases of opportunistic species. This has been well documented for large gulls (*Larus* spp.) in the Northern Hemisphere, which feed on refuse tips and on offal and fish discards from fishing vessels (Blokpoel & Spaans 1991, Migot 1992, Bosch *et al.* 1994, Sol *et al.* 1994, Pons & Migot 1995, Vidal *et al.* 1998, Oro 1999). Such population increases can affect the breeding performance and population dynamics of co-existing species due to prey switching by the opportunistic predator species, especially if its subsidised food source is reduced (Regehr & Montevecchi 1997, Votier *et al*. 2004). Extensive research has been carried out on avian opportunistic predators and their effects on seabird assemblages, in particular with regard to gulls (*Larus* spp.) and Great Skuas (*Catharacta skua*), in the Northern Hemisphere (Furness 1987, Becker 1995, Phillips *et al.* 1999, Bosch *et al.* 2000, Hernández-Matías & Ruiz 2003, Martínez-Abraín *et al.* 2003, Votier *et al*. 2004); and skuas (*Catharacta* spp.), Kelp Gulls (*L. dominicanus*) and giant petrels (*Macronectes* spp.) in the Southern Hemisphere (Hunter & Brooke 1992, Emslie *et al*. 1995, Yorio & Quintana 1997, Weidinger 1998). The effect on prey species is often detrimental, impacting negatively on their breeding success, recruitment and population dynamics. For some species of conservation concern management plans have been implemented. Intervention actions range from population control measures, such as culling and reduction of breeding success of the predator (Finney *et al.* 2003, Guillemette & Brousseau 2001, Vidal *et al.* 1998), to protection of the prey species by building shelters (Prieto *et al.* 2003). A few studies test the use of deterrents to keep avian predators away, mostly by the means of taste aversion experiments (Cowan *et al.* 2000, Neves *et al.* 2006).

Studies linking behaviour and conservation disciplines are crucial to predict the consequences of environmental change, as well as to maintain ecosystem processes and functional, healthy communities (Sutherland 1998). Understanding the behaviour of the species allows making informed management decisions, avoiding undesirable effects as a consequence of well-intentioned interventions to protect vulnerable species or communities (Sutherland 2006).

The elongated bill and large gular pouch of pelicans are adapted to capturing prey in aquatic environments (del Hoyo *et al.* 1992, Johnsgard 1993). In most pelican species this is accomplished by bill thrusting while swimming on the surface, foraging both solitarily and cooperatively (Johnsgard 1993). Some species occasionally scavenge dead fish (Johnsgard 1993). On the west coast of southern Africa, Great White Pelicans (*Pelecanus onocrotalus*) are opportunistic, utilising different sources of food depending on its tem-

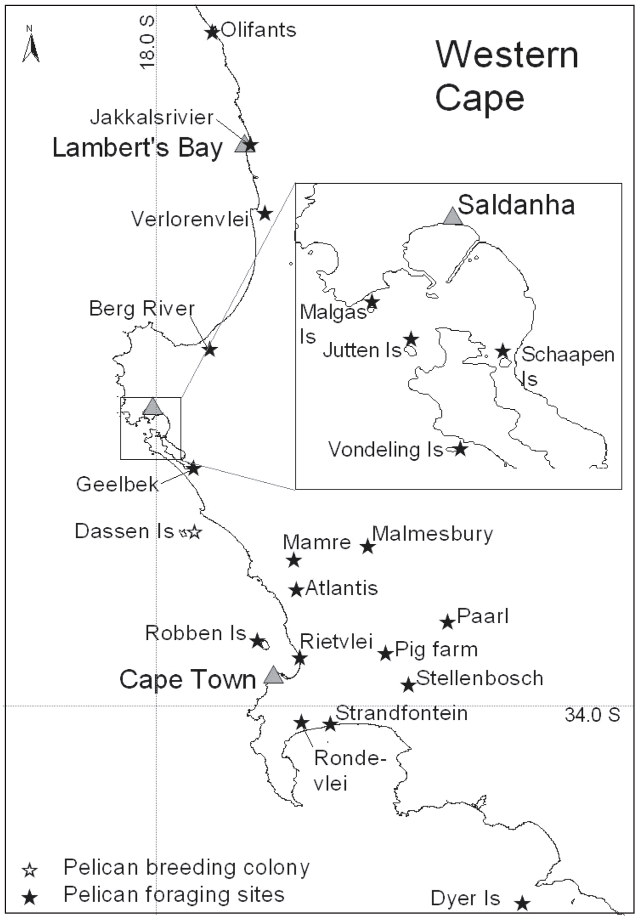

Figure 1: Location of the only Great White Pelican breeding colony in the Western Cape, in relation to foraging sites on islands and on the mainland

poral and spatial availability. They frequent harbours and fishing sites to feed on fish discards, as well as pig and chicken farms to feed on agricultural offal (Berry & Berry 1975, Hockey *et al.* 2005, de Ponte Machado & Hofmeyr 2004). In the last two decades, they have been observed to prey extensively on nest-bound chicks of other seabird species; this behaviour being exclusive of the coastal south-western African populations.

The Great White Pelican is a widely distributed species, breeding in Europe and Africa (Crivelli *et al.* 1998, Johnsgard 1993). In southern Africa they breed annually in three localities: at the Bird Rock guano platform in Walvis Bay, Namibia, on Dassen Island in the Western Cape, South Africa, and at St Lucia Wetland Park, KwaZulu-Natal; and opportunistically at 2–3 inland sites (Williams & Borello 1997, Hockey *et al*. 2005). The Western Cape breeding population of Great White Pelicans increased from 25–30 pairs in 1956 to 185 pairs in 1985, 434 pairs in 1991 and 650 pairs in 2001. It then decreased to 370 pairs in 2006. The increase was initially due to increased protection at the breeding site, and subsequently to the availability of agricultural offal (Crawford *et al.* 1995 updated). Regional censuses show the same trend, indicating a four-fold increase in numbers from ca. 500 pelicans in 1975 to ca. 2000 in the period 2004–2007 (Crawford *et al.* 1995, de Ponte Machado *et al.* in prep.).

Pelican predation on seabirds in the Western Cape has increased in frequency and extent since 1990, with other seabirds becoming a common source of food for breeding pelicans and their offspring on the offshore islands. Predation of co-existing bird species threatens the already vulnerable local seabird communities. However, a more detailed analysis of the impact on seabird populations and its conservation implications will be the matter of successive papers. This paper summarises the history of pelican predation on other seabirds in the Western Cape and reviews existing literature for evidence of this behaviour elsewhere in the world. It also describes the range of foraging techniques used by pelicans feeding on avian prey, as well as the defensive responses of prey species to pelican predation.

Methods

Historical perspectives

In order to trace the history of pelican predation on other bird species I undertook a literature review of local and international sources, including journals, books and electronic media. To include unpublished anecdotal observations I interviewed people, both scientists and members of the public, who had information related to the subject.

Data collection and analysis

Field observations were carried out between 2004 and 2007 on four offshore islands off the west coast of South Africa: Dassen (33°25'S, 18°05'E), Malgas (33°03'S, 17°55'E), Jutten (33°05'S, 17°57'E) and Schaapen (33°05'S, 18°01'E) islands (Figure 1). Predatory interactions were monitored between pelicans and six locally breeding seabird species, namely the Kelp Gull, Cape Cormorant (*Phalacrocorax capensis*), Crowned Cormorant (*P. coronatus*), Bank Cormorant (*P. neglectus*), Cape Gannet (*Morus capensis*) and Swift Tern (*Sterna bergii*) colonies. Observations were made with 10 × 42 binoculars and a 30 × 60 telescope, and some activities were recorded with a digital video camera.

On Jutten Island, observations were made mostly from the top of the main hill, 34 m above sea level, which allowed a panoramic view of about three quarters of the island; only the lower shore was not visible. Pelican activity was observed for 20 days in 2006, totaling 116 hrs of observations. From March to May 2007, the island was visited on six more occasions to monitor the second breeding attempt by Cape Cormorants during the 2006/07 breeding season. On Malgas Island, observations were made from a hide located on top of one of the old guano buildings. Three quarters of the island were visible from this vantage point. A total of six days in 2006 and 12 days in 2007, totaling 105 hours of observations, was spent observing pelican predatory behaviour at this location. To avoid disturbance to the dense breeding colonies occupying the interior of Schaapen Island, predation by pelicans was only monitored on the periphery of the island, from a kayak. This method did not have any perceptible effect on the behaviour of the pelicans. Eleven trips were made around the island between October 2006 and January 2007. On two separate occasions towards the end of the 2005/06 summer season, the interior of Schaapen Island was inspected for the presence of Kelp Gull and Cape Cormorant fledglings. A further nine trips were made to the island in between March and May 2007, to monitor Swift Tern, Hartlaub's Gull (*Larus hartlaubii*) and Crowned Cormorant colonies*. Ad hoc* observations were made on Dassen Island from the lighthouse and at several cormorant and gull colonies.

Observations were carried out from sunrise (05:00) to sunset (20:00) on Malgas and Jutten Islands using standard behavioural sampling methods (Altmann 1974, Lehner 1996). Breaks of 15 min to 1 hr were spread throughout the day. To estimate the pelicans' daily activity budget, I scored all visible pelicans every 30 minutes into five activity categories: (1) locomotive (walking or flying); (2) foraging (searching, vigilance, predation events and swallowing); (3) maintenance (preening); (4) resting (sitting or sleeping) and (5) defensive. Sometimes it was difficult to discriminate between walking 'with a locomotive function' and walking 'for foraging purposes'. In such cases, the activity was defined by the general attitude of the pelican or group of pelicans. E.g. if walking was closely followed by searching behaviour, predation, attempted predation or vigilance of a nest, it was categorized as (2) foraging. Otherwise, the activity was categorise as (1) locomotive. Similarly, preening may take place in short spells during walking, foraging or resting. Where preening occurred at the time of a scan, the activity was categorised as (3) maintenance, irrespective of other activities preceding or following the event.

In between instantaneous behaviour scans, all predation events were recorded. When possible I also recorded prey species, size/age of chick, pelican group size, number of pelicans involved in the attack, number of failed attempts, incidence of fights among pelicans and defensive behaviour towards prey species. Pelicans were continuously scanned for rings or distinguishable individual features. However, very few pelicans were marked or individually distinguishable. This, combined with the quick movements of pelican groups and obstacles that hindered observations, meant that it was not possible to collect focal animal behavioural observations (Altmann 1974, Lehner 1996), which would have allowed the number and size of chicks eaten by individual pelicans to be determined.

Results

History of predation

Pelicans almost exclusively eat fish, and are not thought to adapt readily to other types of prey (del Hoyo *et al.* 1992). Wild Great White Pelicans have not been recorded eating seabirds in Europe or outside southern Africa (A. Crivelli pers. comm.). However, a few cases are reported in the literature of unusual pelican predation on avian prey. Brown Pelicans (*Pelecanus occidentalis californicus*) were observed eating pre-fledgling chicks in a heronry in California (Ketchnel 2003). Brown Pelicans have been reported to eat Common Murre (*Uria aalge)* chicks, as well as ardeid eggs and nestlings in a mixed heronry near a pelican breeding colony in Mexicali, Mexico (Mora 1989). An Australian Pelican (*P. conspicillatus*) was observed swallowing a female

ETHICAL AND CONSERVATION NOTE

Whenever possible, no interference was made with the behaviour of either predator or prey. Depletion of colonies by pelican predation posed both ethical and conservation concerns, as some of the prey species have restricted ranges and are included in both local and international categories of protection (Groombridge 1994, Barnes 2000, BirdLife 2000, du Toit *et al.* 2003) (Table 1). However, collecting 'natural' predation rates and measuring its impact on seabird populations was necessary in order to justify further management actions. If pelican predation were directed to Bank Cormorants (Endangered), intervention would have been implemented by carefully chasing pelicans from the site. Cape Gannets (Vulnerable) are mostly threatened by reduced prey availability, especially of Sardine *Sardinops sagax* and Cape Anchovy *Engraulis capensis*, and by predation of fledglings by Cape Fur Seals *Arctocephalus pusillus* in the waters near the breeding colony at Malgas Island. Pelican predation introduced a new and serious threat to the colony at Malgas Island, which holds approximately 50% of the South African gannet population and 42% of the global population. Cape Cormorants are classified as Near Threatened; however, numbers breeding exhibit marked annual fluctuations related to the abundance of their main prey item, Cape Anchovy. Also, they breed in large numbers in colonies (e.g. Dyer Island) that have not been subject to predation by pelicans. Crowned Cormorants were not targeted extensively on the monitored islands in Saldanha Bay. Kelp Gulls, Swift Terns and Hartlaub's Gulls are widespread species and not threatened. The Great White Pelican is a native species to southern Africa, where it is classified as Near-Threatened due to its small number of breeding colonies (Barnes 2000, du Toit *et al.* 2003). However, the pelican population in the Western Cape has increased as a consequence of human subsidisation of its food supply, and this has increased the impact of its predation on prey species. Any intervention aimed to diminish pelican predation on seabirds should consider: 1) the population dynamics of prey species, their threats and trends; 2) unforeseen ecological consequences of any management strategies chosen; 3) a careful and detailed analysis of costs and benefits of management actions; and 4) an analysis of the action's ethical implications (see Vucetich & Nelson 2007).

Table 1: Distribution and conservation status of Great White Pelicans and the avian prey species targeted by pelicans on the monitored islands according to IUCN red data list categories (EN: endangered; VU: vulnerable; NT: near-threatened; LC: least concern) (Groombridge 1994, du Toit *et al.* 2003)

Species	Distribution	Conservation status
Bank Cormorant	Endemic southern Africa	EN (global)
Cape Cormorant	Endemic to Benguela	NT (global)
Cape Gannet	Endemic southern Africa	VU (global)
Crowned Cormorant	Endemic west coast southern Africa	NT (global)
Great White Pelican	Widespread Africa, Europe and Asia	NT (southern Africa)
Hartlaub's Gull	Widespread	LC (global)
Kelp Gull	Widespread southern oceans	LC (global)
Sacred Ibis	Widespread	LC (global)
Swift Tern	Widespread	LC (southern Africa)

Grey Teal (*Anas gibberifrons*) along with her ducklings (Jonhsgard 1993). A captive Great White Pelican swallowed a live pigeon in St James Park in London in October 2006 (BBC News, Burleigh 2006). Several other incidents have been reported from captive pelicans in zoological parks in London and France, where pigeons, goslings and moorhens have been eaten (Hartley-Brewer 1999, E. Bureau pers. comm.).

Prior to 1990, there were a few reports of predatory interactions between the Great White Pelican and other bird species on the west coast of southern Africa. Pelicans were reported to feed on young cormorant and gannet chicks since at least the 19th century, leading to pelicans being chased off guano islands and their eggs smashed (Layard *et al.* 1884, Green 1947, 1950). The first detailed scientific reference to this behaviour was recorded by Berry (1976), who observed pelicans, including juveniles, swallowing Cape Cormorant chicks and eggs at the Bird Rock guano platform in Namibia. There were no subsequent records until 1989, when a pelican was observed eating a Little Grebe (*Tachybaptus ruficollis*) in the Berg River (32°47'S, 18°10'E; Figure 1) (C. Velazquez pers. comm.).

From the mid 1990s, pelicans were observed walking through Kelp Gull colonies on Dassen Island, catching and swallowing gull chicks (D. Nel pers. comm.). When large colonies of Cape Cormorants were present on the island, the pelicans would also eat their chicks. From at least January 1995, pelican groups larger than 100 individuals were involved in feeding frenzies on Dassen Island, eating Kelp Gull, Cape and Crown Cormorant chicks (D. Nel pers. comm.). During that period, low reproductive success of Kelp Gulls on the island was attributed to the high rate of chick predation by Great White Pelicans (Crawford *et al*. 1997) and Cape Cormorant chicks were found in pelican chicks' regurgitations (Crawford *et al.* 1995). In December 1997 pelicans were suspected of wiping out Kelp Gull and Cape Cormorant colonies on Vondeling Island (Marine and Coastal Management, unpublished data). On rare occasions in the late 1990s, small numbers of pelicans visited Jutten Island and were observed swallowing seabird chicks (B.M. Dyer & E. Papier pers. comm.). In February 2002, pelicans annihilated the two breeding colonies of Swift Terns on Dassen Island (de Villiers *et al*. 2002). They have also been reported disturbing breeding Bank Cormorants and eating surface nesting African Penguins (*Spheniscus demersus*) on Dassen Island (WCNCB 1995).

Since the summer of 2005/06, pelican predation on seabirds has intensified. The species composition of their seabird prey has diversified, and pelicans have been observed prospecting at locations where they were previously unrecorded. In December 2005, pelicans were recorded, for the first time in at least 50 years, eating Cape Gannet chicks on Malgas Island (L. Pichegru pers. comm.). During the 2005/06 and 2006/07 seasons they ate all the Crowned Cormorant chicks (more than 200 nests each year, accountable for 13% of the total population in 2006/07) around the lighthouse on Dassen Island (J. Visagie pers. comm., Musangu *et al.* in prep.). On Jutten and Schaapen islands they caused total failure of Cape Cormorant and Kelp Gull colonies (MdP pers. obs.). In March 2006 pelicans were observed disturbing Red-knobbed Coots (*Fulica cristata*) at Abrahamskraal water hole, West Coast National Park (K. Harrison pers. comm.), and in October, pelicans ate most of the chicks of two Sacred Ibis (*Threskiornis aethiopica*) colonies at Rondevlei Nature Reserve, Cape Peninsula (D. Gibbs pers. comm.). Also in October 2006, a flock of eight pelicans was observed scouting a Kelp Gull colony on Robben Island, where pelicans had not been seen for at least ten years (L.G. Underhill & T.M. Leshoro pers. comm.). Five pelicans were chased after landing among breeding Cape Cormorants on Dyer Island in October 2006 (L. Waller pers. comm.), also a first for this southern coast island.

Predation strategies

Mostly, pelican predation was directed towards colonial bird species, especially Kelp Gulls, Cape and Crowned Cormorants and Cape Gannets. They also targeted Swift Terns, Hartlaub's Gulls and a coastal Sacred Ibis colony. Sacred Ibis and African Oystercatchers (*Haematopus moquini*) breeding on the islands during the peak of the summer breeding season were not targeted directly by the pelicans. Predatory interactions observed between pelicans and Hartlaub's Gull at Schaapen Island were not analyzed in this study, on account of the difficulty of recording pelican activity in the thick vegetation favored by these gulls when breeding.

Typically, small groups of pelicans would fly over larger islands, prospecting the area for conspicuous prey aggregations. Where they landed close to the breeding colonies of prey species, they were frequently followed by other pelicans which landed in amongst them. In most cases, predation was directed at chicks of diverse stages and sizes, although at least five incidents were recorded in which they captured and swallowed an adult Cape Cormorant.

In almost all cases, birds were swallowed alive and whole. Larger chicks could take more than 1 hr to be swallowed, in particular large Cape Gannet chicks. The maximum swallowing time observed was 84 min for a large gannet chick. Pelicans tried to accommodate the irregular-shaped body in its pouch by repeatedly tossing the chick up into the air. They would then shake their head and neck sideways with the bill pointing downwards, alternating with thrusting the bill up to the sky until the chick was successfully lodged in the throat.

Pelican foraging strategy and group size varied according to the diverse breeding characteristics and behaviour of the prey species (Table 2, Figure 2). Pelican approach to the nests was also dependent on the size and behaviour of the chicks, and defense responses of the adults (Table 2).

Kelp Gull

Pelicans approached Kelp Gull colonies by walking in groups consisting of at least five, but often exceeding 12, individuals. At the peak period of pelican predation upon Kelp Gulls, hunting groups of more than 70 pelicans were observed at Jutten Island. On Dassen Island older chicks sometimes joined these feeding frenzies near their own breeding grounds. Pelicans often walked in a line or in V-formation (Figure 2 (4a)), in a similar manner to their commonly used flight formation, and in contrast to the horse-shoe shape they adopt when fishing cooperatively in water.

Kelp Gulls took flight when any intruder, including pelicans, approached the colony, subsequently charging against the pelican or groups of pelicans by executing sharp flight dives directed towards the heads of the pelicans, while uttering aggressive vocalizations. Pelicans kept in close proximity to each other and moved fast, trying to avoid ferocious Kelp Gull attacks. Sometimes they gathered together in disorderly groups (Figure 2(4b)), bumping into each other and directing their open beaks up towards the attacking gulls. Foraging in groups seems to be important especially when predation is directed to Kelp Gulls, due to the adult's aggressive responses towards the pelicans. Kelp Gulls managed to injure some pelicans by hitting them on the head or back with their legs and beaks, to the extent that I observed several pelicans with blood running down their head and neck. Pelicans were not completely deterred by these attacks, although they showed caution and predatory attempts were often unsuccessful, especially when group sizes were small. On several occasions I observed a Kelp Gull chasing a pelican away, flying in close pursuit after it.

Pelicans checked for gull chicks under bushes and rock crevices. Once Kelp Gull chicks were partially covered in feathers and able to leave the nest, they became more visible to the pelicans, which often ran after the more mobile chicks. Responses by adult Kelp Gulls were more intense when chicks were larger, and consisted of a mob of adults flying around the group of pelicans involved in the predation event, producing large disturbance and noise.

Pelicans were frequently observed to fight amongst each other over prey, either by clasping the neck of a pelican in possession of a chick in an attempt to make it release and drop the chick, or by pulling on the chick's wings or body flesh. After such intense hunting incursions, pelicans would stop and preen, often resting or sleeping for hours at a time. During these periods, subgroups of pelicans would go off on short hunting raids.

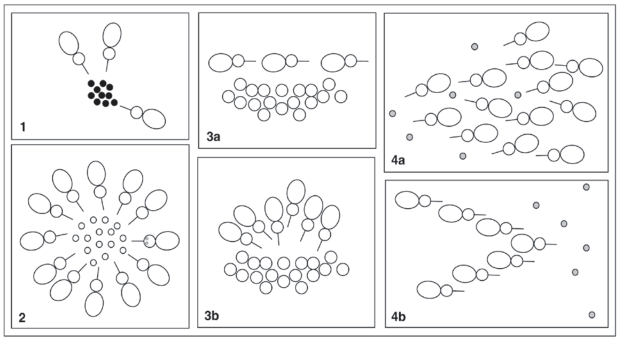

Figure 2: Pelican hunting methods for each prey species: small group surrounds a cluster of Cape Cormorant nests (1); tight group around Swift Tern chicks (2); patrolling the edge of a Cape Gannet colony (3a); stalking a suitable Cape Gannet chick (3b); walking through a Kelp Gull colony in a disorderly group (4a), and in V-formation (4b)

Cape Cormorant

Pelicans approached Cape Cormorant colonies by flying, landing a few metres away from the nests. The remaining distance would be covered by walking and often hopping in between boulders in the highly irregular terrain. Pelicans would also land on top of walls and artificial platforms in order to access cormorant nests. Pelican foraging groups usually were usually small (2–5 individuals). Often they would surround a nest, or group of nests, and stared at it intently for over an hour, waiting for an opportunity to grab a chick from under the brooding adult (Figure 2 (1)). Sometimes they would poke an adult with their beaks, extracting the chick from beneath its body. On some occasions when an incubating or brooding adult cormorant failed to abandon the nest, it was seized by the pelican and unless it managed to escape, leaving the chicks unattended, it was swallowed whole.

The defensive response of adult Cape Cormorants was limited to extensions of the head and neck and gular fluttering. This response was not effective in deterring pelicans or preventing them from eating their chicks. Only at inaccessible nests located on either ledges or isolated rocks did some chicks fledge successfully.

Table 2: Prey species nesting characteristics and defensive responses to intruders (based on Hockey *et al.* (2005) and personal observations). Colonies observed in this study were located on Dassen (D), Malgas (M), Jutten (J) and Schaapen (S) islands

Prey species	Nest location	Nest density	Adult defensive response	Chick defensive response	Colonies observed in this study
Kelp Gull (*Larus dominicanus*)	On the ground, on flats and hills	Sparsely distributed (1–4/m^2)	Dive-bombing intruders, attacking with legs and beak. Loud alarm call	Hiding among bushes and rock crevices	D, M, J, S
Cape Cormorant (*Phalacrocorax capensis*)	Mostly at ground level, on rocks and artificial structures	Dense colonies, often in large clusters (3.1–5.5/m^2)	Shaking head, back and forth movement of neck, pointing to intruder with bill. Groaning noises	None when small. Big chicks run away from intruders *en masse*	D, M, J, S
Crowned Cormorant (*P. coronatus*)	On the ground or on top of alien trees, fish traps and artificial structures	Nests in small clusters, close to each other	Similar to Cape Cormorant, easily abandon nests by flying away	None when small. Bigger chicks move away from intruders	D, M, J, S
Bank Cormorant (*P. neglectus*)	On top of big boulders close to the shore	Sparse to moderate densities. On Jutten Island often among Cape Cormorant nests	Extending neck and bill forward towards intruder	Not observed	D, J
Cape Gannet (*Morus capensis)*	On flat sandy ground	Dense colonies (2.75–6.25/m^2)	Aggressive to conspecifics, including pointing with beak, thrusting neck and pecking neighbours in close proximity	None	M
Swift Tern (*Sterna bergii*)	On flat open ground	Tightly packed colonies (6.1–8.2/m^2)	Loud alarm calls, flying in circles over colony. Diving at intruders not well developed	None when small. Larger chicks move away from intrudersrapidly, often in tight groups	S

Crowned Cormorant

Pelican hunting strategy for Crowned Cormorant chicks was similar to that described for Cape Cormorants. They approached nests in small groups, in particular when nests were built at ground level, as was the case of most Crowned Cormorants nests on Dassen Island. On Jutten, Malgas and Schaapen Islands, Crowned Cormorants select nests on the top of trees or high structures, out of the reach of the pelicans.

Cape Gannet

At Malgas Island, pelicans patrolled the edge of the Cape Gannet colony in groups of 6 to 12 individuals (Figure 2 (3a)). Sometimes they would stand on prominent rocks to search for chicks of adequate size. When they identified a potential prey they would stop, staring at the nest attentively for minutes at the time (Figure 2 (3b)). Often smaller pelican clusters would join in larger groups. Frequently a predation would be followed by a scuffle, in which several pelicans would fight over the chick. Pelicans from nearby would flock to the site where the predation occurred, frequently chasing the pelican in possession of the chick and occasionally stealing the prey.

Gannets aggressively defend their nesting site against neighbouring gannets. However they showed no defensive behaviour towards approaching pelicans, which probably indicates that pelicans were not seen as a threat. Nevertheless, pelicans were cautious when approaching nests and never ventured into the midst of the gannet colony. Only chicks on the edge of the colony were targeted by pelicans. Possibly due to reduction in food availability, the number of gannet breeding pairs diminished in the 2005/06 and 2006/07 breeding seasons (Crawford *et al.* 2007). This resulted in the colony becoming fragmented, which favoured chick and egg predation by gulls and pelicans (L. Pichegru & R. Mullers, pers. comm.).

Gannet chicks eaten ranged in size between small naked chicks brooded by their parent, to chicks 3–4 weeks of age. Later in the season, pelicans attempted to prey on chicks near fledgling size (possibly >1.5 kg in mass) which were still covered in down but beginning to grow feathers. On several occasions groups of two to three pelicans attempted to eat extremely large gannet chicks. Occasionally, a pelican that had captured a large chick would be barely able to lift its bill off the ground, struggling for up to 90 min to swallow the chick, not always successfully. One chick survived a 75 minute struggle inside the pouch and even the throat of a pelican before being released. One pelican managed to swallow a chick of 2.05 kg but dropped it when disturbed in order to take flight (L. Upfold pers. comm.).

Swift Tern

To be able to capture highly mobile Swift Tern chicks, pelicans would surround the colony by forming a tight circle around it, enclosing a large number of chicks in the centre (Figure 2 (2)). Almost synchronously, pelicans thrust their bills forward and then lifted them upwards in order to swallow the chicks.

Adult terns flew frantically around the group, uttering loud alarm calls. However, they did not attack and hit the pelicans as Kelp Gulls did. Chicks ran in all directions when attacked by pelicans. Pelicans also looked for chicks between and under bushes. Older tern chicks moved to the shore with their parents; they jumped into the water and swam in compact groups when disturbed. Pelicans were observed chasing and swallowing escapee chicks in the waters near the tern colony on Schaapen Island (P. Nel pers. comm.).

Seasonal progression of predation

During the study period, pelicans moved between islands depending on prey availability. In October 2006, they fed on Cape Cormorants on Malgas and Schaapen islands. By the beginning of November, they had destroyed most of the nests and moved to Jutten Island, where Cape Cormorant chicks had recently hatched. At this point in time, they fed on cormorants for most of the day, small pelican groups concentrating on cormorant clusters spread throughout the island. In the evenings and sometimes early in the morning they flocked in larger groups to feed on Kelp Gull chicks. From mid November, there was a change in foraging behaviour, as pelicans switched to a diet of almost exclusively Kelp Gull chicks. Pelicans would join in groups of up to 70 individuals, sweeping the colonies and feeding in frenzies early in the morning, resting and preening most of the day, and topping up just before sunset. At this stage there were about 4 500 Cape Cormorant nests still available on the island, so it is likely that the main reason for this change in diet was the increased availability of Kelp Gull chicks on their becoming more mobile and leaving the relative safety of the nest and the fierce protection of their parents.

At the beginning of December 2006, Jutten Island was almost completely vacated by breeding Cape Cormorants and Kelp Gulls. Pelicans had eaten or disturbed about 7 500 nests of the former and about 2 500 of the latter. At this stage they started visiting Malgas Island daily to feed on gannet chicks, which had became available. They arrived at Malgas a couple of minutes after sunrise, fed for most of the day, and left in the afternoon to sleep on neighboring Jutten Island (4.3 km away). This daily pattern was repeated until the gannet chicks became too large, and therefore unavailable, for the pelicans.

In most years, most pelican chicks at Dassen Island have fledged by February (Cape Nature unpublished data, Hockey *et al.* 2005). During March and April 2007, no large scale predation of seabirds by pelicans was observed at Jutten and Schaapen island, in spite of there being large numbers of Cape Cormorants (ca. 8 000 pairs) at Jutten Island and large numbers of Swift Terns (>3 000 pairs), Hartlaub's Gulls (several colonies) and ground-nesting Crowned Cormorants on Schaapen Island. Pelicans were present in the area and small groups of up to 22 birds were seen eating cormorants and terns, but they did not cause serious damage to their colonies and they also regularly foraged on fish.

Individuals involved in predation events

The maximum number of pelicans counted during simultaneous counts (the same day) at the three islands monitored in Saldanha Bay, was 220. These pelican counts are in likelihood underestimates because in the case of Jutten and Malgas, it was not possible to view the entire islands from the vantage points. Pelican numbers were highest between the beginning of November and the beginning of December 2006. Jutten Island had the highest number of pelicans, with a peak of 176 on 22nd November 2006. The numbers dropped abruptly once the island was depleted of breeding seabirds (Figure 3). Pelicans roosted at Jutten Island throughout the study period, even after mid December, by which time both Jutten and Schaapen islands were devoid of breeding seabirds. Pelicans continued to forage on gannet chicks at Malgas Island by day, and then returning to Jutten Island to roost.

The straight line distance between Malgas and Jutten Islands is 4.3 km. Pelicans would usually fly from Jutten to Malgas early in the morning, most of them arriving with the first light before sunrise. Time of departure was variable.

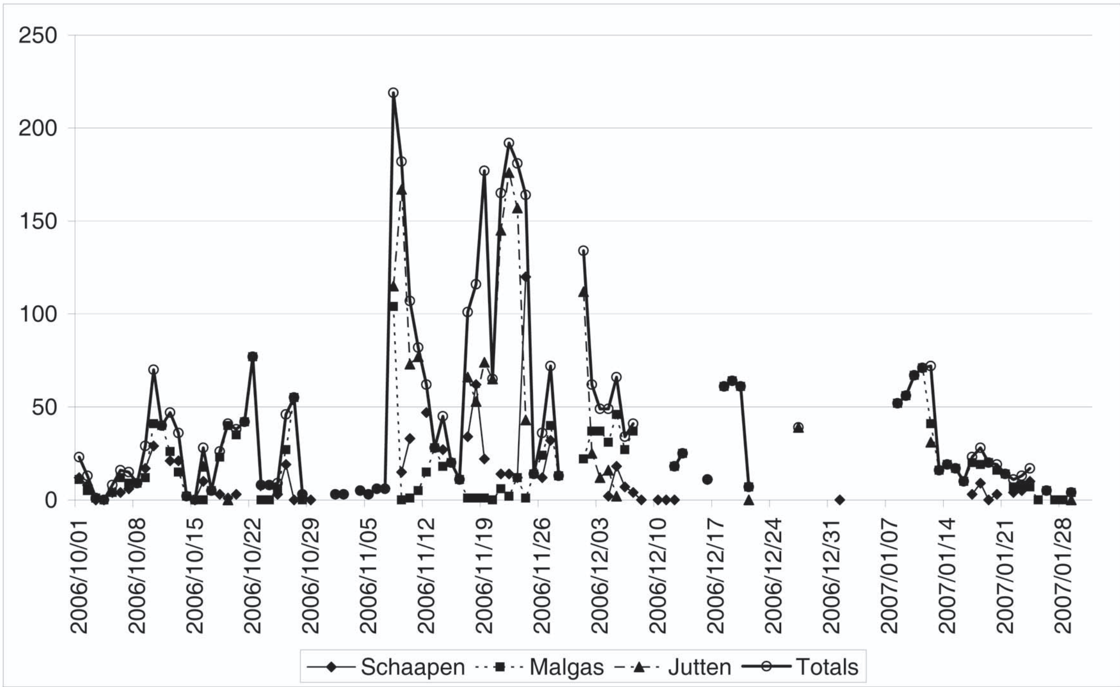

Figure 3: Pelicans counted on Jutten, Malgas and Schaapen islands during the period 1 October 2006 to 31 January 2007

When left undisturbed they would leave Malgas Island any time between 16:00 and 17:00. However, sudden changes in weather conditions (mainly wind strengthening) sometimes prompted them to leave earlier. Travelling time from Malgas to Jutten Island averaged 6.5±1.4 min (n = 37) or 41.5 km/hr, and was clearly dependent on wind strength and direction. The maximum speed recorded was 64.5 km/hr against a mild S–SE wind, and the minimum was 23.5 km/hr against a strong SW wind. Pelicans would use different flight pathways and strategies to cross the sea between the two islands, depending on the wind conditions, often changing direction to fly in the lee of the island. Mostly they flew low over the water in a horizontal line, beating wings synchronously and gliding for short periods in between wing beats.

About 10% of the Western Cape pelicans carry either colour or metal rings, or both. Ringing effort started in 2001 at the breeding colony on Dassen Island. Six cohorts of pelican chicks have been ringed thus far; hence all ringed birds are aged 6 years old or younger. At most, seven individually recognisable pelicans were observed preying on seabirds during the entire observation period (Table 3). This proportion is low in comparison to feeding sites on the mainland, where 10% of birds are regularly observed to have rings. Almost all pelicans observed on the islands had adult plumage, and many were in full breeding plumage. Age of first breeding for Great White Pelicans is 3 or 4 years old (Hockey *et al.* 2005).

Discussion

Why do pelicans eat seabirds?

Although all pelican species are largely piscivorous, they are able to exploit other sources of food and even scavenge on dead animals or fish discards (Johnsgard 1993). However, feeding on prey other than fish is uncommon behaviour for pelicans. Yet, in the case of the Great White Pelicans in the Western Cape, feeding on chicks of other bird species has increased noticeably in intensity and extent in the last decade. A much smaller pelican population in the past and a recent shift in dietary preferences could have been the reasons for this behaviour receiving so little attention until recently.

The Western Cape pelican population exhibits some characteristics that make it unique compared to Great White Pelican populations elsewhere in the world. With the exception of the western African population, the Benguela population is the only one that is wholly coastal in terms of its breeding distribution. The situation in western Africa (specifically Mauritania and Senegal) is different to the Western Cape in that pelicans live in vast wetlands that exist in the coastal regions. Sandy islands separated from the mainland by narrow and shallow channels of water offer protected sites for breeding, while the adjacent waters are suitable for foraging. In the Western Cape, where most marine resources surrounding the colony at Dassen Island are not available to the pelicans because of their inability to dive, pelicans rely mainly on the fish they capture in the estuaries and freshwater systems on the adjacent mainland, notwithstanding artificial food sources. However, the nutrient rich west coast of southern Africa is the only place throughout the range of

Table 3: Ringed pelicans seen on the islands involved in predation activities

Date	Island	Ring	Years old
13 Oct 06	Schaapen	Blue on left, no metal	6
8 Nov 06	Jutten	Green on left, metal	3
10 Nov 06	Jutten	Blue on left	6
10 Nov 06	Jutten	Red on left, no metal	5
11 Nov 06	Jutten	Red on left, no metal	5
8–12 Jan 07	Malgas	2 × Red on left, no metal	5
8 Jan 07	Malgas	Hole in pouch	–
9 Jan 07	Malgas	Black/white CS on left	2
9 Jan 07	Malgas	Black/white (other)	2
14 Mar 07	Schaapen	Blue on left, no metal	6
14 Mar 07	Schaapen	Hole in pouch, no metal	–
15 Mar 07	Schaapen	Blue on left, no metal	
4 May 07	Schaapen	Blue on left, no metal	6
16 May 07	Jutten	Blue on left, no metal	6
17 May 07	Schaapen	Blue on left	6

the Great White Pelican where ground-nesting seabirds are available in large densities nearby breeding pelicans. This and the fact that pelicans are opportunistic feeders (Hockey *et al.* 2005) are probably the most significant causal factors of predation on seabirds by pelicans, which has occurred in the region for as long as records are available (although probably not at the present scale).

The marked population increase of pelicans in the Western Cape since the 1980s has probably contributed to the steep increase in the observed incidence of predatory interactions. When the pelican population was much smaller (up until the late 1980s), the impact of predation on seabird colonies would have been orders of magnitude lower, and less noticeable. The rapid increase in the size of the pelican population in the region has been attributed to the increased availability of offal on pig farms in the mid-1980s (Crawford *et al.* 1995, de Ponte Machado *et al.* in prep.). The first large-scale predation events in recent decades were observed on Dassen Island in the 1990s. Since then, predation on seabirds by pelicans in the region intensified and reached extremely high levels in 2005/06 and 2006/07.

Up until January 2005, an average of 1 500 pelicans fed daily on a pig farm near Stellenbosch (Figure 1) (de Ponte Machado *et al*. in prep.), which therefore sustained some 60% of the pelican population in the region. Offal became increasingly scarce at this site from the end of 2004 (de Ponte Machado *et al.* in prep.) therefore pelicans had to rely more and more on 'natural' food sources, i.e. fish and other vertebrates from fresh water lakes and dams. However, while there is no apparent shortage of fish in coastal water bodies and some farm dams have been stocked with fresh water fish (Guillet & Crowe 1981, Guillet & Furness 1985, Crawford *et al.* 1995), the number of fresh water food sources in range of the breeding colony is limited (Figure 1, Table 4).

The 25-fold increase in pelican breeding pairs, together with the sudden shortage of artificial food supplies, would certainly increase intra-specific competition for food between breeding pelicans, which have to cover distances of 120–180 km between their colony and freshwater bodies to satisfy their chick's high energetic demands. Ashmole (1963) postulated that seabird populations are limited by density-dependent competition for food during their nesting period.

Table 4: Return trip distance (km) from the pelican breeding colony on Dassen Island to the most utilized pelican foraging sites in the Western Cape, indicating main source of food for pelicans (a: straight line; b: following the most common route to Yzerfontain and then straight to the foraging site; * fish indicates aquatic organisms other than seabirds)

Foraging sites	Main prey	a	b
Geelbek	fish*	52	58
Schaapen Island	birds	74	84
Jutten Island	birds	78	90
Malgas Island	birds	88	100
Rietvlei	fish	120	150
Rondevlei	fish	162	189
Strandfontein	fish	175	202
Paarl	fish	180	198
Stellenbosch	fish	182	204
Pig farm	offal	160	178
Atlantis	fish	82	102
Malmesbury	fish	118	130
Mamre	fish	78	94
Berg River	fish	144	168
Verlorenvlei	fish	252	274
Jakkalsfontain	fish	300	326
Olifants	fish	382	396

In support of this theory, a number of studies have indicated that seabird populations undergo density-dependent regulation of population size as a consequence of limited prey resources in range of the colony (Hunt *et al.* 1986, Furness & Birkhead 1984, Birt *et al.* 1987, Lewis *et al.* 2001, Votier *et al.* 2007). The diminishing artificial supply of food since 2005 and increased competition due to the population increase, may have led to depletion of fresh-water fish at sites near the pelican colony. However, data on trends in fresh-water fish populations and evidence of competition for food among pelicans are required to test this hypothesis.

The observed increased predation pressure by pelicans on seabirds in recent years could be a response of food-stressed pelicans following the reduction of artificial sources of food since 2005. Interactive effects of food shortages (affecting both predator and prey), and increased predation rates by *Larus argentatus* and *L. marinus*, have been described as a cause of widespread breeding failure of Black-legged Kittiwakes (*Rissa tridactyla*) in Newfoundland, Canada (Regehr & Montevecchi 1997). Also, diminishing availability of fish discards, together with a reduction of pelagic stocks, caused increased predation rates on seabirds by Great Skuas (*Stercorarius skua*) (Oro & Furness 2002, Votier *et al.* 2004). For Great White Pelicans in the Western Cape, it was predicted that reduced availability of food at the pig farm could cause intensified predation on seabird chicks (de Ponte Machado & Hofmeyr 2004). Until 2004, predatory behaviour was mostly restricted to the proximity of the pelican breeding colony on Dassen Island, but from 2005 it expanded to new localities (e.g. at Rondevlei and Malgas Island, with prospecting for food occurring at Robben and Dyer islands). Pelicans also targeted a wider array of species and increased the intensity and impact of predation on the prey species. According to Votier *et al.* (2004) the suppression of artificial feeding sources could in the long-term reduce breeding performance and population size of the predator, although their ability to find alternative prey may maintain their populations for some time.

Seasonal progression of predation

Results show that pelican predation on seabirds is mostly seasonal, peaking in the summer season (October to January), coincidental with the Great White Pelican breeding season in the region (Hockey *et al.* 2005). Kelp Gulls, and to a lesser extent Cape and Crowned Cormorants, also experience breeding peaks during the austral summer (Hockey *et al*. 2005). Predatory interactions between pelicans and seabirds attempting to breed in autumn–winter (March to June) were of a much smaller magnitude compared to summer. This suggests that predation on seabirds could be triggered by the elevated energy requirements of the pelican chick raising period, coupled with intraspecific competition for food in accessible water bodies. Further research is also needed to corroborate this theory.

Coloniality and other prey species defensive mechanisms

Colonial breeding has been proposed as a mechanism to reduce predation pressure on birds and their eggs and chicks (Wittenberger & Hunt 1985, Siegel-Causey & Kharitonov 1990, Clode 1993, Danchin & Wagner 1997). Reproductive synchrony would produce a superabundance of chicks, and satiation of the predator would allow some to survive (Darling 1938, Gochfeld 1982). In this study, colonial breeding appeared ineffective at improving the individual survival probability of chicks in the face of pelican voracity and predator–prey ratios; breeding rates were extremely low with certain species at some of the monitored islands experiencing near total breeding failure for the season.

It has also been postulated that a high concentration of chicks and eggs in a reduced area acts as an attraction to predators (Becker 1995; Hernández-Matías & Ruiz 2003). This was apparently true for this study, with pelicans prospecting for foraging sites and identifying conspicuous aggregations of prey species. They were able to identify prey availability and optimum chick size in the different colonies, eating all the chicks in a cluster before moving to the next one.

Nest location was fundamental with regard to protection from predatory pelicans. Crowned Cormorants that selected sites out of reach of pelicans on the top of trees or high structures were safe from pelican predation and fledged many chicks. At Jutten and Schaapen islands, Cape Cormorants breeding on isolated high rocks or ledges – where pelicans were unable to land – were also able to fledge some chicks. Kelp Gulls chicks that survived predation were those near by to hiding places. Furthermore, Cape Cormorants colonies located in close proximity to the researcher's housing on Malgas Island showed normal recruitment levels, as pelicans would avoid human presence.

After over a decade of pelican predatory pressure on seabirds on Dassen Island we could expect some adaptive responses on the behaviour of the prey species. On this island, Cape Cormorants seem to be selecting more protected breeding sites, often building nests under rocks (J. Visagie pers. comm.). Also, the Cape Cormorant breeding population on Dassen Island has shown a sharp decline, while other sites (e.g. Dyer Island) show an increase in the number of breeding pairs (Cape Nature unpublished data). However, pelican predation is not the only factor that could have instigated this numerical shift. Fluctuations in the distribution and abundance of pelagic fish, the main prey of Cape cormorants, may also have contributed.

Conclusions and management interventions

As discussed earlier, feeding on live avian flesh is not unique behaviour among pelicans, although most incidences of pelican predation outside the study area were anecdotal, isolated cases. Seabird chicks have become an important part of the diet of Great White Pelicans in the Western Cape. It has been suggested that predation is a learned behaviour that has expanded in the population by cultural transmission, triggered by an artificially increased population and scarcity of food during the breeding season near the colony. This behaviour, currently expanding, is causing increasing concern for the conservation of resident seabirds. Pelican dispersal and movements are not fully understood, but this behaviour could be exported to other areas of their distribution.

Due to the delicate conservation status of the prey species, intervention may be necessary to counteract the negative impact of pelican predation on local breeding seabird populations, especially considering that agricultural offal has triggered the pelican population expansion, and therefore may be an underlying cause of the intensification of pelican's predatory behaviour.

Different management strategies have been considered, and some preliminary trials performed at Dassen and Malgas islands in 2006/07 (de Ponte Machado *et al.* in prep, Musangu *et al.* in prep). Here I compile some of the management options, with the aim of providing a preliminary platform to discuss their effectiveness, pros and cons and ethical considerations. They include: (a) cutting down subsidised sources of food; (b) preventing pelicans from breeding; (c) culling pelicans; (d) negative conditioning for pelicans; (e) active chasing of pelicans in order to prevent predation; and (f) building artificial structures and enclosures to protect prey species.

Cutting down subsidised sources of food may in the long term be an adequate measure to reduce the artificially increased pelican population. Pons & Migot (1995) measured body condition, fecundity and adult survival rates in a population of Herring Gulls (*Larus argentatus*) after the closure of a refuse tip that provided abundant food for the species. They found a sharp decrease in fecundity while adult survival rates remained unchanged. This result is consistent with the predictions of life-history theory, which predicts that in long-lived species a decrease in food supply should affect fecundity before affecting adult survival (Ashmole 1963, Goodman 1974, Stearns 1976, Birkhead & Furness 1985). In the short term however, due to the capacity of the pelicans to switch prey, the elimination of artificial sources of food it will (and has) contributed to increased predatory pressure on nesting seabirds. Therefore, although this is a worthwhile recommendation, it should not be implemented in isolation but combined with other measure/s.

Preventing pelicans from breeding on Dassen Island has been presented as a solution to reduce pelican numbers towards a more 'natural' pre-subsidised level, by reducing recruitment into the population, but more effectively by removing the higher energetic demands of brooding pelicans. However, pelicans are able to change breeding sites in response to disturbance, as shown by their historical breeding distribution (Crawford *et al.* 1995). This action could result in exporting the problem to other islands; therefore this option should be considered only in combination with other management actions.

Removing avian predators (i.e. gulls) from an area has been described as having positive effects on the reproductive success of threatened seabird species (Guillemette & Brousseau 2001). However, proper evaluations of the effects of such programmes are scarce, in some cases causing undesirable secondary effects like transference of the problem to neighbouring sites (Vidal *et al.* 1998), high costs in term of manpower and material resources (Bosch *et al.* 2000), or demonstrated reduced success in the long term (Oro & Martínez-Abraín 2007). The implementation of such a management strategy to control pelican predation would be a controversial and highly unpopular measure. Additional data on the numbers and identity of pelicans involved in predation events should be obtained to assess whether it will be feasible to reduce or eradicate the behaviour from the local populations by removing individuals. Attempts at identifying 'rogue' pelicans during this study were not successful due to the low number of marked pelicans involved in predation events. Also a number of ethical, legal and conservation-related considerations need to be explored. Pelicans are classified as protected species both internationally and in South Africa. Furthermore, pelicans are charismatic animals with a vast potential for use as flagship species. Any measure involving pelican culling would require large amounts of additional effort and funds to for an information campaign justifying the action to the public.

Non-lethal methods to reduce predation by birds have been used successfully to modify the feeding behaviour of species to meet management objectives, mostly for ravens and starlings (Avery *et al.* 1995, Cowan *et al.* 2000, Neves *et al.* 2006). Negative conditioning of pelicans using bad tasting seabird chicks or other kinds of deterrents present logistical, technical and economical challenges, given the susceptibility of breeding seabirds to disturbance (this action would involve manipulating chicks on the nest) and the large area and number of islands that would need to be covered to make this measure effective. However, it may be worthwhile exploring the efficacy of such intervention on Malgas Island, to deter pelicans and gulls from feeding on gannet's eggs and chicks. Of the species targeted by the pelicans, gannets enjoy the highest priority for conservation actions due to their current decline in population numbers.

During November and December 2006, MCM personnel and researchers tested the effectiveness of chasing pelicans away from cormorant and gannet colonies at Malgas Island, in order to prevent them from eating their chicks. The preliminary results were positive, as it is possible to chase pelicans off the colonies without drastic disturbance to nesting birds. Human presence is often enough to keep pelicans at a safe distance. However, constant monitoring of the pelicans' movements is necessary, as they tend to return quickly after people are out of sight. This would therefore require a permanent presence on the islands by two or more people wholly dedicated to monitoring pelican activities. Not all islands (or parts of them) are suitable for this type of intervention, so balanced decisions will have to be made on priority prey species and areas. Both a scientific assessment on the effectiveness of this management intervention, and monitoring of the breeding success of prey populations in the absence of pelican predation, will be necessary.

At Dassen Island, two fenced perimeters were erected in 2006 and Kelp Gull breeding performance was monitored inside and outside the fenced areas. Breeding success was found to be slightly higher inside than outside the enclosure (details in Musangu *et al.* in prep). Building artificial structures for cormorants to nest on is another option to be considered. The design should mimic the topographic characteristics and location of the nest sites where chicks fledged successfully at the monitored islands; and any evident shortcomings (due for example to human disturbance or flawed design) should be carefully evaluated. Careful experimental design is required to avoid bias due to human disturbance while erecting the structures or monitoring the nests (Prieto *et al.* 2003).

Based on this discussion, it is recommended that management interventions should include a combination of the following: eliminating artificial food supplies for pelicans; chasing of pelicans from the breeding grounds of threatened species; and designing artificial structures to provide protection from predation to prey species. Further, an integrated ecosystem-based form of management that addresses food shortage problems for prey species (gannets and cormorants) and habitat restoration in order to improve the conservation of threatened seabirds is advocated. The aim of this paper is to assist the decision-making process, contributing data and an ecological insight to the problem of pelican predation. The solution/s to this conservation conundrum, in which a protected species negatively affects the conservation of other threatened species, is not simple, and should be carefully examined. There is also wide scope for further research and hypothesis testing. Management strategies should be further discussed and decisions be made by the pertinent authorities.

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Predators also improve foraging efficiency by learned avoidance, a behavior in which predators quickly learn to recognize poisonous or distasteful species by remembering adverse reactions from attempted predation events (Brower 1988). Prey defenses.Â The rules of foraging are simple. The predator must only use its feeding appendage to capture prey. The predator must stop foraging when the stomach (cup) is full or when time expires.Â Students who were inefficient in capturing prey trade for new mouth parts to simulate death of some predators and birth of other types. In advanced classes, students could be asked to determine the rules for predator reproduction. Students can be guided to the idea that predators that eat more will have higher rates of reproduction.