

King Shag

(Leucocarbo carunculatus)



in Marlborough Sounds New Zealand



Literature review and draft management plan

Friends of Nelson Haven and Tasman Bay

Mennobart R. van Eerden & Marjolein J. Munsterman, 2012

Front cover: *Outer Marlborough Sounds as seen in SE direction with D'Urville Island in front and North Trio Islands, Chetwode Islands and the mouth of Pelorus Sound clearly visible; inset: King Shag adult (M.R. van Eerden).*

King Shag (*Leucocarbo carunculatus*) in Marlborough Sounds, New Zealand

Mennobart van Eerden & Marjolein Munsterman, June 2011

PART A – LITERATURE REVIEW

This work was commissioned by Friends of Nelson Haven and Tasman Bay (FNHTB), <http://www.nelsonhaven.org.nz/> by contract to the first author Dr. Mennobart R. van Eerden (MRE), chair of IUCN - Wetlands International Cormorant Research Group. It consists of three deliverables:

Part A Literature review of King Shag biology contains the annotated literature review on the species. Part A also includes an assessment and discussion of other shag species, especially for those aspects of King Shag biology which are poorly-understood or unknown.

Part B Preparation of a Conservation Management Plan puts the findings of part A into a visionary framework, relevant for the management and conservation issues of the species. The plan has been written according to the IUCN standards. A study tour to Marlborough Sounds, New Zealand was organised by FNHTB from 20 January – 3 February 2011 in order to get MRE acquainted with the current situation. The findings during the study tour are incorporated in this part.

Part C Identification of research required and prioritisation of activities focuses on gaps in knowledge and aims to formulate the needs and priorities for future research on the species.

Acknowledgements

Throughout the project the authors received much support by Rob Schuckard and David Melville. MRE was introduced to the species and area of Marlborough Sounds during a working visit from 20 January until 3 February 2011. The discussions and field excursions were vital to the understanding of the ecosystem in the larger context.

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Introduction

In relation to conservation of species, the process of speciation, niche partitioning in relation to habitat diversity is of global importance. Islands play a crucial role in this as they form the basis of the existence of separate units to which certain organisms are confined, by genetic isolation to other populations. On a world scale studies on island faunas and biogeography have led to important theories about the mechanisms of speciation and evolution (Darwin 1859, Wallace 1858). From these comparisons of faunas MacArthur & Wilson (1967) developed Island Theory and principles such as rate of extinction in relation to island surface area, rate of emigration and immigration were related to island geography (Simberloff & Wilson 1969). Nature conservation practice has greatly benefited from this as leading guidelines have been developed that are commonly used nowadays with respect to issues such as habitat fragmentation and designation of nature reserves (size and relation to availability of feeding areas).

From a more practical perspective island populations are vulnerable because of the fact that island habitat is limited in relation to the feeding habitat surrounding the islands. This is particularly the case for seabirds, which, depending on species, fly out for long distances to gather their food. As “central place foragers” they have to deal with the economics of travelling distance, and hence foraging costs in relation to energetic gain in terms of obtained prey (for Double-crested Cormorant see Birt *et al.* 1987).

New Zealand is well known for its peculiar fauna and flora. Being isolated from Australia some 80 million years ago (Wilson 2004) as the result of breaking up of the super continent Gondwana, both on land (endemic species) and at sea (richest waters in the world due to convergence of currents) speciation took place. As a consequence, New Zealand has the most diverse seabird community in the world, with no fewer than 85 species (95 different taxa) breeding in the region which includes NZ's Sub-Antarctic islands, the Chathams Group and the Kermadec Islands. This seabird fauna includes 35 endemic species and 49 endemic taxa. In addition to the breeders, many other seabirds visit New Zealand waters throughout the year, arriving from the area close to Antarctica or from islands of the Great Southern Ocean and the tropical Pacific.

Sea level rise after the last glaciations ended some 10,000 years ago has created the flooded mountainous area of what is now the Marlborough Sounds, a relatively protected coastal sea with steep gradients in water depth and with numerous islands and islets about 4,000 km² in size and situated at the northernmost fringe of the South Island of New Zealand.

The Marlborough Sounds are home to the New Zealand King Shag (*Leucocarbo carunculatus*), one of the rarest species of cormorants in the world. It bears parallels to other rare white-bellied shags and cormorants in the southern hemisphere (South America, South Africa, the belt of sub-Antarctic waters and islands therein). According to IUCN the species is classified at world level as vulnerable. Although protected and considered stable as numbers are concerned its population size of less than 700 birds warrants the compilation of a species conservation and management plan.

1 Species description

King Shags constitute a rare species with an extremely limited distribution. It is one of the so called Blue eyed shags group. The taxonomic status is still uncertain and therefore it is important to compare the species' characteristics with that of other species of the group. This chapter describes plumage, biometrics and briefly points at conservation status and values.

1.1 Blue eyed shags, general phylogeny of related species

The **Blue eyed shags** are a group of 14 closely related cormorant taxa. All have a blue, purple or a red ring around the eye (not a blue iris); most have white underparts (at least in some individuals) and pink feet (Nelson 2006).

They are found around the colder parts of the Southern Hemisphere, especially near southern South America (1 species), Antarctica (1), sub-Antarctic Islands (10), and New Zealand (2). Many are endemic to remote islands and there is no overlap in range. Determining which types are species and which are subspecies of what larger species is problematic; various recent authorities have recognized from 8 to 14 species and have placed them in a variety of genera.

Delimiting this group after Nelson but assigning species limits after the regional Handbook (Marchant & Higgins 1990) gives the following species list, divided into two "complexes":

Table 1. *Blue eyed shags, divided in two complexes*¹

| |
|--|
| Imperial Shag or Blue eyed Shag, <i>Leucocarbo atriceps</i> |
| White-bellied Shag or King Cormorant, <i>Leucocarbo albiventer</i> |
| Antarctic Shag, <i>Leucocarbo bransfieldensis</i> |
| South Georgia Shag, <i>Leucocarbo georgianus</i> |
| Heard Island Shag, <i>Leucocarbo nivalis</i> |
| Crozet Island Shag, <i>Leucocarbo melanogenis</i> |
| Macquarie Island Shag, <i>Leucocarbo purpurascens</i> |
| Kerguelen Island Shag, <i>Leucocarbo verrucosus</i> |
| |
| New Zealand King Shag, <i>Leucocarbo carunculatus</i> |
| Stewart Island Shag, <i>Leucocarbo chalconotus</i> |
| Chatham Island Shag, <i>Leucocarbo onslowi</i> |
| Auckland Island Shag, <i>Leucocarbo colensoi</i> |
| Campbell Island Shag, <i>Leucocarbo campbelli</i> |
| Bounty Island Shag, <i>Leucocarbo ranfurlyi</i> |

¹ *This group of white-bellied, pink-footed Phalacrocoracidae is sometimes placed in the genus *Leucocarbo*, sometimes in the genus *Phalacrocorax*. For the New Zealand species the nomenclature of the Checklist Committee (OSNZ; 2010) is used.*

The distribution of this group is circumpolar in a wide belt around Antarctica, in three mega clusters of which one at and around New Zealand, see Fig. 1. The distribution encloses the nutrient-rich sub-Antarctic oceanic zone between the subtropical and Antarctic convergence. Relative to other species within the group, King Shags breed relatively far to the North.

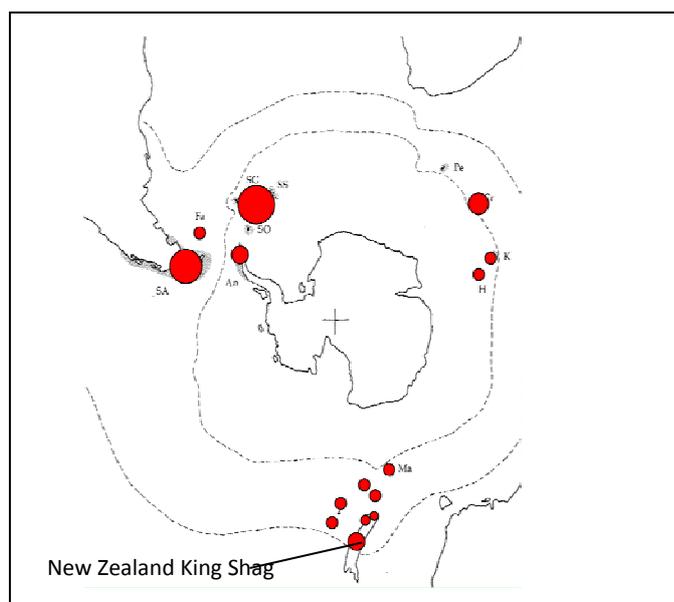


Fig. 1. Distribution of Blue eyed shags at the southern hemisphere, from Heinzel & Tucker 1985 , Nelson 2006. The dotted lines enclose the nutrient-rich sub-Antarctic oceanic zone between the subtropical and Antarctic convergence. Notice the northerly position of King Shag relative to the other species.

Blue eyed shags are a group that is closely associated zoogeographically with the Antarctic zone and the oceanic convergences. The dotted lines in Fig. 1 enclose the nutrient-rich sub Antarctic oceanic zone between the subtropical and Antarctic convergence. All six New Zealand Blue eyed shags have relatively small populations and are classified as either “vulnerable” or “critically endangered” (IUCN 2011), see Table 2. The national status of the Blue eyed shags is according to Miskelly *et al.* 2008.

Table 2. Status and population size of six Blue eyed shags breeding in New Zealand

| Species | Status IUCN (2011) | Status New Zealand | Population size |
|---|-----------------------|-----------------------|-----------------|
| King Shag (<i>L. carunculatus</i>) | Vulnerable | Nationally endangered | 645 |
| Stewart Island Shag (<i>L. chalconotus</i>) | Vulnerable | Nationally vulnerable | Few thousand |
| Campbell Island Shag (<i>L. campbelli</i>) | Vulnerable | Nationally uncommon | 8000 |
| Bounty Island Shag (<i>L. ranfurlyi</i>) | Vulnerable | Nationally critical | <1200 |
| Auckland Island Shag (<i>L. colensoi</i>) | Vulnerable | Nationally vulnerable | <2000 |
| Chatham Island Shag (<i>L. onslowi</i>) | Critically endangered | Nationally endangered | 842 pairs |

The taxonomic status of the Blue eyed shags is still not satisfactorily solved. The fact that plumage characteristics show overlap causes confusion. For example, Stewart Island Shags *Leucocarbo chalconotus* in Otago, New Zealand occur in a pied and a bronze form. The pied morph is indistinguishable in plumage and size from King Shags in the Marlborough Sounds according to Lalas (1983). Half the Stewart Island Shags in Otago have a similar intermediate “*carunculation*” as King Shags from the Marlborough Sounds. This in contrast to “scattered papillae” of all Stewart Island Shags in Foveaux Strait and half the Otago population and the “pronounced caruncles” from all Chatham Island Shags. The only significant difference between Otago Stewart Island Shags and King Shags from Marlborough is a 5% bigger bill.

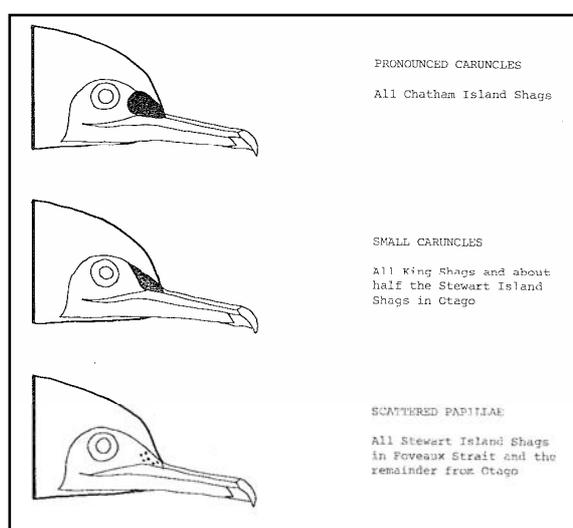


Fig. 2 Variation in extent of warty yellow patches of bare skin, “*carunculation*”, indicated in black in Stewart Island Shags and King Shags according to Lalas (1983).

Worthy (1996) found no skeletal differences between King Shags and Stewart Island Shags. He referred to them as subspecies (Worthy 1996, 1998). Kennedy *et al.* (2000) studied taxonomic relationships among 22 of the approximately 37 cormorant species. King Shags were not analysed as yet but their study included Stewart Island Shags and Chatham Island Shags, which are closest to King Shags. These two species were not genetically discrete (0.0% divergence), but displayed a DNA sequence divergence of up to 11% from other shag species. Current investigation on the position of King Shag in this group of taxa is presently undertaken (Till 2011 *in prep.*)

See Appendix 2 for overview of species and distribution of different species of Phalacrocoracidae in New Zealand and Australia.

1.2 Taxonomy

To Maori **Te Kawau-a-Toru** was a sacred bird loyal to Kupe. Possessing a huge wingspan, the bird was reputed to be ‘the eye of the ancestor’, a special bird with insights into ancient knowledge. (See: <http://www.nzbirds.com/birds/kingshag.html>).

The species was collected by Forster in Queen Charlotte Sound during Cook's second voyage. Forster's description of *Pelecanus carunculatus* was not published until 1844 but Latham described his "Carunculated Shag" from Forster's specimen and painting, and Gmelin in 1789 Latinised Latham's name. The Russian explorer Bellinghausen visited Queen Charlotte Sound in 1820 and collected "cormorants with a bluish eye membrane". It was not until 1875 when H.H. Travers collected the species again in Queen Charlotte Sound that its proper status in the New Zealand avifauna was established (Oliver, 1955, see also <http://www.nzbirds.com/birds/kingshag.html>).

The species is currently known as **New Zealand King Shag (*Leucocarbo carunculatus*)**. The two most important recent classifications for the shags and cormorants (see Johnsgard, 1993) are based on the morphological taxonomy of Siegel-Causey (1988) and the behavioural taxonomy of van Tets (1976). Van Tets (1976) proposed a division of the group of cormorants into two subfamilies 1) *Phalacrocorax sensu stricto* (or subfamily Phalacrocoracinae) "cormorants" and 2) *Leucocarbo sensu lato* (or Leucocarboninae) "shags". The proposed division by Van Tets (1976) does indeed have some degree of merit but based on DNA sampling the entire family cannot be clearly divided at present beyond the super-species or species-complex level (Kennedy *et al.* 2000). In addition many species remain unsampled, the fossil records have not been integrated in the data, and the effects of hybridization - known in some Pacific species especially - on the DNA sequence data are unstudied.

Orta (1992) follows the single-genus approach (*Phalacrocorax*) for three reasons: first, this approach is preferable to tentatively assigning genera without a robust hypothesis. Second, it makes it easier to deal with the fossil forms, the systematic treatment of which has been no less controversial than that of living cormorants and shags. Third, this scheme is also used by the IUCN (IUCN 2010) making it easier to incorporate data on status and conservation.

As long as genetic studies have not revealed a thorough set of new data including all species, we follow Kennedy *et al.* (2000) and use the genus ***Leucocarbo*** also for the group of white-bellied and pink-footed cormorants, in New Zealand and Australia called shags.

1.3 Biometry and plumage characteristics

King Shag is a large (76 cm long, Ca 2.5 kg in weight) black and white cormorant with pink feet. Above each side of the base of the bill a patch of sulphur-yellow (orange in early breeding period) bare warty skin is conspicuous. These "caruncles" vary in size and extension among individuals. The greyish-black gular pouch is reddish in the breeding season. Iris greyish-green. Head including cheeks, nape and shoulders dark black with greenish metallic shine. A blue eye-ring is surrounding the eye. Bill fleshy-grey to brownish-pink, generally lighter at the tip than at the base.

Chin, throat, fore-neck, breast, belly and flanks pure white, as well as the undertail coverts. Back and rump uniform black as well as thighs. Two conspicuous patches of white feathers on upper back. Wings black with white patches by a row of larger upper wing coverts appearing as bars when the wings are folded (alar bars). Some individuals have a white trailing edge at the base of the wing, roughly extending from the basis to halfway the carpal joint.

Muller (1888) describes some further details of male and female plumage of the King Shag in "A History of the Birds of New Zealand":



King Shag (Leucocarbo carunculatus) at Te Kuru Kuru or Stewart Island, 25 January 2011 (M.R. van Eerden)

Adult male. Similar to Imperial Shag *Leucocarbo atriceps*, but considerably larger and wanting the crest; it is furthermore distinguishable by the two large square spots of white which cross the back under the wings, by the larger extent of the white alar bar, and by a patch of white on the outer scapulars. The rows of papillæ along the forehead are red, and the naked space around the eyes bluish purple; feet yellowish brown. Total length 32 inches; wing, from flexure, 12.5; tail 5.75; bill, following the curvature 3, along edge of lower mandible 3.75; tarsus 3; longest toe and claw 5.

Adult female. The sexes are exactly alike in plumage, the fine metallic tints being as bright in the female as in the male. The former is, however, somewhat smaller in size: Extreme length 27.5 inches; wing, from flexure, 11.75; tail 5.5; bill, along the ridge 2.75, along the edge of lower mandible 3.5; tarsus 2.25; longest toe and claw 4.5.

Young. General upper surface dull greenish black, with a slight gloss in certain lights, the feathers on the shoulders margined with a darker shade; the whole of the wing-coverts and the outer scapulars greyish brown with whitish margins; tail-feathers greyish black, with whitish shafts and margins.

Like the King Shag, the Imperial Shag (*Leucocarbo atriceps*) is monomorphic in plumage, but males are larger than females. Svagelj & Quintana (2007) analyzed the sexual size dimorphism and variability of six morphometric characteristics (bill length, bill depth, head length, tarsus length, wing length, and body mass) measured on 291 breeding Imperial Shags at Punta León colony in coastal Patagonia, Argentina, during 2004 and 2005 breeding seasons. Discriminant analyses were performed on external measurements that were considered potentially useful in sexing Imperial Shags. All the birds were sexed by a distinctive behaviour (vocalizations) and a sub

sample of fifty were also sexed by DNA-based genetic techniques, showing 100% agreement between the two methods. All measured characteristics differed between the sexes, with males being larger than females. Body mass (17.8-18.0%) and bill depth (12.8-13.2%) showed the highest level of dimorphism whereas bill, head, tarsus, and wing length were less dimorphic (ranging 4.8-6.0%).

Lalas (1983) compiled data of biometric parameters in King Shags, Chatham Island Shags and Stewart Island Shags. In Stewart Island Shags he distinguished between pied and bronze (dark) morphs, collected in Foveaux Strait and Otago (Table 3). No differences existed between morphs but bill size was smallest in Chatham and Foveaux birds and was significantly larger in Stewart Island Shags from Otago and King Shags from Marlborough. This trend is also apparent in wing length and toe length although differences were not statistically significant between Stewart Island Shags from Otago and Kings Shags.

King Shag is likely to be the largest of the four groups measured by Lalas (1983), although sample sizes are limited and no corrections were made for sexual differences. In the Stewart Island Shags from Otago measured by Lalas (1983), no sexual dimorphism could be demonstrated (10 males, 8 females).

Table 3. Biometric parameters of King Shags (Marlborough) compared with Chatham Island Shags *P. onslowi* (Chatham) and Stewart Island Shags *P. chalconotus* (Foveaux Strait and Otago). Stewart Island Shags have a pied (light) and a bronze (dark) morph. All data according to Lalas (1983)

| BILL | | NUMBER | MEAN | RANGE | SD | WING | | NUMBER | MEAN | RANGE | SD |
|--------------------|--------|--------|------|---------|-----|--------------------------|--------|--------|-------|---------|------|
| CHATHAM | total | 17 | 54.2 | 48-57 | 2.7 | CHATHAM | total | 16 | 277 | 264-286 | 6.5 |
| FOVEAUX | pied | 14 | 54.9 | 50-61 | 3.1 | FOVEAUX | pied | 13 | 288 | 270-308 | 10.5 |
| | bronze | 14 | 54.1 | 50-60 | 3.0 | | bronze | 14 | 287 | 278-298 | 8.5 |
| | total | 28 | 54.5 | 50-61 | 3.0 | | total | 27 | 287 | 270-308 | 9.3 |
| OTAGO | pied | 17 | 61.7 | 57-67 | 3.3 | OTAGO | pied | 11 | 308 | 295-323 | 12.2 |
| | bronze | 27 | 62.5 | 57-69 | 2.8 | | bronze | 21 | 306 | 275-322 | 11.7 |
| | total | 44 | 62.2 | 57-69 | 3.0 | | total | 32 | 306 | 275-323 | 11.5 |
| MARLBOROUGH | total | 14 | 65.4 | 62-72 | 3.5 | MARLBOROUGH | total | 12 | 307 | 297-317 | 7.0 |
| OUTER TOE AND CLAW | | | | | | STUDENT <i>t</i> - TESTS | | | | | |
| CHATHAM | total | 7 | 110 | 100-120 | 6.6 | CHATHAM v. FOVEAUX: | bill | 43 | 0.34 | >0.10 | |
| FOVEAUX | pied | 8 | 109 | 102-113 | 3.7 | | toe | 21 | 0.96 | >0.10 | |
| | bronze | 8 | 108 | 102-119 | 5.6 | | wing | 41 | 4.16 | <0.001* | |
| OTAGO | total | 16 | 108 | 102-119 | 4.6 | CHATHAM v. OTAGO: | bill | 59 | 9.66 | <0.001* | |
| | pied | 15 | 118 | 111-124 | 3.7 | | toe | 40 | 4.67 | <0.001* | |
| | bronze | 20 | 121 | 113-127 | 4.3 | | wing | 46 | 9.60 | <0.001* | |
| MARLBOROUGH | total | 35 | 119 | 111-127 | 4.2 | FOVEAUX v. OTAGO: | bill | 70 | 10.65 | <0.001* | |
| | pied | 15 | 118 | 111-124 | 3.7 | | toe | 49 | 8.62 | <0.001* | |
| | bronze | 20 | 121 | 113-127 | 4.3 | | wing | 57 | 6.84 | <0.001* | |
| MARLBOROUGH | total | 13 | 117 | 110-123 | 4.0 | OTAGO v. MARLBOROUGH: | bill | 56 | 3.36 | <0.002* | |
| | pied | 13 | 117 | 110-123 | 4.0 | | toe | 46 | 1.72 | <0.10 | |
| | bronze | 13 | 117 | 110-123 | 4.0 | | wing | 42 | 0.06 | >0.10 | |

1.4 Conservation status

According to the IUCN Red list the species is categorized as “Vulnerable” (IUCN 2011). It has a very small population (criterion D1: **population less than 1000 individuals**) and is restricted as in the breeding period to four very small islands (criterion D2: **five or less locations**), rendering it susceptible to stochastic effects and human impacts. If by some reason a population decline would occur and/or fluctuations in numbers or locations would happen, it would require up-listing to “Endangered”.

Within the national legislation DOC (New Zealand Department of Conservation, Taylor 2000) ranked the King Shag as category ‘B’, the second highest priority grouping for conservation (Molloy & Davis 1994).

Within the New Zealand Threat classification System the species is listed as “Nationally Endangered” (Miskelly *et al.* 2008).

1.5 Values

Marlborough Sounds is of particular importance to New Zealand’s biodiversity. As a unique seascape the archipelago contributes significantly to the natural heritage that the world has to offer. The area is rich in fish and seafood which is an important nutrients by largely unpolluted run-off from rivers attracts tourists from all over the world. Over the year 2009 the Marlborough Regional Tourism Organisation recorded 887,000 visits to the Marlborough Sounds, see www.tourismresearch.govt.nz/By-Region/South-Island/Marlborough-RTO.

This part of the coastal seas around New Zealand forms a specific entity which is home to a number of typical species, part of which is endemic to New Zealand (*). Besides the occasionally 6 species of cormorants and shags that may be encountered, fish-eating birds include Little Blue Penguin (*), Australasian Gannets, Fluttering, Sooty’s and Flesh-footed Shearwaters, Giant Petrels and Mollymawks. In the austral summer these are joined by Arctic and Pomarine Skuas which kleptoparasitise on White-fronted Terns (*). Mammal species likely to be encountered include dolphins (Dusky (*), Bottlenose, Hector’s (*), Common Dolphins), Orca and occasionally larger whales (Southern Right, Humpback, Pilot). The shores of islands, peninsulas and remote bays harbour New Zealand Fur Seals (*).

The relative shelter in combination with the production of planktonic algae gives rise to the function as a grow-up area for young fish (nursery area). Adult fish species in the region amount to more than 150 (see part B). Inshore populations of crustaceans, crab, crayfish, mussels and oysters are relatively high compared to other stretches of the coastline. The greatest level of commercial fishing and aquaculture activity (fishing, landings and processing) is concentrated in the wider Nelson/Marlborough region. This region represents around 37% of the regional contribution to the seafood industry (see www.fao.org/countryprofiles/).

Being a relatively protected environment man has since historic times explored the biological richness of the area. First as fisherman from the shore using primitive tools as spears, baited hooks, fish weirs a.o., later on using trawl nets, set nets and long lines from motorised vessels but nowadays increasingly as aqua-culturist growing mussels and other seafood.

King Shag as a species represents no direct commercial value in terms of edible food source or other service. Indirectly the species is beloved by birdwatchers as one of the rare species in the region.



Marlborough Sounds near French Pass, 25 January 2011; D'Urville Island at the back and at the upper left Hapuka Rock and Rahuinui Islands, being the NW most sites where King Shags occur at present (M.R. van Eerden)

2 Distribution and demography

Cormorants and shags use certain territories where they form assemblies. These can be colonies where they breed, depending on the species either on rocks, sea cliffs, in trees, reed beds or bare soil. Because they form a conspicuous element colonial breeding sites have been known to man for a long time. The history of man and his habits as a hunter is important in the context of understanding the development of distribution and population size. This chapter summarises the published information about distribution of colonies and roosts as well as the available data on population size.

2.1 Past colony distribution and demography

In historic times King Shags have always been limited in terms of population size. Before the arrival of the Maoris the population may have been larger. Worthy (1996) has reported sub-fossil bones of *Leucocarbo* shags in late Holocene dune deposits in Doubtless Bay, Tokerau Beach in Northland. He assigned these to King Shags because of geographical position in relation to other cormorant species of that size. This is considered the first record of King Shags in the North Island, although it is likely that other samples have been assigned to Black Shag *Phalacrocorax carbo* in error. Other *Leucocarbo* bones (resembling King and Stewart Island Shags) have been reported from the region North Cape, Nelson, and Blenheim (Worthy & Holdaway 2002). The sheltered harbours of Northland would have provided very similar habitat to the Marlborough Sounds. Worthy (1996) stated that the distribution in the outer Marlborough Sounds is a relict one and concluded that a range contraction must have happened within the last 2000–3000 years. He attributed this to the arrival and successive hunting activities of the Maori, who first arrived c. 1000 years ago. However, there appears to be no evidence of whether King Shags were once distributed continuously between the Sounds and Northland or not. Any distribution beyond that known at present would probably have been patchy, and limited by suitable feeding areas and colony sites. Evidence that the range was greater in the past does not necessarily mean that the population in the Sounds was any larger then (Worthy 1996).

Nelson (1971) reviews the distribution and demography of King Shags from 1773 to 1960s. In 1773, J.R. Forster, naturalist on Cook's second voyage, collected the first King Shags from White Rocks outside Queen Charlotte Sound. He estimated the total population at about 160 birds (see also Hutton 1878). Over a hundred years later, White Rocks was still the only known breeding colony, but Buller (1891) stated that there were then only 50 birds; eggs and young were found in both July and October of that year. Later expeditions collected more specimens but added no further information. In 1875, H.H. Travers made the first reference to breeding of King Shags on White Rocks (Medway 1987). Birds were killed for the feather trade for muffs (Nelson 1971) at the beginning of the 1900s and for museum skins. Although White Rocks was described as a colony since 1875, birds had been collected from other colonies as well, for example from the Trio Islands in 1896 (Dawson & Dawson 1958). Both the Canterbury Museum and the Museum of New Zealand Te Papa Tongarewa hold skins of King Shags (AV3111; MNZ 9367, 9368, respectively) collected from other colonies in 1914 (Schuckard 2006a).

Later in the twentieth century, Falla (1933) found smaller irregular colonies on other islets nearby, and counted 80 adults on White Rocks in July 1932. He explicitly noticed that nesting occurred in midwinter. By 1948, Falla (unpublished, Internal Affairs Department file) had recorded a new major colony on the North Trio Island as

well as a regular roost on Sentinel Rock. However, both White Rocks and North Trio then had only 25 nests each, the total of 50 nests being a small increase compared with that of about 40 nests at White Rocks alone in 1932. In 1949 the population was estimated as “probably being under 100 individuals” (Dawson & Dawson 1958). On 1 Sep 1951 about 150 adults and 29 nests were discovered on the penultimate rock in Duffers Reef by Dr. Fleming, the chain of stacks off the west side of Forsyth Island (Dell *et al.* 1952). The barren outermost rock, where the colony is now, has been used since 1964, whereas the 2nd and 3rd rocks from the outer end were in use since the discovery of this colony (Nelson 1971, Schuckard 2006a).

Oliver (1955) gave the first complete list of breeding colonies, including White Rocks, stacks off Forsyth Island, Sentinel Rock (“formerly”), North Trio Islands, and Chetwode Islands (Fig. 3). However, skins from the Chetwodes in Canterbury Museum (AV655) and the Museum of New Zealand (MNZ10419) are both dated 1925 and are thus of much earlier origin than the first published reference made by Oliver (1955).

Since the 1950s, the Wildlife Service has kept the record on the birds; new colonies have been found at Duffer’s Reef (1951), Sentinel Rock (1951) and Te Kuru Kuru or Stewart Island near French Pass (1960). A temporary colony on D’Urville Peninsula found in 1951 and occupied up to 1959 probably gave rise to the rookery on Te Kuru Kuru Island from 1960-65 (Schuckard 2006a).

The Te Kuru Kuru colony (Stewart Island) near French Pass was washed out during a severe easterly gale in Aug 1967, and no other records are known until July 1981, when c.19 birds with “several” nests were recorded (Booth 1983). Birds were observed roosting there occasionally between 1988 and 1995 but no breeding attempts were recorded (D. Brown, pers. comm. to R. Schuckard). A small breeding colony has been present there since 1995. Schuckard (2006a) mentions that King Shags were first reported from Rahuinui Island (SW of D’Urville Island) in January 1988. The Offshore Island Research Group identified c. 23 King Shags there, of which 18 were newly-fledged juveniles, but there was no obvious sign of breeding (Anon. 1988).

Probably there have always been several colonies of King Shags in Marlborough Sounds, with changes of sites from time to time. It is not until the 1950s that these changes have been recorded systematically.

2.2 Present colony distribution and demography

Nelson (1971) describes the habitat and location of the five main breeding islands of King Shags in Marlborough Sounds (see Fig. 3):

- (i) **White Rocks**, where the colony is on the only sloping area, the southern face, of an otherwise vertical, narrow stack 15-18 m high.
- (ii) **Sentinel Rock**, a high razorback in Cook Strait east of Outer Chetwode Island. The colony is on its eastern slope (37-45⁰), out of reach of high seas and partially protected from wind by Taupata scrub (*Coprosma repens*).
- (iii) **Duffer’s Reef**, a chain of rocks extending west from Forsyth Island at the entrance to Pelorus Sound. King Shags have nested on the three outermost rocks which was the main colony site up to about 1964. The birds nest on a plateau which has a clear area of 17 by 5 m facing west and beyond the reach of the waves.

(iv) **North Trio Island**, to the northwest of the Chetwode Islands. Here the area occupied changes from year to year; in 1964 nests were being built on a pinnacle on the northern end, but in 1965 a new area 8 by 5 m had been cleared on the steep southern face.

(v) **Te Kuru Kuru Island** ("Bushy" or "Stewart" Island) in sight of French Pass Township. The position of the colony changed from a steep face looking south-eastwards in 1964 to a low rock about four feet above sea level, on the western side, in 1965.

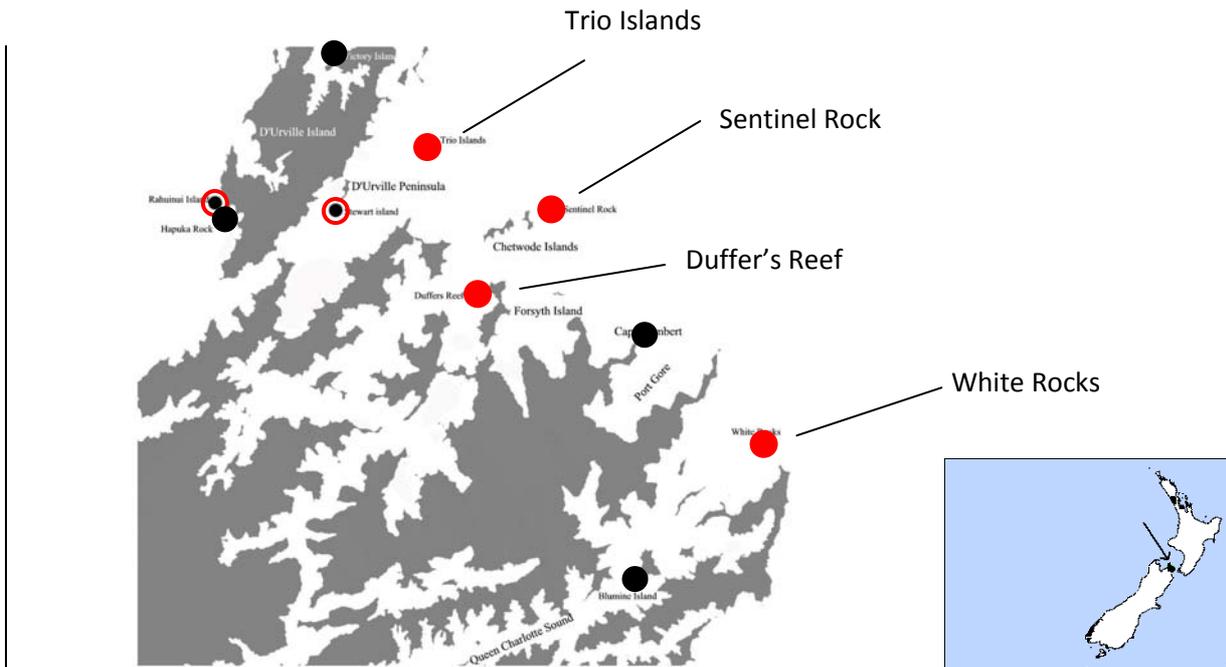


Fig. 3 Marlborough Sounds with 4 major colony sites (filled red dot), some additional breeding sites (open red dots) and main roosts (black dot), after Schuckard (2006b)

Since the early 1990s the population of King Shags has been surveyed in a more systematic way. Between 1992 and 2002, the four main colonies of the King Shag in the outer Marlborough Sounds, were surveyed ten times Schuckard (2006b), showing no overall trend in numbers. Additional information was gathered at two smaller colonies SW off D'Urville Island, Rahuinui Island and Hapuka Rock.

Table 4 summarises recent counts of nests and birds in the different colonies. It shows that a relatively small number of birds appears to breed in any year, a minimum of 70 pairs and maximum of 166 pairs being counted in the years 1992-2002 by Schuckard (1994, 2006b).

The average total population was estimated during these simultaneous investigations to be 645 birds, with 92% in the four main colonies at Duffers Reef, Trio Islands, Sentinel Rock, and White Rocks. This includes 102-126 breeding pairs, with an annual recruitment of 39-69 birds (Table 4). Compared to the other larger colonies, those on Trio Island produce proportionally fewer young.

There was a great disparity in the total number of birds recorded between the historic counts of King Shags and those recorded in this study, but numbers of nests and of juvenile or subadult birds were comparable. The number of birds recorded between



Duffer's Reef near Orchard Bay near the mouth of Pelorus Sound, 31 January 2011. This is one of the larger colonies of King Shag and a year-round roosting site (M.R. van Eerden)



*King Shag roost and colony site at North Trio Island east of D'Urville Island, 28 January 2011
(M.R. van Eerden)*

1992 and 2002 was about 2.5 times higher than that suggested by historic data. Schuckard points out that surveys before 1992 may have included only c. 40% of the population, because most counts seem to have been done during the middle of the day when, according to recent data, significant numbers of shags were absent because of feeding. If historic counts at colonies are adjusted for birds absent feeding, numbers appear to have been stable for at least the past 50 years — and possibly over 100 years — which would suggest a long-term balance between recruitment and mortality.

Table 4. Recent census data of King Shags in Marlborough Sounds. Data of 1992 – 2002 from Schuckard (1994, 2006b and pers. data); data of 2006 from Bell (2010).

| | Duffer's Reef | Trio Island | White Rocks | Sentinel Rock | Stewart Island | Rahuinui Island | Blumine Island | Squadron Rocks | The Twins | Taratara | Total |
|-------------------|---------------|-------------|-------------|---------------|----------------|-----------------|----------------|----------------|-----------|----------|----------|
| Population | | | | | | | | | | | |
| 1992-2000 | 204 | 205 | 134 | 55 | 30 | 30 | 22 | | | | 658 |
| 2002 | 230 | 200 | 141 | 17 | 27 | 23 | | | | | 638 |
| 2006 | 183 | 220 | 125 | 35 | 20 | 55 | | 8 | 13 | 28 | 687 |
| | | | | | | | | | | | |
| Juveniles | | | | | | | | | | | |
| 1992-2000 | 25-30 | 12-17 | 7-16 | 1-3 | ? | ? | 3 | | | | 45-69 |
| 2002 | 18 | 12 | 9 | 0 | 0 | 0 | 0 | | | | 39 |
| 2006 | 34 | 19 | 23 | 6 | 1 | 7 | | 1 | 2 | 3 | 96 |
| | | | | | | | | | | | |
| % juveniles | 7-19 | 5-9 | 5-18 | 0-17 | 0-5 | 0-13 | | | | | 6.1-14.0 |

2.2 Past and present roost distribution and demography

Like other cormorants King Shags use daytime and night roosts. Colony sites serve as roosts for non-breeding birds in the breeding period. Outside the breeding season the majority of birds stay for the night at the colony sites as well (Schuckard 2006a).

Night roosts are used by birds to spend the night. Schuckard (1994) describes several night roosts which may contain several tens of King Shags (e.g. Te Kaiangapiro roost max. 22 in June and July). In January 1988, the Offshore Island Research Group (unpubl. report) found a new roost on Rahuinui Island, on the western side of D'Urville Island, with about 23 King Shags (Schuckard 1994). Likewise 26 King Shags were counted at Cape Lambert in February 1993 (R. Taylor). These sightings of roosts with relatively high numbers of King Shags coincided with a period of low numbers at Duffers Reef, i.e. prior to or outside the breeding season (Schuckard 1994).

Daytime roosts are used by birds on their feeding trips to and from the night roost. Especially on longer foraging flights birds may use daytime roosts. These are left in the (late) afternoon as birds return for their night roost. Daytime roosts are used after foraging and have only a few birds (1-5) and may vary with respect to position and

time of use. There is no systematic inventory available of daytime roosts in the area. Daytime roosts may be on rocky shores, isolated boulders or artificial structures like buoys and various floating devices used for fish farming and aquaculture. No systematic data exist on distribution and use of all types of roosts by King Shags in the past.



Sentinel Rock at the outer Pelorus Sound, east of the Chetwode Islands. The King Shag colony and roosting site is visible as a white patch, 26 January 2011 (M.R. van Eerden)

3 Ecology and behaviour

Ecological and behavioural parameters are key elements in the array of assets that characterise a species. This chapter first describes general habitat of the Marlborough Sounds and continues with published data on feeding range and water depth of the foraging grounds. Feeding activity, diving depth and dive duration zoom in at more detail as to where King Shags spend most of their time on open water when not assembled in the colony or at the roost. Foraging niche, prey choice and diet are outlined according to the literature and the chapter ends with a summary on breeding and wintering biology.

3.1 Habitat

The Marlborough Sounds comprise the coastal system at the NE fringe of the South Island of New Zealand. From Cape Soucis in the west to Rarangi in the east including the inlet systems of Croisilles Harbour, Pelorus Sound, Queen Charlotte Sound, Torey Channel and Port Underwood; to the West D'Urville Island separates the area from Tasman Bay, to the East Arapawa Islands in the East. The area is connected to Cook Strait which forms the trench between New Zealand's North and South Island. The region is roughly 70km in extent from west to east, and 80km north to south. Shoreline length exceeds 1,400 km. Shores can be rocky and steep as well as more gently sloping and shallow. The variability of the shore is further reflected in the presence of many islands and bays. Larger islands and the mainland coasts are either forested or covered with extensive bush vegetation or grazed by sheep which have turned the landscape into wide open areas with meadows. Water depth varies from several metres in front of sandy coasts and near estuaries to over 100 m in deeper trenches in the central and outer parts of the Sounds. Water depths of 10-60m are most common in the area. For a more detailed description of the region, including the geological and geomorphologic background in relation to King Shag habitat use see Part B of this study.

Islands in the outer sounds provide breeding habitat for King Shags. These islands have little or no vegetation and King Shags are present here year-round. Breeding occurs at the ground in colonies and is therefore vulnerable to predators (rats, stoats, weasels, possums a.o.). As a result of avoidance of predators breeding on the ground is restricted to remote islands and nests need to be well above the reach of swell during stormy weather. Nests can be washed away during high tides and stormy weather (e.g. Te Kuru Kuru colony, R. Schuckard pers. comm.). King Shag colonies are situated on gently sloping or flat, more or less bare parts of isolated rocky islands. Breeding on cliffs and ledges is rarely the case. The sloping platforms are covered with a thick layer of faeces, appearing chalk-white from a distance.

Lalas (1983) describes breeding colonies of Stewart Island Shags. They nest on flat areas on the top of islands but also on slopes with inclinations of 30° (Green Island), 40° (Taiaroa Head) and Centre Island (45°). Nests were made of grass, seaweed and cemented with guano. Re-use resulted in piles that were up to 60 cm. Nest density was up to 1-2 m⁻², the nest rims being only 40-80 cm apart. For King Shags no such detailed data are available.

Breeding colonies of King Shags are generally exposed on South or Southwest slopes. Based on the field visit in 2011 this is the case for Duffer's Reef (S), North Trio Island (S), Te Kuru Kuru Island (SW), Sentinel Rock (SW) and White Rocks (S).

Formerly at Sentinel Rock the colony was reported facing eastward according to Nelson (1971). This author also mentions Te Kuru Kuru colony facing SE on a steep slope in 1964, after which the birds settled on the western side on lower rocks (Nelson 1971).

King Shag colonies are monospecific, without any mixing with other seabirds recorded. However, other seabirds may be present at the same island or neighbouring islands (a.o. Little Blue Penguin, Spotted and Pied Shag, Fluttering Shearwater, Variable Oystercatcher, White-fronted Tern, and Red-billed Gull).



White Rocks NE of Long Island, outer Queen Charlotte Sound, 27 January 2011 (M.R. van Eerden)

3.2 Feeding range and water depth

The optimal colony location for seabirds is usually downwind of their feeding area, which provides a tail wind for the return trip by birds carrying heavy loads of prey (Pennycuick 1989). About 67% of all winds in the colony areas of the outer Sounds comes either from the northwest-west or southeast sector (Mallinson 2001 data from 1990 till 2001). Most departures from the Trio Islands and Duffer's Reef were between west and southeast directions (Schuckard 1994, see Fig. 4).

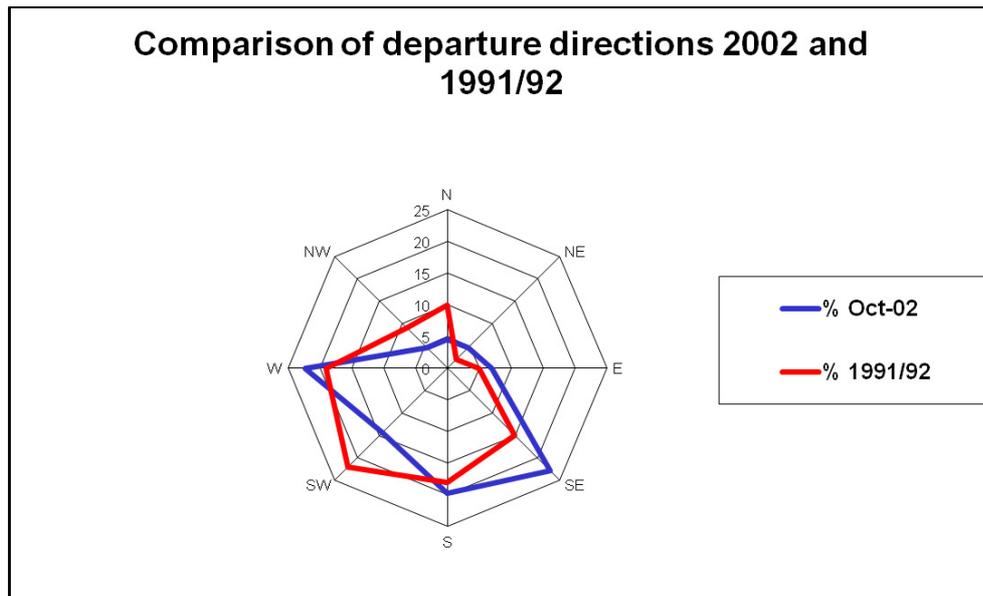


Fig. 4 Direction of foraging flights of King Shags from Duffer's Reef in 1991/1992 and 2002 (from Schuckard 1994)

Schuckard (1994) made observations on feeding range of King Shags from Duffer's Reef. During the monthly trips, 289 birds were observed in the study area of which 219 were actually fishing. Fig. 5 shows range of foraging flights of individual King Shags according to main direction from Duffer's Reef and North Trio Island. The birds fed at an average distance of 8.2 km (s.d. 4.1km, n = 219), from Duffer's Reef. The maximum observed distance between feeding birds and the colony was 24 km. This area, far into the Pelorus Sound, was not a part of the study area but was regularly visited by boat. There was no significant difference in feeding range between the courtship/breeding period (7.6 ± 4.1 km, n = 104) and the non breeding period (8.7 ± 4.0 km, n= 115).

For their foraging trips King Shags seem to be confined to those parts of Marlborough Sounds with deeper water (Schuckard 1994, 2006a); although direct observations of dive depth in King Shags are lacking, systematic recordings of dives in relation to local water depth were analysed (Schuckard 1994, 2006a).

Most King Shags from Duffers Reef (74%) were observed feeding where the bottom was 20-40 metres deep (see Figure 6) whereas only 50% of the study area consisted of waters of these depths. At depths of 20-40 metres the bottom is mainly flat (63%) or moderately sloping (23%). Most of the King Shags were feeding in waters which are not deeper than 40 metres (Waitata Reach, waters around Maud Island, Beatrix Bay and Forsyth Bay and the eastern side of Forsyth Island). Almost no birds fed in the centre of Waitata Reach, where depths are far beyond 40 metres and up to 70 metres. Likewise King Shags from Trio Islands in Admiralty Bay foraged almost exclusively in waters < 50 m deep avoiding the deeper parts of the trench, whereas most King Shags from Duffer's Reef foraged where the water depth was 20-40 m.

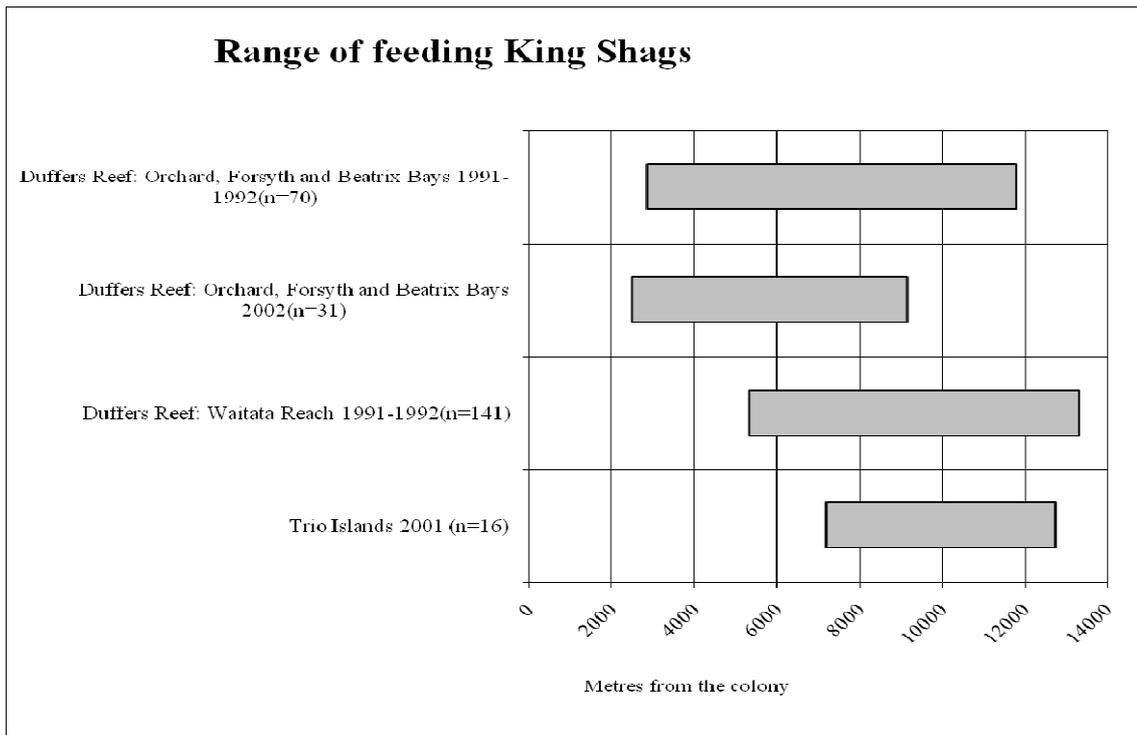


Fig. 5 Observed feeding range of King Shags from Duffer's Reef and Trio Islands in different years. Forsyth and Beatrix Bays are SSW of Duffer's Reef, Waitata is to the WSW. N=number of birds observed fishing (from Schuckard 2006a)



Most King Shags perform foraging flights of 2-13 (24 km) km from the colony or roosting site; adult King Shag near Sentinel Rock, 26 January 2011 (M.R. van Eerden)

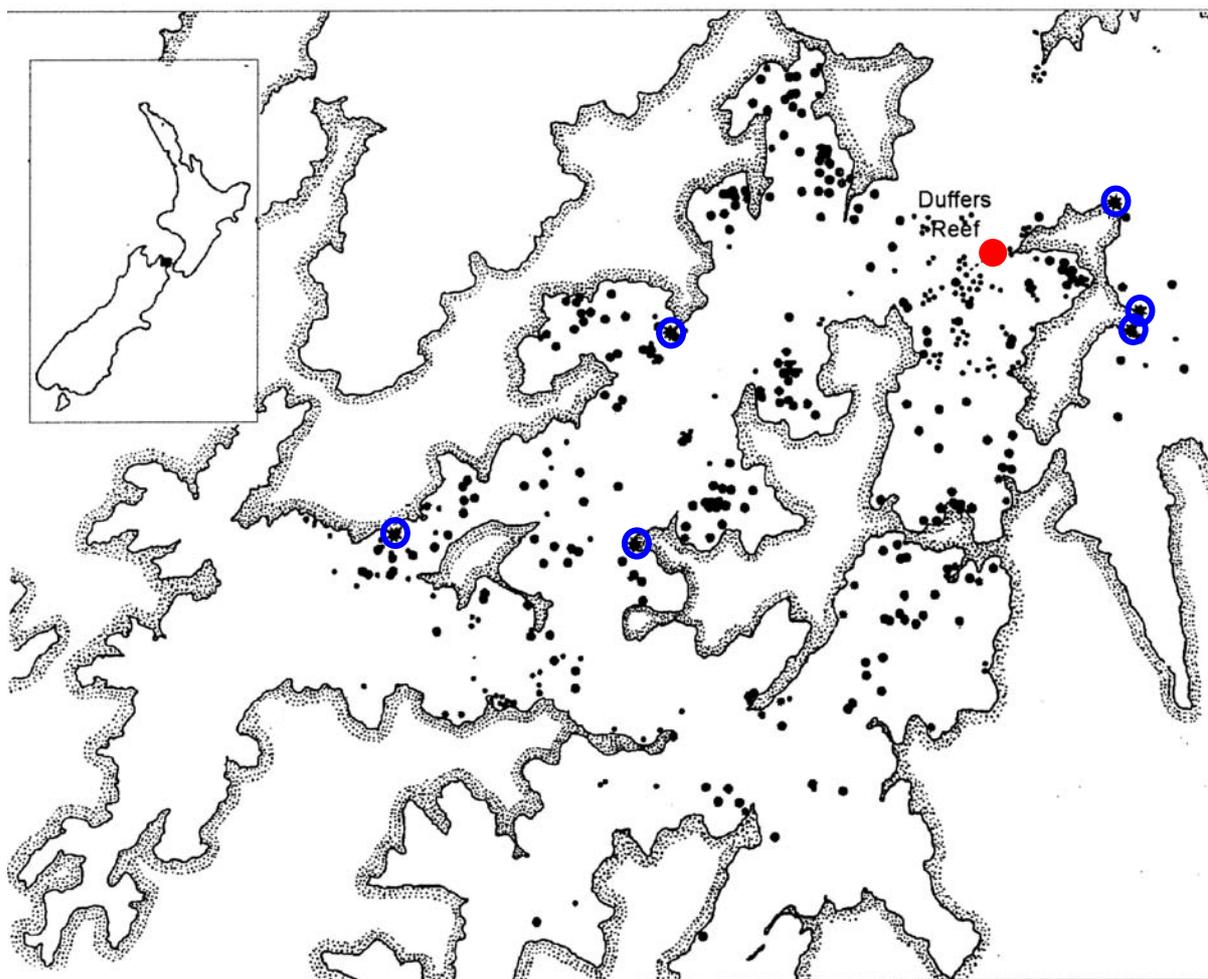


Fig. 6 Observed feeding locations of King Shags from Duffer's Reef (red dot) in the outer Pelorus Sound area during systematic sailing tracks (larger dots) and occasional observations 1991-1992 (Schuckard 1994, and pers. comm.). Daytime roosts indicated in blue. Notice the presence of dive locations generally not inshore and in the deeper parts of the bays and sounds.

Records of King Shags further West in Admiralty Bay have been amalgamated with sightings from the Dusky Dolphin Research Group ($n=40$, winter 2001 and 2002), from D. Boulton ($n=92$, 2001-2002), from D. Brown ($n=82$, 1985-1989), and data from the Bird Mapping Scheme ($n=26$, 1985-1989). These 240 sightings show a main distribution of foraging King Shags W and SW from Trio Islands (Schuckard pers. comm.).

During the day, King Shags sometimes roost away from the main colonies. These roosts can be either on land or on mussel floats of marine farms. Most of the land-based roosts are found on the east coast of D'Urville Island, in particular between Anatakupu Island and Penguin Island and around the Rangitoto Islands (Fig. 7).

The mean distance of foraging birds from the Trio Islands in March and June 2001 was 9.96 ± 2.78 km with a maximum of about 18 km. The foraging range of birds from the Trio Islands compares with 8.2 ± 4.1 km (maximum 24 km) for King Shags from Duffer's Reef (Schuckard 1994).

Although field observations in Admiralty Bay have been limited and the results are preliminary, it is apparent that there is general similarity with the results of an earlier study at Duffers Reef colony (Schuckard 1994). At Duffers Reef about 75% of the birds left between southeast and western directions where Trio Island birds predominantly depart in west and south-western directions. King Shags in Admiralty Bay almost exclusively foraged in water depths less than 50, only 17 (7%) of foraging King Shags were recorded from areas where the water depth exceeded 50 m.

The main feeding area of King Shags would thus best be delineated as water with bottom depths of 20-40 metres within 25 kilometres of breeding sites and major roost sites of this species.

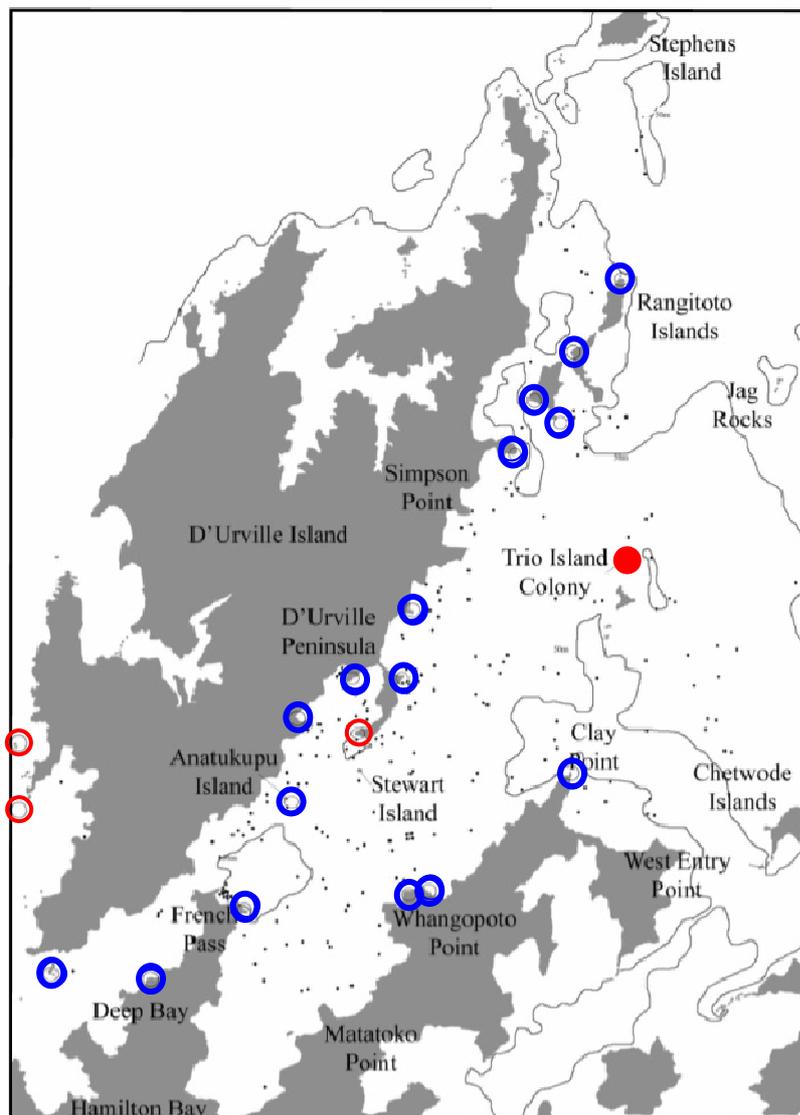


Fig. 7 Assembled total of 240 feeding locations of King Shags from the main colony at Trio Islands (filled red dot) in Admiralty Bay area during systematic sailing tracks by the Dusky Dolphin Group in 2001-2002 and observations in 2001-2002 by R. Schuckard and D. Boulton, amalgamated with older observations by D. Brown and the bird mapping scheme 1985-1989 ($n=82$, $n=26$ respectively). Daytime roosts in open blue dots, smaller colonies in open red dots.

3.3 Feeding activity, diving depth and duration

Daily activity patterns differed between the courtship/breeding period and the non breeding period (Schuckard 1994). During the courtship/breeding period many birds departed around 07:00 hrs, shortly before or at sunrise. A second wave of departures took place around 13:00 hrs, caused by birds obtaining nesting material nearby the colony, and they arrived back within one hour. Incoming flights were gradually over the day, indicating large differences in individual pattern of foraging activity. Between October and March, the non breeding period, the peak of departing birds was later at 09:00 hrs, and the number of departures gradually declined during the rest of the day. Birds returned gradually during the morning with a peak between 13-16h, indicating foraging trips of 5-7 hours. Birds that leave the colony/roost do not necessarily spend all their time foraging. Part of the time off can be used as resting time at a daytime roost.

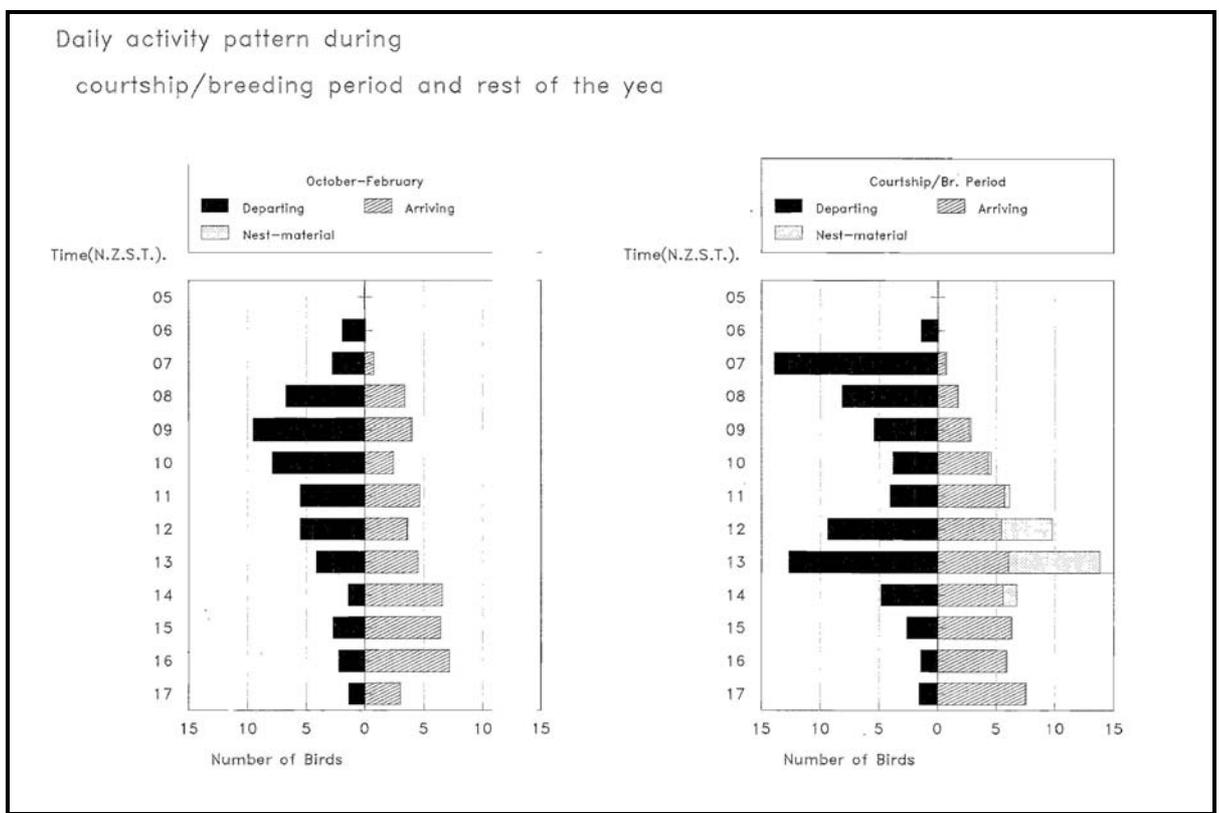


Fig. 8 Activity pattern of King Shags at Duffer's Reef, Marlborough Sounds, apart for non-breeding time (October-February) and courtship-breeding time (March-May). Time in New Zealand Standard Time (from Schuckard 1994). Notice the existence of a bimodal pattern in departing foraging flights for the breeding period that remains after correction for birds returning with nest material.

This pattern compares well to that described for Stewart Island Shags at Maukieki Island, Otago by Lalas (1983). Major outbound flights occurred at sunrise and were followed by a gradual return during the day, peaking 8 h after departure. Quintana (2001) studied Rock Shags (*Leucocarbo magellanicus*) in Patagonia. They undertook 2.6 ± 0.6 sd trips per day. The mean duration of a feeding trip was 2.6 ± 0.7 hours, so more often and much shorter than King and Stewart Island Shags. Rock Shags fed in waters less deep (<10m) and less far from the colony (<5 km) than King Shags.

In King Shags no information exists on possible sexual differences in activity patterns. In South Georgia Blue-eyed Shags (*Leucocarbo georgianus*) females were found to forage during the morning hours whereas males tended to forage in the afternoon and early evening (Bernstein & Maxson 1984, Kato *et al.*1992). In the chick-rearing period Blue-eyed Shags were spending more time in foraging activities than in the egg time (Bernstein & Maxson 1985).

Dive duration in King Shags was recorded by Brown (2001) timing fifty-three individual dives for 22 different shags on 14 different days (19 September 1990 to 9 March 2000). Individual dives ranged 65-190 s (average 127 s). Rest times between dives (N=38) averaged 157 s (range 55 - 745 s). Mean dive duration was considerably longer than the dive times suggested by Heather & Robertson (1996), based on observations of 22 dives by 6 individual shags (mean 45 s, max. 90 s) recorded by Nelson (1971).

Stewart Island Shags were demersal feeders according to Lalas (1983) and who recorded diving times up to almost three minutes. Time underwater increased with water depth throughout the recorded range of 1-30m, suggesting bottom dives.

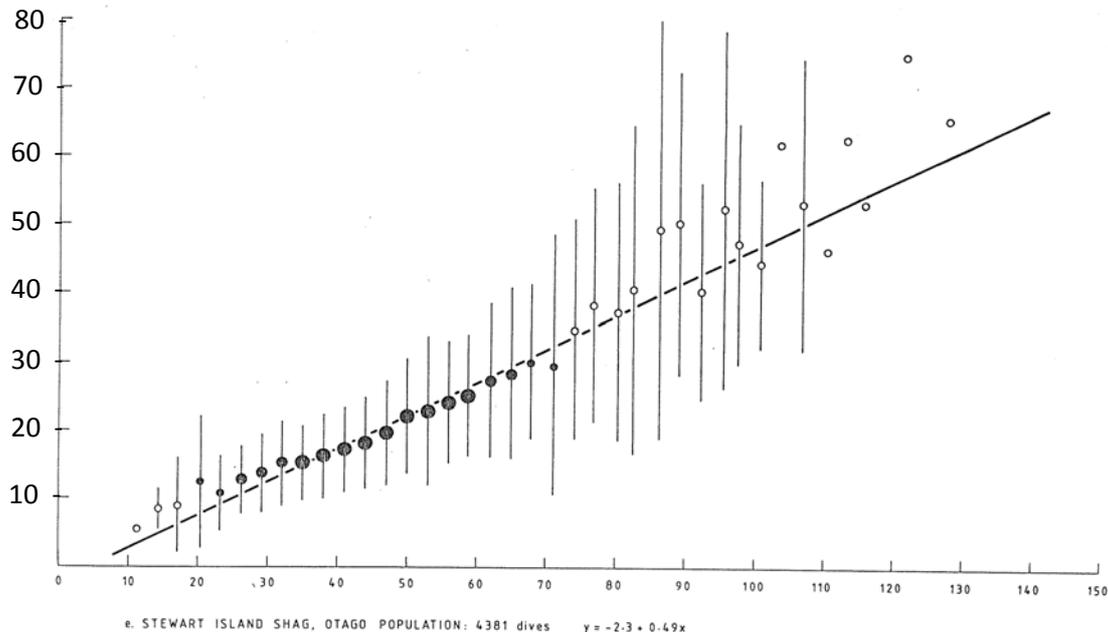


Fig. 9. Relationship of pause time (Y-axis) and diving time (x-axis) in Stewart Island Shags according to Lalas (1983)

Measuring dive times Lalas (1983) found that pause time was linearly correlated to the preceding dive time (Fig.9). This was also the case for 7 other New Zealand species of cormorants. By calculation of the ratio between dive and pause duration Lalas (1983) used this as an index of diving performance for different species. As average recuperation time is shorter relative to dive duration then birds are supposed to perform better under water.

Table 5. Dive/pause ratios in Darter and seven species of shags foraging in New Zealand waters (from Lalas 1983).

| % of time under water | Species | | Dive/pause ratio |
|-----------------------|----------------------------------|--|------------------|
| 80-90 | Darter | <i>Anhinga melanogaster</i> | 5.05 |
| 70-80 | Little Black Shag * | <i>Phalacrocorax sulcirostris</i> | 3.15 |
| 70-80 | Black Shag | <i>Phalacrocorac carbo novaehollandiae</i> | 2.74 |
| 70-80 | Little Shag | <i>Phalacrocorax melanoleucos brevirostris</i> | 2.73 |
| 70-80 | Pied Shag | <i>Phalacrocorax varius varius</i> | 2.53 |
| 60-70 | Stewart Island Shag ¹ | <i>Leucocarbo chalconotus</i> | 2.25 |
| 60-70 | Spotted Shag | <i>Stict carbo punctatus</i> | 2.20 |
| 60-70 | Pitt Island Shag | <i>Stictocarbo featherstoni</i> | 2.04 |
| 60-70 | Stewart Island Shag ² | <i>Leucocarbo chalconotus</i> | 1.75 |

* freshwater ¹ Otago ² Foveaux

Stewart Island Shags from Foveaux Strait had on average the longest dive pause times recorded, whereas Little Black, Black, Little and Pied Shag spent more time under water (Table 4). Darter (*Anhinga melanogaster*) spent most time under water of the species recorded by Lalas (1983).

Lea *et al.* (1996) applied the optimal breathing model by D.L. Kramer on their observations of shags and cormorants in Europe and New Zealand. They found correlations between dive time and following pause time in Little Shags (*Phalacrocorax melanoleucos*) and interpret this as reactive response in the sense of recuperation. On the other hand European Shag *Ph. aristotelis* showed an anticipatory pattern with longer pause times preceding longer dives. Great Cormorant *Ph. carbo carbo* and Pied Shag *Ph. varius* showed no overall correlation between pause time either before or after dive time (Lea *et al.* 1996). The ratio of dive times and surface times is thus not just a reflection of the bird's diving ability but may be part of a strategy.

More recent studies on diving behaviour have used various recording instruments and data loggers in order to describe the actual behaviour under water in a quantitative way.

Dive depth was significantly positively related to dive duration and inversely related to bottom time in the recorded male Blue-eyed Shags *Leucocarbo atriceps* (Kato *et al.* 1992).

In their study of male Blue-eyed Shags *Leucocarbo atriceps*, Croxall *et al.* (1991) using continuous-recording time-depth recorders, found that deep dives (> 35 m, averages 80–90 m, max. 116 m) were twice as common (64% versus 34%) as shallow dives (< 21 m and 90% < 10 m). Deep dives were long (averages 2.7-4.1 min, max. 5.2 min) with half the time spent near maximum depth and fast travel speeds under water (averages 1.0-2.4 m s⁻¹). Shallow dives were short (average 0.5 min, max. 1.3 min), without bottom time and with slow travel speeds (0.1-0.6 m s⁻¹). The time spent at depth and the diet (mainly benthic fish and octopus) was consistent with benthic foraging; the function of shallow dives is uncertain.

Male Blue eyed shags forage mainly in the afternoon in 3–5 distinct bouts of diving. Within bouts (and shorter homogeneous sequences of diving) surface intervals are consistently 2–3 times the preceding dive duration, i.e. dive/pause ratios of 0.3-0.5. Blue-eyed Shag diving depth, duration and pattern is extreme amongst shags; and the relationship between dives and surface intervals suggests that they may regularly exceed their aerobic dive limit (Croxall *et al.* 1992). The ca. 3 kg weighing Blue-eyed Shag holds the record for greatest recorded dive depth for any bird except the two largest species of penguins (Croxall *et al.* 1991, Kato *et al.* 1992).

Kerguelen Island Shags (*Leucocarbo verrucosus*), another species of the blue-eyed group, was recently studied by Watanabe *et al.* (2011), using a set of different data loggers able to record diving depth, GPS, air speed and under water speed under field circumstances. Kerguelen Island Shags are deep divers, showing an average diving depth of 23.4 m, average maximum 45.6 m and absolute maximum 94.2 m for 25 birds followed two consecutive days (rearing one or two young). These authors stress the implications of deep diving at the cost of flight performance. Kerguelen Island Shags spent on average 6.5 h. day⁻¹ at sea but did not fly far from the colony: average 8.1 km (max 26 km). Total time spent diving was 130.4 min.day⁻¹ whereas 24.4 min.day⁻¹ was on average spent in flight (Watanabe *et al.* 2011). These birds regularly rested at sea during both outbound and inbound flights without any diving, which was interpreted by the authors as necessary recuperation for the high flight costs.

Quintana *et al.* (2007) state that Imperial Cormorants (*Leucocarbo atriceps*) and in general cormorants of the blue-eyed complex have a plumage with a substantial layer of insulating air. This is given credence by a simple model. High volumes of plumage air lead to unusually high power requirements during foraging in shallow, warmer waters, which are conditions that would favour wettable plumage. However, deep dives and/or cold water should favour the blue-eyed phenotype, which would explain their essentially high latitude distribution.



Foraging King Shags may stay well over 2 minutes under water, Forsyth Bay, 31 January 2011 (M.R. van Eerden)

3.4 Foraging niche, prey choice and diet

Regarding interference with other cormorant species at the foraging grounds, Schuckard (1994) shows that King Shags from Duffer's Reef use a specific area in the outer Pelorus Sound to feed; they always fed individually and never in social aggregations. Presumably they dive to flat bottoms in waters between 20 and 40 m water depth. Here they do not compete with the other two most common shags in the Marlborough Sounds, the Pied Shag and the Spotted Shag. Pied Shags breed throughout the Marlborough Sounds. They are also solitary feeders, but fish close inshore, often in depths of 3 - 10 m at distances of 100 - 300 m from the shore (Stonehouse 1967). By contrast, Spotted Shags are social feeders in flocks of up to 100 birds, often between 2 - 16 km from the coast (Stonehouse 1967). They feed on pelagic fish in deeper water (Lalas 1983) and breed in the outer sounds.

King Shags apparently hunt bottom-living fish: Falla (1932, 1933) found small Blue Cod (*Parapercis colias*), Red Scorpionfish (*Scorpaena papillosus*), Red Rock lobster *Uasus edwardsii*) and crabs at the White Rocks colony. Oliver (1955) noted Pilchard (*Sardinops neopilchardus*), Red Cod (*Pseudophycis bachus*) and Lobster krill (*Munida gregaria*).

Nelson (1971) noticed that birds disturbed at their nests in 1964 regurgitated soles (*Peltorhamphus novaezelandiae*) and sand-eels (*Gonorhynchus gonorhynchus*). King Shags are often blamed for depleting the Blue Cod fishery, but birds illegally shot to stop this competition for Cod are said to have contained only soles.

Lalas & Brown (1998) studied the diet of New Zealand King Shags in the Waitata Reach of Pelorus Sound. They collected 22 complete regurgitated pellets at the King Shag roost at Te Kaiangapi (41° 01' S, 173° 56' E). Twelve pellets were collected on 14 November 1991 and 10 on 6 May 1992. Otoliths and other distinctive bones of fishes are known to be reliable remnants of fish species. Otolith size is linearly correlated with fish length. Pellets represented a total of about 683 prey items with an estimated wet mass of fish being 14.9 kg. Witch (*Arnoglossus scapha*), a left-eyed flatfish (Bothidae), dominated the diet and accounted for about 90% of prey items and 95% of wet mass in both samples. The average total wet weight per pellet matched the theoretical estimate for daily energy expenditure for the shags. Prey species of interest to commercial or recreational fishers accounted for only 1.3% of the diet.

Witch predominated in every regurgitated pellet. For pellets collected on 14 November 1991, number of witch per pellet varied five-fold with a range 17-82, mean 37.5 (n = 12, s.d. = 17.12). For pellets from 6 May 1992, the range in number of witch per pellet was reduced to a two-fold range 12-25, mean 16.7 (n = 10, s.d. = 3.40).

Modes in the estimated lengths of Witch represented in each regurgitated pellet varied between 6 cm and 11 cm from the November sample and between 12 cm and 15 cm from the May sample. These length-frequency distributions of Witch taken by King Shags were summed for each sampling date. The modal lengths differed between the two sampling dates (November = 9-11cm and May = 12-16 cm) although ranges were similar (November = 6-26 cm and May = 6-29 cm). The estimated mean length of witch taken in May was 14.8 cm (n = 167, s.d. = 4.47), significantly longer than the mean length of 10.8 cm (n = 450, s.d. = 3.64) taken in November (t = 11.23, P < 0.001), most probably representing the same 1+ cohort.

Daily energy expenditure (DEE) was provisionally estimated as 3 x basal metabolic rate (BMR). Published records for body mass of King Shags are limited to only two birds at 2.5 kg and 2.7 kg (Marchant & Higgins 1990). These body masses applied by Lalas & Brown (1998) to the above relationships produce a theoretical DEE

equivalent to a daily consumption of 545-575 g of fish. This range is 12-22 % lower than the average estimated total wet mass per pellet of 655 g in November 1991 and 695 g in May 1992. However, the similarity between values for total calculated wet mass of fish per pellet and theoretical DEE for King Shags indicates that complete regurgitated pellets may represent daily food intake. Stated otherwise, due to their expensive diving and flying habit, King Shags could well possess a DEE of 3.3-3.6 * BMR, thus matching the higher amounts of total fish consumption.

Lalas & Brown (1998) state that their results are applicable to about one-quarter of the total King Shag population and that they cannot be extrapolated to King Shags elsewhere in their restricted distribution. Unpublished data regarding 4 pellets of these authors from Trio Islands indicated a far less importance of Witch, representing only 20% of the 20 prey items recorded. The sample also included seven Leatherjacket (*Parika scaber*), three Blue Cod (*Parapercis calias*) and two Sea Perch (*Helicolenus percoides*).

Kato *et al.* (1996) studied sexual differences in diet of King Cormorants (*Leucocarbo albiventer*) during the 1993/1994 austral summer at Macquarie Island. The major food items, identified by otoliths in regurgitations, were demersal fish; fish mass consumed could be estimated using a wet mass-otolith length relationship. Two fish species, *Paranotothenia magellanica* and *Harpagifer georgianus*, constituted 98% of the wet mass (male and female cormorants combined). Estimated individual fish mass of *Paranotothenia magellanica* (19.6 ± 11.6 g) was greater than that of *H. georgianus* (2.8 ± 1.3 g). Total wet mass of food and number of fish in regurgitations did not differ statistically between the sexes of cormorants. However, males tended to feed on larger fish than did females. For *Paranotothenia magellanica* by mass: male $94.3 \text{ g} \pm 19.0\%$, female: $81 \text{ g} \pm 32.4\%$; $U = 483$, $P < 0.02$. For *H. georgianus* male: $2.4 \pm 6.7\%$, female: $16.7 \pm 30.1\%$; $U = 468$, $P < 0.01$).

Prey choice in King Shags is thus only superficially known. Neither temporal effects (seasonal and over the years) nor geographical differences in prey choice and fish mass ingested (e.g. between colonies) nor sexual differences are known.

3.5 Breeding biology

Nelson (1971) reviewed data on breeding cycle and concludes that King Shags usually nest once each year at each colony, but that on fairly rare occasions there has been a second breeding period in the same year (6 times in 49 colony/years); whether or not the same birds are involved is unknown. A normal breeding cycle takes about five months, and the bulk of breeding activity occurs between March and December. Breeding normally starts about May, but tends to start two or three months earlier if two cycles are attempted. The onset of breeding varies from colony to colony and from year to year. In some years breeding activity would be seen throughout the year if all the colonies were visited month by month.

Among other New Zealand Shags, it is normal for each colony to follow its own timing and for breeding to occur in a diffuse way with generalised peaks of activity, rather than substantially in unison. Lalas (1983) found that Stewart Island Shags may start breeding from May onwards. Young fledge from September to November. This is later than King Shags which start in March and have a similar six months breeding cycle with young fledging in August/September (Schuckard 1994) but earlier than the other shag species which normally start breeding in August/September. Only Pied Shag (*Ph. varius*) may have young year round, although most egg-laying occurs in July-October and January-March (Heather & Robinson 2005). King Shag and Stewart

Island Shag are thus breeding during the coldest months of the year, quite in contrast to other shags and seabirds in New Zealand.

Nelson (1971) measured nests and number of eggs of King Shags. Nests were about 20 inches wide (range 14-26 inches), up to 17 inches high at the downhill side, with a nest chamber about 11 inches wide and 3 to 4 inches deep (21 measured). Nests were usually about 40 inches apart (range 24 to 91 inches). Of 167 nests measured in the period 1949-1965 an average of 1.8 eggs per clutch was found. One egg clutches accounted 35%, two eggs 52.7% and three eggs 11.9%. Eight eggs were measured: mean length was 65 mm (range 63-67 mm) and mean width 41 mm (range 40-43 mm). Two eggs weighed about 62 g each.

Of a total population of 645 birds in 6-7 colonies, 102-126 pairs of King Shag were found breeding between 1992 and 2002. Some 40-68 young fledged each year, which is considered low (Schuckard 2006b). Annual breeding success and the proportion of the population participating in breeding both seem low in comparison to other shag species. From a mean total of 645 birds, with just over 100 breeding pairs (i.e. 200-250 birds breeding, or 31-39% of the population breeding in any year), a mean annual recruitment of 40-68 birds represents 6.2-10.5% of the total population. Calculated over breeding pairs this compares roughly to an estimated fledgling success of 0.3-0.7 young per breeding pair.

With an estimated total population of 330 birds, the Heard Island Shag (*Leucocarbo nivalis*) produced 100-200 fledglings in each of the 1991/92 and 1992/93 seasons (Green *et al.* 1998). The data on chick production suggest that chick production on Heard Island is extremely uneven and that the population goes through boom and bust phases in reproductive success. Periods such as the late 1980s are therefore compensated for by boom seasons such as 1991/92 and 1992/93 when a known 235 and possible 326 chicks fledged. Boom and bust cycles in reproduction probably result in periods of high and low adult mortality respectively, as boom and bust cohorts age and die leading to some cycling of the population level.

Nineteen colonies of the King Cormorant (*Leucocarbo albiventer*) occur on Macquarie Island (Brothers 1985) varying in size from 3 to 320 breeding pairs. The total population was estimated at 660 breeding pairs in 1975-79. Breeding varied annually, but most eggs were laid in the last half of October with an average clutch size over two seasons of 2.7 eggs. Most chicks hatched by late December and fledged from late January onwards. Minimum age at first breeding was 2 years but most shags did not breed until the age of 4 years or more. Faithful breeding pairs tended to be more successful than those that changed mates although most remained together for only one or two seasons. Male shags had a stronger tendency to retain their nest-site than did females, and it was the female that was responsible for the breakdown of the pair-bond. This breakdown and annual variation in breeding success was thought to be mainly due to shortage of food, which consisted solely of benthic fish. The mean annual mortality of the Macquarie Island Shag (*Leucocarbo purpurascens*) is 16.2%, for males and females combined.

Green *et al.* (1998) summarize egg and chick mortality in Imperial Cormorant (*Leucocarbo atriceps*) known to have an uneven reproductive success with high failure rate in some years: Williams & Burger (1979) reported egg mortality of 38.1% and 46.4% for two years at Marion Island, and a chick mortality of 78% (compared with 41% at Crozet Islands: Derenne *et al.* 1976). Brothers (1985) reported egg mortalities of 10%, 27% and 28% over three seasons at Macquarie Island, and the presumed chick mortality was about 39%, 12% and 37% over the same three

seasons. In 1992/93, mortality on Heard Island was 41%. This was confined mainly to eggs with virtually no chick mortality after the first few days of life (Green 1997).

For King Shag neither long-term data exist on annual young production nor on mortality. This makes the records on young production difficult to interpret.

3.6 Wintering biology (the austral summer)

Islands, islets and remote rocks in Marlborough Sounds provide basic resting habitat for the species year-round. Birds are more scattered outside the breeding period, but colony sites remain the most important compare resting sites (Schuckard 1994, 2006). No data exist on specific feeding habitat, or differences therein with the breeding period. Also area and the range at which the species forages has not been investigated systematically outside the breeding period.

Other species of seabirds with which the King Shag may interact remain comparable to that in summer. As most shearwaters, diving petrels, blue penguins and gannets are breeding in the austral summer, this period has the highest densities of these birds in the region of the Sounds. Little is known about direct competition with King Shag over food items captured, indirect feeding competition by overlap of feeding areas and commonly used resources. However, due to the fact that most seabirds depend on prey in the top water layers, little overlap exists with King Shags. Sea mammals like New Zealand Fur Seals (Taylor *et al.* 1995) and Bottlenose Dolphins (Merriman *et al.* 2009) remain in the area year-round. Dusky Dolphins (Würsig *et al.* 2007) mainly visit the Marlborough Sounds in winter, that is during the period of chick rearing of King Shag; interactions with all of these species are unknown, but, given the densities and the more pelagic way of foraging of these predators seemingly of little importance beforehand.

4 Interferences and threats

The seas in Marlborough Sounds are unprotected for most of the surface area, only the islands and some sea reserves are; for King Shags no management plans or species protection plans have been developed earlier on. Historically the species has been little studied but during the last two decades attention has been given to several aspects of its biology. Accurate and comprehensive diagnosis of processes threatening the species is important (IUCN 2010) and threats can be distinguished as:

- *Proximate threats (immediate causes of population decline, e.g. conversion of forest to cultivation)*
- *Ultimate threats (the root causes of proximate threats, e.g. human population growth)*

The following possible threats to King Shags have been identified by Taylor (2000) and Butler (2003).

4.1 Predators and pest animals

Rats, mice, cats, dogs, rabbits, deer, possums, pigs, ferrets, stoats and weasels each have a devastating impact on the ecology of many bird species in New Zealand (Dowding & Murphy 2001). All nesting colonies of King Shags are found on predator-free islands although ship rats have briefly colonised Duffer's Reef in the recent past but were eradicated by 1983 (Murphy 1984). They were removed by trapping and poison stations are maintained to prevent a recurrence. The possibility of the accidental introduction of rats to this and other sites remains, e.g. following a shipwreck. Distribution of mammalian predators (all introduced to New Zealand by humans) will thus largely determine the possibilities that King Shags (and other seabirds) have to breed. No other records exist of natural predators that would cause any significant disturbance or predation in colonies. Potentially this could be Black-backed Gulls (*Larus dominicanus*) and Red-billed Gull (*Larus novaehollandiae scopulinus*). However, predation by these birds is normally limited to occasions of disturbance by other causes, or at times when parents have difficulties in food provisioning and tend to be less weary defending the nest.

4.2 Human disturbance

Nelson (1971) explains why disturbance may be fatal to King Shags in the egg stage. Before the chicks hatch, merely a close approach from a sight-seeing launch is enough to cause birds to fly from their nests in alarm. Because the eggs and small young are brooded between the feet and the belly, many are tumbled out of the nest in the hurry to get away, and others are taken by Red-billed Gulls (*Larus novaehollandiae scopulinus*) before the shags come back.

King Shags are highly vulnerable to human disturbance and do not tolerate people landing on breeding islands or even the close approach of boats (within 100 m, Taylor 2000). Nesting birds are very susceptible to disturbance by boats and low-flying aircraft (fixed-wing aeroplanes and helicopters) and may abandon eggs or chicks, which can be lost due to chilling or predation by gulls. Commercial fishing boats, tourist charter boats and leisure craft and yachts can therefore have a significant impact on breeding success.

No specific research has been carried out in order to determine possible effects of different sources of disturbance on King Shags.

4.3 Fisheries

Whilst there have been no reported captures of King Shags in commercial fishing operations, such as long line-fishing and trawling (see Abraham *et al.* 2010), recent quantitative risk assessment work found very high potential risk to this species, primarily from flatfish trawl (Richard *et al.* 2011). These authors estimate that between 8 and 81 King Shags might be killed annually by commercial fisheries. Bottom feeding shag species are sometimes caught in crayfish pots and this may pose a slight risk as well. However, set-netting, especially near the breeding colonies, presents a major risk to this species (Taylor 2000, Butler 2003). Several nets have been observed next to the Te Kuru Kuru site near French Pass recently (D. Boulton pers. comm.).

Disturbance by tourism is potentially more important as commercial fishing vessels are restricted to large parts of the inner sounds in the austral summer (Fig. 10) . However, no detailed information is available as yet showing the impact of fisheries in relation to the foraging areas of King Shags.

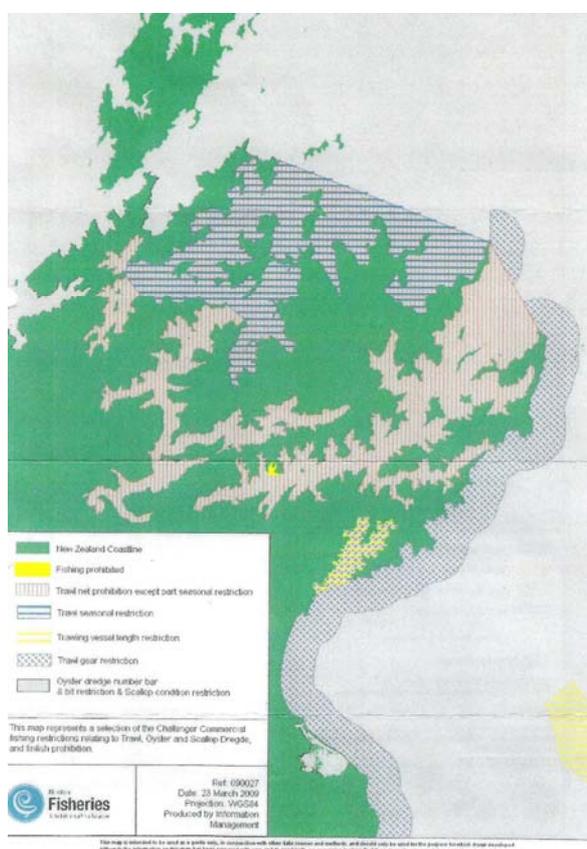


Fig. 10 Trawl restrictions in the inner parts of the Pelorus and Queen Charlotte Sounds (all season, orange vertical hatching) as well as a restriction of trawl net fishing during summer in the outer Pelorus Sound (blue horizontal hatching). The outer sounds and the area around D'Urville Island has no restrictions with respect to trawling.

4.4 Shellfish aquaculture

Aquaculture production in New Zealand is growing fast and rose steeply from 3000 tonnes in 1980 to 105,000 tonnes in 2009. Most important species cultured are New Zealand Green-lipped mussels (*Perna canaliculus*) and Pacific Oysters. In 2006, the New Zealand aquaculture industry developed an industry-wide growth strategy aimed at achieving annual production of US\$ 720 million by 2025 (NZAC, 2006).

For comparison, sales in 2007 and 2008 amounted to US\$ 400 million. (see www.fao.org/fishery/countrysector/naso_newzealand/en). Production of farmed mussels in New Zealand is on average 9.85 tonnes ha⁻¹ yr⁻¹.

Stattersfield & Clapper (2000, cited in Melville unpubl. 2001) recommended the prevention of marine farming close to King Shag colonies and feeding areas. Keeley *et al.* (2009) studied effects of shellfish aquaculture on the environment. Fig. 11 depicts the main effects in a schematic way. Effects can be divided in seabed effects and water column effects. Seabed effects result from the deposits of mussels (“pseudo faeces” accretion) underneath the actual growing site and by the deposit of shell litter and debris following harvest. The water column effects result from the filtering of seawater for phytoplankton and other sources of food.

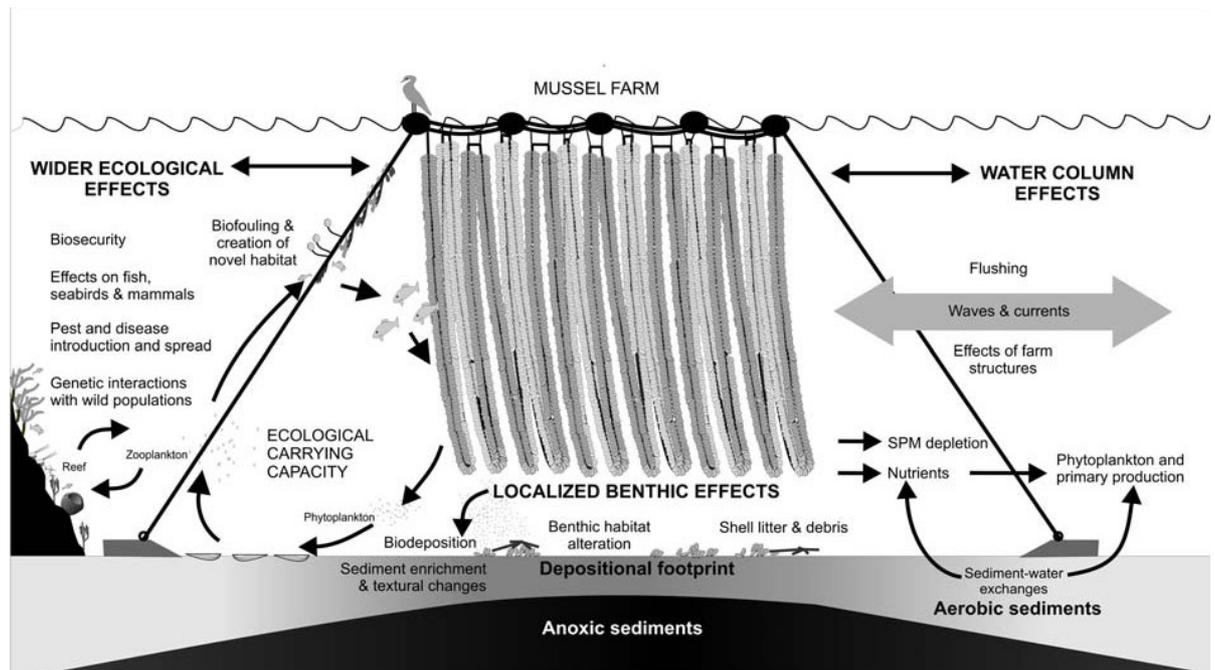


Fig. 11 Schematic overview of the general set-up and ecological interactions near a mussel farm (from Keeley *et al.* 2009).

Seabed effects

The main ecological effects on the seabed from farming mussels, oysters and other filter-feeding bivalves arise from bio-deposits and drop-off of shell and associated biota. In most instances, the severity of seabed effects has been assessed as low to moderate. The effects exhibit as minor enrichment of the seabed sediments (organic content increases by ca 7.5%), increased build up of shell litter directly beneath the site, and in some instances increased aggregations of starfish and other epifauna taxa. Sediment enrichment, in turn, affects the composition of sediment dwelling biota with productivity generally enhanced (*i.e.* some smaller species become more prolific). Changes to the surface dwelling biota (*e.g.* starfish) have been documented but are difficult to quantify and vary significantly between sites (Keeley *et al.* 2009). Seabed effects are most pronounced directly beneath farm sites, reduce rapidly with distance, and are usually difficult to detect within 20-50 m away. The most important factors influencing the magnitude of effects are water depth and current speeds; hence severity of effects is very much site-specific and effects are minimised by locating farms in well-flushed areas, where species and habitats of special value are not present.

Water column effects

Effects of mussel cultivation on the water column are less well defined than for the seabed, because water column characteristics are more dynamic and inherently harder to quantify. The physical presence of farms can alter and reduce current speeds, which affects water residence times and has implications for associated biological processes. Farm structures can also attenuate short-period waves, which can affect inshore ecology, but these issues are not considered significant at the present scale of development in New Zealand (Keeley *et al.* 2009). Bivalves and other associated fauna release dissolved nitrogen (*e.g.* ammonium) directly into the water column, which can cause localised enrichment and stimulate phytoplankton growth. Toxic micro-algal blooms may lead to ecological or health problems, but according to Keeley *et al.* (2009) there is no evidence of this being exacerbated by mussel farming in New Zealand waters. Filtration pressure by mussels is sufficient to potentially alter the composition of the phytoplankton and zooplankton/mesoplankton communities through feeding, but the extent to which this occurs and its ecological consequences are still poorly understood. Hawkins *et al.* (1999) recorded cases of retarded growth of New Zealand Green Shell Mussels™ between 1996 and 1998, suggesting food limitation to occur. Bivalves not only consume phytoplankton but are occasionally also recorded feeding on zooplankton and other small particles such as fish eggs and larvae in freshwater Zebra Mussels (*Dreissena polymorpha*, MacIsaac *et al.* 1995). Davenport *et al.* (2000) found a range of planktonic items of non algal origin ingested by marine Blue Mussels (*Mytilus edulis*) such as up to 6 mm large amphipods, fish eggs, crab eggs and zoeae, nematode and polychaete worms. Such feeding habits by bivalves could have important effects in the foodweb due to the distortion of food provisioning *e.g.* for fish.

These potential effects remain largely unrecognised in Marlborough Sounds so far, but the fact that no significant water column related issues have been documented suggests that effects associated with traditional inshore farming practices are relatively minor (Keeley *et al.* 2009).

Wider ecological issues

The wider ecological issues that are assessed include: habitat creation and alteration, effects on fish, sea birds and sea mammals, bio-security risks, disease and genetics. These issues are generally even less well studied than seabed and water column effects, due either to logistical difficulties in obtaining quantitative data, lack of awareness, or because the need has not arisen (*i.e.* potential for adverse effects is generally perceived to be low).

As stated by Keeley *et al.* (2009) habitat creation recognises the fact that, in addition to growing the culture species, farms function as mid-water artificial reefs. Artificial structures provide novel foraging habitat, detrital food sources, breeding habitat, and refuge from predators for some species, and can contribute to seabed enrichment issues through bio- deposits and drop off. As well as changing habitat characteristics, and with it, the composition of the wild fish assemblages, marine farms can affect fish populations through changing fishing pressures and aggregation behaviour. In addition, recruitment of fish larvae to wild fish populations could theoretically be affected by the filtration pressures of large bivalve farms.

Potential effects on seabirds and marine mammals (seals, dolphins and whales) relate mainly to habitat modification, entanglement in structures and habitat exclusion.

4.5 Shellfish aquaculture and seabirds

Overview

Several New Zealand and overseas studies discuss the potential ecological effects of shellfish aquaculture on seabird populations, but only a few direct studies have been conducted (Roycroft *et al.* 2004; Zydels *et al.* 2006; Kirk *et al.* 2007). Based on these studies, mussel aquaculture potentially affects seabirds by altering their food resources, causing physical disturbances (*e.g.* noise) and/or being a possible risk of entanglement. The structures associated with aquaculture may also provide benefits including additional perching and feeding opportunities.

Effects on food supply

The attraction of certain seabird species to aquaculture structures has been noted within New Zealand and overseas aquaculture regions (Ross *et al.* 2001; Butler 2003; Roycroft *et al.* 2004). An increased abundance of seabirds associated with shellfish farms may indicate increased fish abundance within the sites, as aquaculture structures are thought to provide alternative or additional habitats for some fish species (Costa-Pierce & Bridger 2002). In New Zealand, shags (Little, Pied, Spotted and King), terns (White-fronted) and gulls (Black-back and Red-billed) have been observed foraging in and around mussel farms (Brown 2001; L alas 2001; Butler 2003). An Irish study found significantly more piscivorous seabird groups (*e.g.* shags, guillemots, razorbills and gulls) utilising mussel farm sites compared to control areas (Roycroft *et al.* 2004), suggesting birds were benefiting from elevated fish numbers in farm areas.

From overseas studies, several seabird species (*e.g.* oystercatchers, plovers, gulls) are known to feed directly on shellfish stocks or associated fouling biota (Ross *et al.* 2001; Roycroft *et al.* 2004; Kirk *et al.* 2007). For example, Kirk *et al.* (2007) noted that farmed mussels tended to be larger, thinner-shelled and attached more weakly than wild mussels, and along with higher stocking densities these characteristics may attract avian predators to a farm. Currently, there are no reports of New Zealand seabirds foraging directly on shellfish farm stock. Overall, New Zealand (Butler 2003) and overseas (Ross *et al.* 2001; Roycroft *et al.* 2004; Kirk *et al.* 2007) studies suggest that the general attraction of particular seabirds to mussel farms is likely due to increased foraging success on fish and bio-fouling, and even on the cultured stock itself. The consequences of this attraction will likely depend on the species' dietary preferences and response to both direct and indirect ecosystem changes induced by mussel cultivation.

Human disturbance by exploitation of shellfish farms

Several studies have noted that certain shore and seabird species are relatively sensitive to human presence and disturbance (Goss-Custard & Verboven 1993; Butler 2003; Roycroft *et al.* 2004, Goss-Custard *et al.* 2004). Butler (2003) found that nesting King Shags in the Marlborough Sounds were highly susceptible to disturbance by boats and even aircraft, leading to part or complete abandonment of nests and chicks. Such findings suggest that day-to-day maintenance, harvesting and other activities taking place on mussel farms located near breeding or roosting sites have the potential to adversely affect bird populations, possibly in tandem with other sources of disturbance (*e.g.* recreational vessel activities). Nonetheless there is no direct evidence for such effects from mussel farming in New Zealand, and the little available information is inconclusive. For example, varying levels of responses to boat disturbance have been reported for several different shag species in New Zealand depending on location and their activity state (Brown 2001; L alas 2001). However, L alas (2001) concluded that boat traffic alone was not a significant disturbance factor to King Shag foraging and/or resting activities.

During certain times of the year (especially summer) seabirds may use farm structures as perching sites as look-outs (*i.e.* to spot fish) or to evade shore predators and avoid human disturbance on shore. Roycroft *et al.* (2004) found evidence of shorebirds as well as more terrestrial species, such as oystercatchers and plovers, using farm structures rather than more traditional land sites in Ireland. Despite their apparent sensitivity to disturbance, New Zealand King Shags have been observed regularly roosting on mussel buoys (Brown 2001; Lallas 2001). Brown's (2001) results suggest that King Shags favour roosting on floats over land sites. However, the importance of mussel farms as foraging sites for king shags or alternative roosting sites to land was not substantiated by Fisher *et al.* (2011 *in prep.*).

Overall, the potential disturbance of seabirds from nearby mussel farms appears to be dependent on the bird species, farm location in relation to nesting or breeding sites, and the relative disturbance of farm operations (*e.g.* noise and boat traffic) in comparison to other local forms of disturbance (*e.g.* recreational boating, casual or commercial use of nearby beaches).

Entanglement and drowning in fishing gear

Incidental seabird entanglement in fishing gear, including set-netting, line fishing and even crayfish pots (Butler 2003; Bull 2007), are a recognised national and international problem to seabird survival (Taylor 2000). However, to date, no entanglements of seabirds in New Zealand or overseas shellfish farm lines have been reported. As with marine mammals, loose and more fibrous thin lines pose the greatest threat to diving seabirds. Hence, entanglement risk appears low in the New Zealand mussel industry where the long-line method places lines under considerable tension. A potentially greater risk within the mussel industry is operational by-products of farms, including lost lines and plastics (Weeber & Gibbs 1998). The mussel industry has an Environmental Code of Practice that seeks to minimise such risks, and they are likely to be minimal to non-existent in well-maintained farms. The potential is considered to be greater, however, after stormy weather (Page *et al.* 2000) and in poorly operated farms. Butler (2003) found young and adult Australian gannets (*Sula serrator*) in the Marlborough Sounds entangled in discarded rope ties from mussel farms that had been incorporated into nests by parents. In an overseas example, ingestion of plastic debris by albatross chicks caused mortality through dehydration, gut blockage and/or toxic effects during digestion (Auman *et al.* 1998).

4.6 Fish farming

King Salmon or Chinook Salmon (*Oncorhynchus tshawytscha*) is a Pacific salmon native to Japan and eastern Russia. It is reared in New Zealand in Marlborough Sounds at eight localities over deep water. New Zealand King Salmon Ltd. harvests around 8,900 metric tonnes of salmon annually, providing around 75 percent of the domestic New Zealand market and 55 percent of the world market for farmed King Salmon. The company intends to increase production to 15,000 tonnes by 2015, proposing 8 new sites. Of these 5 are located in the outer Pelorus Sound, 2 in Queen Charlotte Sound and 1 in Tory Channel (Fig.4.6). The proposed sites are 16.5 hectares each, except for Papatua which is 91ha and Ruaomoko which is 14.1ha. Each salmon farm is 1ha of water space with about 15ha needed for the anchoring system.

The key environmental issues for sea farmers are the effects of organic particles of feed and fish faeces settling on the seabed below the pens, depletion of dissolved oxygen in the water, and nutrient enrichment. Local practices include steam washing

nets rather than coating them in copper based anti-fouling, and an automated feed system to reduce the amount of feed waste that would otherwise fall to the sea floor and disrupt the natural ecology. New Zealand King Salmon fish do not suffer from sea lice as King Salmon are naturally resistant and sea lice in the Southern Hemisphere are smaller than those found in the far north. Therefore New Zealand King Salmon do not carry out any sea lice treatments. Compared to shellfish farming, fish farming requires more active management, so transport to and from farms is more intensive as compared to mussel farms. As it is a recent development the specific short term and long term effects of fish farms on King Shags have not been investigated.

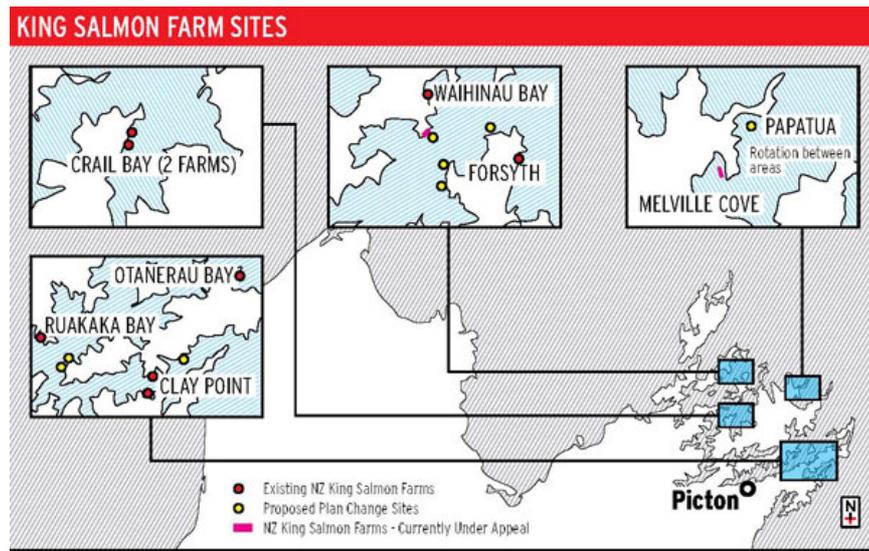


Fig. 4.6 Existing and proposed sites for farming King Salmon (Source: *The Marlborough Express* 14 October 2011)

4.6 Shooting

King Shags are sometimes shot illegally to supposedly protect local fish stocks. Shooting of shags is illegal but because they are considered competitors of fishers or fish farms is known to occur, and King Shags could be affected (Taylor 2000).

4.7 Oil spills

There is a potential risk of oil spills owing to the volume of shipping through Cook Strait and in the Marlborough Sounds. Transport of oil as well as drilling activities in the entire area of Cook Strait may cause a serious threat to the population.

4.8 Climate change

Lalas (unpubl. 2001) noted that the King Shag is the most northerly of the White-bellied shags and he considered that the small population size might be related to the climate. In summer, birds on the colonies are observed panting, actively fluttering with their gular pouch which may be an indication of heat stress. If this is the case, then global warming might threaten the population on the longer term. White *et al.* (2011) investigated the population of the Great Cormorant (*Phalacrocorax carbo carbo*) in Greenland in relation to global change. Arctic seas have warmed and sea ice has retreated. Great Cormorants have a partially wettable plumage and seem poorly suited to foraging in Arctic waters. Rates of population change of Cormorant colonies around Disko Bay were positively correlated with sea surface temperature,

suggesting that they may benefit from a warming Arctic. However, although Cormorant populations may increase in response to Arctic warming, the extent of expansion of their winter range may ultimately be limited by other factors, such as sensory constraints on foraging behaviour during long Arctic nights. Goodwin (2009) summarises the effects of climate change in the Nelson-Tasman region over the coming century:

Sea level rise of 1.9 m

The Nelson/Marlborough region has nearly 1000 km of coastline, including about 20,000 ha of wetlands below 3 m altitude (Cromarty & Scott 1996). These wetlands are breeding and foraging grounds for numerous seabird species and offer important ecological services linked to the wider ecosystems; their conservation is a recognised priority (Ramsar 1971). Many of the current breeding islets of King Shags will be lost or significantly affected as sea levels rise. Only the higher elevated locations as Trios and Sentinel Rock are relatively safe.

Temperature rise of 2.5 °C

Current winter temperature minima in New Zealand are such that the region is largely untroubled by severe winter weather and with climate change it will become easier for King Shags to stay over winter. Effects of temperature rise on King Shags may have adverse effects in summer as heat stress in the colony increases. Moreover, temperature rise will also affect the distribution of fish species but this is an entirely unknown area as yet.

Increase in rainfall of 10%

The region could probably tolerate an increase in annual rainfall of 10%. This will do little however to the ecology of King Shags, although periods of intensified rainfall may cause locally increased turbidity due to runoff, landslides and peak discharge of rivers. High turbidity has a negative effect on prey detection but details are lacking as yet.

Increase in drought periods

Despite the expected increase in rainfall, intervening drought conditions are also expected to become worse. For King Shags this has no envisioned effect as they have no need for freshwater for drinking.

Increase in extreme wind events

In July 2008 severe easterly gales caused damage that cost the Nelson City Council nearly NZ\$ 2 million (Marshall 2009) and the Tasman District Council another NZ\$ 2 million (Kempthorne 2008). As the frequency and intensity of such events is expected to increase, breeding sites may suffer as storms may sweep away nests and young off the exposed rocks.

Effect on fisheries and aquaculture (and also on ecosystem):

While geographic properties are unlikely to be significantly affected by climate change in the next century, oceanic conditions may well shift, to the detriment of currently important species. Warmer temperatures could displace some species further south, which could mean we lose some desirable species as well as gaining undesirable ones. Salmon are sensitive to warm water temperatures, with death occurring at temperatures as low as 12 °C in the spawning stage of some species (Danie *et al.* 1984). Warming of oceanic water may bring new invasive species and marine pests that could foul aquaculture farms, parasitize wild fish, or render the harvest toxic to humans.

Additionally, the combined influence of warmer temperature and ocean acidification can increase organisms' vulnerability to thermal extremes (Pörtner 2008), resulting in responses such as reduced capacity to respond to heat-stress (e.g. echinoderms, O'Donnell *et al.*, 2009), altered shell structure (e.g. molluscs, Melatunan *et al.* 2009) and increased mortality (calcareous algae, Martin and Gattuso 2009). These changes have the capacity to reduce the resilience and recovery of whole ecosystems, potentially to the detriment of fish assemblages, fishing activities by humans and King Shags and aquaculture industries.

4.9 Autonomous threats

Poor reproduction of fish prey may affect King Shags breeding success in a given year. Failure of key species e.g. Witch production could be detrimental if juveniles of this species are a key food for King Shags (Lalas & Brown 1998) and the species is unable to switch to other species. Only in the unlikely event that such a single-food dependence would be extreme and the decline in food stocks would be continuously for several years in a run, overall effects on population structure and numbers would be noticed.

A variety of diseases may cause considerable losses in populations of wild birds, especially colonially breeding species, e.g. Newcastle disease, West Nile Virus, Avian Cholera and Avian Influenza. See also www.Wildlifedisease.nbio.gov/

Stochastic (random) events can cause problems in a population when numbers are very low. An example might be a strongly biased sex ratio among the chicks produced one year which could lead to a shortage of one sex of adults and in turn to reduced productivity.

5 Conservation and management

Selective management and conservation measures directed at species level are used to protect species with a limited distribution or with an unfavourable population size. In New Zealand a lot of effort is paid to protect and restore populations of threatened and endangered species of amphibians, reptiles and birds. In the coastal region seabirds form an important conservation target. This chapter provides information on published management efforts to protect Kings Shags in past and present as well as an overview of published future needs with respect to management and conservation as well as research priorities.

5.1 Past conservation and management

The species was afforded complete protection already in 1927. (The New Zealand Gazette no. 27 – 1384). In an extensive overview Taylor (2000) summarises previous conservation activities, aimed at increasing scientific knowledge and eradicating predators from a breeding site:

1. Counts have been conducted at breeding colonies in the 1950s, 1960s, and recently in the 1980s. Some observations on breeding biology were made during these surveys (Nelson 1971, Marchant & Higgins 1990).
2. Ship rats were eradicated from Duffer's Reef in 1983 (Murphy 1984).
3. A complete census of the total population of King Shags was carried out between 1992 and 2002. Studies were also conducted on foraging range and diving behaviour, and daily and seasonal movements from colonies (Schuckard 1994, 2006).
4. The diet of King Shags in Pelorus Sound was studied by Lallas & Brown (1998).

5.2 Present conservation and management

Current conservation measures in Marlborough Sounds are centred around island sanctuaries with a strong focus on terrestrial conservation. These are protected areas because the presence of seabird breeding colonies or home to threatened populations of endemic species of animals, mostly birds, reptiles and amphibians.

Stephens Island / Takapourewa Nature Reserve holds the world's largest population of Tuatara (*Sphenodon punctatus*). Other species found here include Fairy Prion (*Pachyptila turtur*), Giant Weta (*Deinacrida* spp.), seven species of lizard and the endemic Hamilton's frog (*Leiopelma hamiltoni*).

Maud Island / Te Hoiere Nature Reserve is the second largest of numerous island reserves in the Marlborough Sounds. Although the island had been virtually denuded of forest and heavily grazed for decades, its native vegetation has been making an impressive comeback. Remarkably, mice and rats have never established, so the island is home to some charismatic and rare residents. Te Hoiere's largest mature forest remnant supports virtually the entire population of the threatened Maud Island frog (*Leiopelma pakeka*). Maud is also one of only two locations for the vulnerable

Stephens Island striped gecko (*Hoplodactylus stephensi*), one of New Zealand's rarest geckos. See:

<http://www.doc.govt.nz/upload/documents/about-doc/concessions-and-permits/conservation-revealed/island-sanctuaries-marlborough-sounds-lowres.pdf>.

Long Island / Kokomohua Marine reserve is in the outer part of Queen Charlotte Sound. It measures 619 ha and was established officially in April 1993 after a voluntary stop of taking fish by diving clubs in 1989 (DoC). Long Island Marine Reserve is close to White Rocks, one of four major colonies of King Shags.

The breeding colonies of King Shags are protected as wildlife sanctuary. Boat operators are asked to stay at least 100 metres away from shore on Duffers Reef, Sentinel Rock, White Rocks and North Trio Island in order to avoid disturbing nesting King Shags. However, there is no legal regulation on distance of boat approach or net setting around these islands.

Table 6. Status and accessibility of King Shag colonies (Millar & Gaze 1997)

| Site | Status | Access | King Shags after Schuckard 2006b and Bell 2010 *) |
|---------------------------------|--------------------|----------------------|---|
| North Trios | Wildlife Sanctuary | Restricted to owners | 205-220 |
| Duffers Reef | Wildlife Sanctuary | Restricted | 183-204 |
| White Rocks | Wildlife Sanctuary | Restricted | 15-141 |
| Sentinel Rock | Wildlife Sanctuary | Restricted | 17-55 |
| Rahuinui | Privately owned *) | Restricted to owners | 23-55 |
| Stewart Island | Privately owned *) | Restricted to owners | 20-30 |
| Blumine Island | Scenic Reserve | Open | 0-22 |
| Taratara, Port Gore | Scenic reserve | Open | 0-28 |
| The Twins | Section 62 | Open | 0-13 |
| Squadron Rock, D'Urville Island | Privately owned *) | Restricted to owners | 0-8 |

*) range in number of birds according to counting data **) administered under the Maori Affairs Act 1953

5.3 Future conservation and management

The Action plan for seabird conservation in New Zealand (Taylor 2000) gives recommendations for conservation measures for King Shags:

5.3.1 All breeding grounds need to be legally protected and a code of practise adopted with local commercial charter-boat operators and fishers to minimise disturbance of colonies. It is recommended that no boat approach closer than 100 m from the colonies during the breeding season (March to August).

Educational material should be made available to local (Nelson, Marlborough, Wellington) boat and yacht clubs pointing out the threatened status of this species and the risk of disturbing the birds by approaching too closely to nesting colonies.

5.3.2 An advocacy programme is needed to encourage set net users to adopt practices that will minimise seabird by catch. Restrictions in the use of set nets near King Shag colonies may be necessary to protect this species.

5.3.3 Pest quarantine measures are needed to prevent new animal and plant pest species reaching King Shag breeding colonies. A pest contingency plan should be available to enable a rapid response to any new introductions or events that may cause an introduction.

5.3.4 Techniques need to be developed to establish shags at new colony sites. The most promising techniques probably include using models and tape recordings to lure birds to new colony sites.

Future Survey and Monitoring Needs

A census of each breeding colony should be carried out simultaneously at 5-year intervals using the methodology described in Schuckard (1994).

5.4 Future research priorities

Taylor (2000) summarises research priorities for Kings Shags:

5.4.1 The population dynamics of all New Zealand pink-footed (*Leucocarbo*) shags are unknown. There is no information available on age of first breeding, longevity, adult mortality rates, chick survival and recruitment, natal philopatry, pair and nest site fidelity. The population of King Shags may be too small and sensitive to collect this information. Initially the studies should be started on Stewart Island or Auckland Island shags. However, banding cohorts of King Shag chicks with a single colour-band for each year class and a second colour for each colony site may be possible and should be considered if disturbance of birds can be minimised. This information will help to determine the extent of inter-colony movement and indicate any differences in recruitment rates of chicks into each breeding population. Banding will also establish whether or not breeding adults remain faithful to the same nesting colony.

5.4.2 The breeding biology of King Shags has not been studied in any detail. The timing of the breeding season (pairs displaying at nests, eggs or chicks present) and laying dates (months of year that eggs are laid), descriptions of nests, eggs and nestlings, and clutch size have been partly studied but need more detailed observations. There is no information on incubation period and shifts, chick growth rates and nestling period, post fledgling dependence period etc. The opportunity to research these parameters of the breeding cycle will depend on either developing remote study techniques (nest cameras, weighing platforms etc.) or an acceptance that limited research will temporarily impact on the birds. Alternatively, some of this information may be collected from closely related species, e.g. Chatham Island shag, Stewart Island shag.

5.4.3 The taxonomy of all the sub-Antarctic shags and other pink-footed (*Leucocarbo*) shag species in New Zealand (e.g. Chatham Island shag and Stewart Island shag) needs reviewing to determine relationships.

5.4.4 The diet of King Shags was examined by Lallas & Brown (1998). However, annual and geographical variations in the diet still need to be assessed. Every opportunity should be taken to collect diet samples (e.g. regurgitations or pellets from adults or chicks, or stomach contents of drowned birds or corpses found on the breeding grounds).

As stated by Till (2011 in prep.) a review of the Blue eyed shag group is needed using modern DNA techniques and a comparison of plumage, anatomy, body measurements, vocalisations, and body lice.

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APPENDIX 1 - STATUS OF WHITE BELLIED CORMORANTS

New Zealand and Australia

Little Pied Cormorant (*Phalacrocorax melanoleucos*)

Syn.: Little Shag/White-throated Shag

Size: 56-61 cm

Population: 51,000 – 1,100,000

Status: common

Range: New Zealand (white-throated, intermediate as well as pied form), light phase E. Indies, Pacific, Australia and Tasmania

Pied Cormorant (*Phalacrocorax varius*)

Size: 71-81 cm

Population: 35,000 – 1,000,000

Status: common

Range: coast of Australia and New Zealand

Spotted Shag (*Stictocarbo punctatus*)

Size: 74 cm

Population: 35,000 – 150,000

Status: common

Range: South Island New Zealand

Black-faced Cormorant (*Phalacrocorax fuscescens*)

Size: 71-76 cm

Population: 20,000 – 50,000

Status: common

Range: south coast of Australia and Tasmania

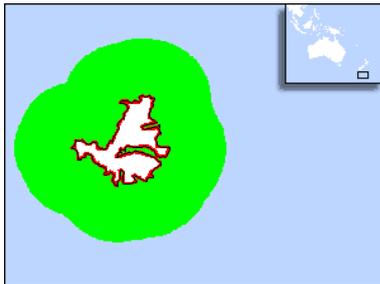
Campbell Island Shag (*Leucocarbo campbelli*)

Size: 64 cm

Population: 8000

Status: Vulnerable

Range: 880 km², Campbell Isles, New Zealand



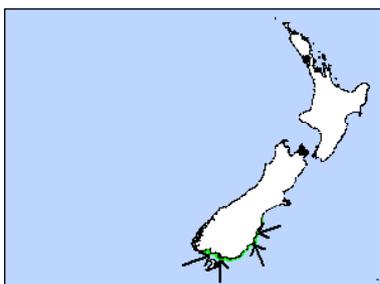
Stewart Island Shag (*Leucocarbo chalconotus*)

Size: 68 cm

Population: 5,000 – 8,000

Status: vulnerable

Range: 8,900 km², south coast of South Island New Zealand



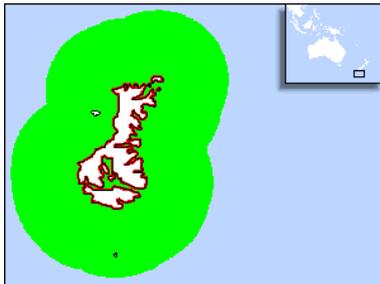
Auckland Island Shag (*Leucocarbo colensoi*)

Size: 63 cm

Population: 2,000

Status: vulnerable

Range: 5,300 km², Auckland Islands New Zealand



Pitt Island Shag (*Stictocarbo featherstoni*)

Size: 64 cm

Population: 1,100

Status: endangered

Range: 22 km², confined to Chatham Islands New Zealand

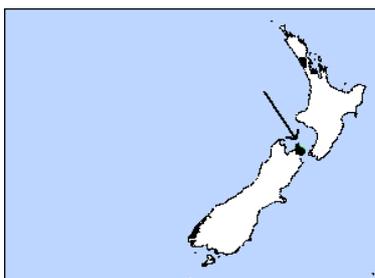
New Zealand King Shag (*Leucocarbo carunculatus*)

Size: 76 cm

Population: 250 - 1000

Status: vulnerable

Range: 1100 km², Cook Strait, Marlborough Sounds New Zealand



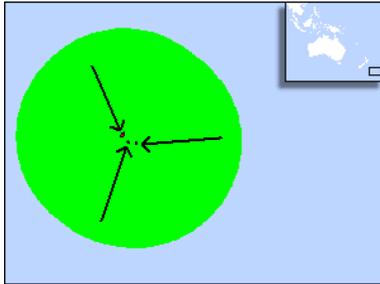
Bounty Island Shag (*Leucocarbo ranfurlyi*)

Size: 71 cm

Population: 620

Status: vulnerable

Range: 2,100 km², confined to Bounty Islands New Zealand



South America

Guanay Cormorant (*Leucocarbo bougainvillii*)

Size: 76 cm

Population: 2,500,000 – 5,00,000

Status: common

Range: 79,500 km² entire west coast of S. America

Blue-eyed Cormorant (*Leucocarbo atriceps*)

Size: 69-74 cm

Population: 340,000 – 1,400,000

Status: common

Range: 365,000 km², Islands adjacent to Antarctica and islands before west coast of S. America

King Cormorant (*Leucocarbo albiventer*)

Syn.: White-bellied Shag also considered as subspecies of *L. atriceps*

Size: 69-74 cm

Population: 135,000-252,000

Status: locally common

Range: Falkland isles, Patagonia, Crozet Is. and Macquarie I.

Magellan Cormorant (*Leucocarbo magellanicus*)

Syn.: Rock Shag

Size: 66 cm

Population: 96,000 – 180,000

Status: common

Range: 528,000 km², west and east coast of S. America, Falkland islands

Kerguelen Island Shag (*Leucocarbo verrucosus*) (very similar to King cormorant)

Size: 69 cm

Population: 30,000 – 35,000

Range: Kerguelen Isles

Other cormorants in New Zealand

Great Cormorant (*Phalacrocorax carbo*)

Syn.: Black Shag

Size: 92 cm

Population: 1,400,000 - 2,900,000

Status: common worldwide, wintering in New Zealand

Range: 25,800,000 km², throughout the world

Little Black Cormorant (*Phalacrocorax sulcirostris*)

Size: 61-64 cm

Population: 110,000 - 1,000,000

Status: common, wintering in New Zealand

Range: E. Indies, Australia etc., breeding in New Zealand

APPENDIX 2 - CONTENTS OF PART B

OUTLINE OF DRAFT KING SHAG CONSERVATION MANAGEMENT PLAN

- 1. Environmental background and rationale of Marlborough Sounds ecosystem**
 - 1.1. Landscape and seascape in perspective
 - 1.2. Geology, lithology and sedimentology of Marlborough Sounds
 - 1.3. Climate and global change
 - 1.4. Hydrology, limnology and water quality
 - 1.5. Fishes and fisheries in the system of Marlborough Sounds
 - 1.6. Aquaculture developments
 - 1.7. Tourism and other human interests

- 2. Summary of King Shag biology (from part A)**
 - 2.1 Taxonomic aspects
 - 2.2 Ecological aspects
 - 2.3 Demographic aspects

- 3. Vision and Goals: King Shag in Marlborough Sounds (from 1, 2 & part A)**
 - 3.1. King Shag in comparison with other species of Blue eyed shags
 - 3.2. King Shag in Marlborough Sounds: factors contributing to carrying capacity
 - 3.3. Scenario's of possible development
 - 3.4. Outline of management goals

- 4. Objectives and targets of King Shag Conservation Management Plan**
 - 4.1. Short-term management goals
 - 4.2. Long-term management goals

- 5. Actions and implementation of plans**
 - 5.1. Outline of actions
 - 5.2. Draft agenda of Stakeholder meeting
 - 5.3. Elaborating an integrated management approach
 - 5.4. Legal enforcement of necessary actions in the region of Marlborough Sounds

Appendices

- Annotated list of fish species of Marlborough Sounds and Cook Strait
- Outline of Part C: necessary future studies