REPORT ON KING SHAG CENSUS FEBRUARY 2018 AND POPULATION TREND

Prepared for The New Zealand King Salmon Co. Limited

By Rob Schuckard May 2018

King shag census 2018, an update of the population trend.

1 Introduction

New Zealand King Salmon (NZKS) holds two consents Waitata-U140294 and Kopaua-U140295 to farm salmon in the Waitata Reach of the Marlborough Sounds. Both consents were granted in April 2014 and require NZKS to prepare a King Shag Management Plan (KSMP)[1]. A KSMP was adopted in June 2015. The first feed for the Waitata Reach salmon farm was applied in January 2016 and the Kopaua salmon farm started in May 2016. First environmental monitoring reports were published in May 2017[2,3]. For the Waitata Reach farm, a total of 2,761 tons of feed was used for the period prior to February 2017. The Kopaua farm had a partial production cycle (May to December) and 1,107 tons of feed was discharged at this site.

The main objective of the KSMP is to ensure that the establishment and operation of the new salmon farms do not result in a reduction in the population of king shag in the Marlborough Sounds. No less than once every three years a king shag population survey in the Marlborough Sounds needs to be conducted.

In the event that a statistically significant decline of king shag numbers ($p<0.05$) has occurred since the baseline survey, the consent holder shall investigate whether the operation of Waitata and Kopaua farms do cause or contribute to the decline. A response mechanism is to be implemented if the marine farms are found to be causing or contributing to the decline in king shag numbers. Such a mechanism includes, but is not be limited to, immediate changes to marine farm management practices including a reduction in feed or stocking levels.

[1] Schuckard, R. 2015. New Zealand King Salmon – King Shag Management Plan. Client report prepared for New Zealand King Salmon.
[2] Elvines D, Knight B, Berthelsen A, Fletcher L 2017. Waitata Reach salmon farm: annual monitoring report (2016–2017). Prepared for The New Zealand King Salmon Co. Ltd. Cawthron Report No. 2999.
[3] Elvines D, Knight B, Berthelsen A, Fletcher L 2017. Kopaua salmon farm: annual monitoring report (2016–2017). Prepared for The New Zealand King Salmon Co. Ltd. Cawthron Report No. 3001.

2 King shag Reporting Requirements

Duffers Reef colony is closest to Waitata Reach and Kopaua farms and monitoring will consider this colony in particular. However, data from all other colonies are needed in order to give statistically relevant information in the long term and to account for natural and/or external influences that may affect other colonies or the species as a whole.

A simulation study was conducted[4] to investigate the power of different survey designs to detect declines of a specified magnitude (between 1% - 5% per annum). A recommendation was provided for management actions and integrated in the KSMP in case such a decline was identified. To standardize the census, boat-based surveys have been replaced with aerial surveys as the primary method for detecting changes in the king shag population. A sounds wide census was recommended and adopted to be able to distinguish between single colony changes and those that affect the whole species.

If monitoring data indicate a population decline of 3% per annum or more, it needs to be established if salmon farming is causing or contributing to this decline. Additional research may also be required to help identify the cause and effect of a decline. A change to annual aerial (instead of triannual) surveys will be a first step in response to a significant decline. If further annual monitoring data indicate an ongoing decline (or any decline >5% in any one year) then annual surveys will continue and further research will be undertaken to determine if salmon farming is causing or contributing to the decline. A research plan for additional research is already being developed with participation from multiple stakeholders. After annual monitoring detects a persistent recovery in the king shag population over three consecutive years or more, aerial surveys will return to a triennial regime.

A ground control prior to the flight is required to provide a time slot for each survey. The aerial survey must be completed prior to the first departures but with enough light to provide acceptable image quality. Duffers Reef has been the biggest colony and is used as a proxy for first departures of all colonies and roosts during the king shag census.

[4] MacKenzie, D. 2014. King Shag Population Modelling and Monitoring. Client Report New Zealand King Salmon.

3 Results

For a ground-control to establish first departures, Duffers Reef was visited by boat at 31st January 2018 between 06:03AM and 09:00AM. Weather conditions were fair, with a slight overcast and wind of 10-15kn coming from a westerly direction. There was a slight increase in wind at the end of the survey, while wind direction changed to WNW. The boat was drifting at about 200m from the colony and did not cause any noticeable disturbance. A total number of 202 birds counted at Duffers Reef. At 09:00 am, the end of the visit, no departing birds have been recorded.

Accordingly, the advice was provided to fly the survey between 07:15 and 08:15am. The aerial survey was undertaken with a Cessna 402 aircraft. The UltraCam Eagle camera used a 100m lens; a large format photogrammetric camera of 260 megapixels with a CCD sensor array. The UCE camera system operates with an IGI Aerocontrol flight management system which includes an inertial measurement unit (IMU) for high precision active camera mount stabilization. The imagery captured is stitched together using monolithic stitching to generate one full frame that is color balanced.

The survey involved flying over all 12 current king shag colonies. The imagery was captured on 24 February 2018 between 07:10 - 08:36 am. Weather conditions were settled with scattered cloud and some patchy drizzle periods. Some sites were captured under full cloud. Rahuinui Island and Squadron Rock were the first colonies captured and appeared too dark. These sites were flown again at the end of the survey, slightly expanding the 08:15 am time cap.

The flight plan for the 2018 mission included a stereo capture in case a more detailed assessment was required or requested. To achieve this stereo output, the aircraft needed to be slowed down so that the frame rate had enough distance to cover each colony in each stereo frame. Two different images for each colony proved to be helpful for the assessors.

The speed of the aircraft over the sites varied from 100 to 113 knots, a low speed limit for the aircraft. Each site was captured at 0.015m (1.5cm) or 0.016m (1.6cm) Ground Surface Distance

(GSD), where each pixel covers 1.5cm of ground surface. With the 100mm lens and at 1.5cm GSD the aircraft flew at an average altitude of 300 m. The GSD of the camera would be close to the limit of the camera. The camera settings were set for low light conditions because of the low sun angle. These conditions are also not ideal for any camera to handle due to the strong contrast between light and dark. Image motion, all three rotation angles (roll, pitch and yaw) affect image quality. The UCE camera sits on a gyro-stabilized mount controlled by the AGPS/IMU system and with Time Delayed Integration (TDI) technologies in the camera, image motion can be eliminated from the imagery.

At request, a special assessment was made to explain blurring in some frames. The frame over Tawhitinui was used as an example and after the images were released a detailed assessment was made. The raw image data was re-processed from Level0 to Level3 and compared with the log reports for any errors. All reports were within specification:

- No issues with the monolithic stitching or any radiometric anomalies.
- No issues with the reports from the AGPS/IMU data and all the data presented were within specification.
- No issues with increased or decreased acceleration; pitch or roll; banking turn of the aircraft.

Due to the aircraft flying at very low speed, it is more susceptible to turbulence and a suspected slight bump at the time of exposure meant the camera did not have time to calculate the DTI causing a blur. Turbulent behavior was explained by the blur in one direction (with movement up to 12 pixels). The frame went through motion-blur removal software, significantly improving the image.

Despite the weather conditions, slow speed, an aperture at 5.6 (the amount of light the lens lets through) and a shutter speed at 1/125 (had to slow the shutter speed to let in more light) the quality of the images was sufficient for the analyses. Three assessors finalized their assessments at 26th March 2018.

KSMP also requires the aerial images to be taken at lower altitude compared to the baseline survey in February 2015. Accordingly, flight altitude in 2018 changed from 400m to 300m (Fig.1.).

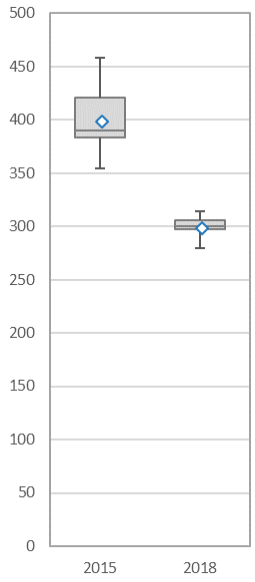

Fig. 1. Difference in flight height between 2015 and 2018

The number of King shags in 2018 was 634. This number is 200 birds (24%) less when compared with the 2015 baseline[5] (Fig. 2, Table 1). King shags at Duffers Reef, Trio Islands, White Rocks,

[5] Schuckard, R., Melville, D.S., Taylor, G. 2015. Population and breeding census of New Zealand king shag (*Leucocarbo carunculatus*). Notornis Vol 62: 209-218.

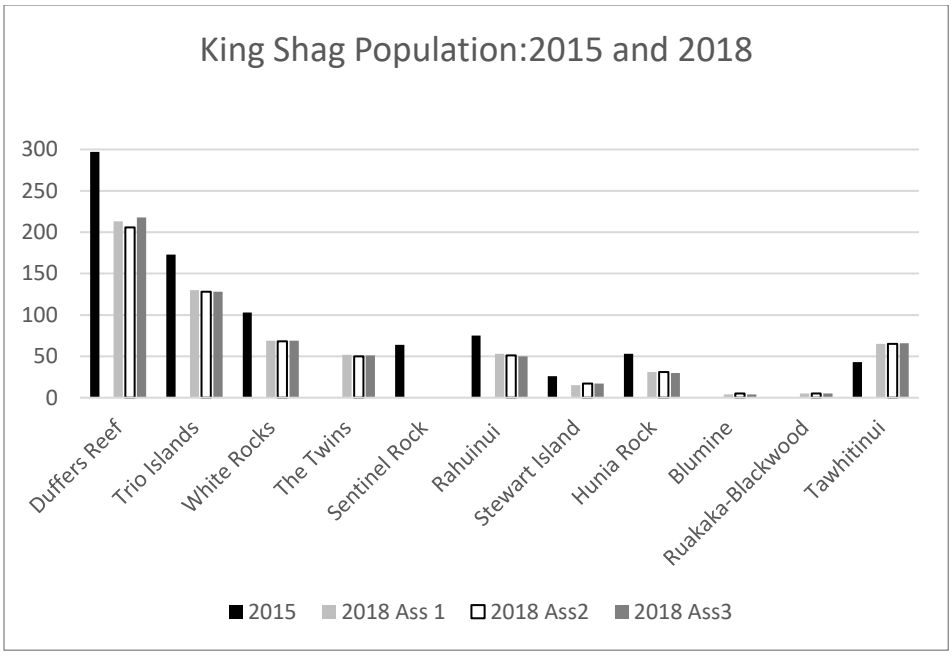

Fig. 2. Survey results of 3 assessors for 2018 survey of King shag.

	2015	2018 Ass 1	2018 Ass2	2018 Ass3	Average	Decline in %
Duffers Reef	**297**	213	206	218	**212**	**29%**
Trio Islands	**173**	130	128	128	**129**	**26%**
White Rocks	**103**	69	68	69	**69**	**33%**
The Twins	**0**	52	50	51	**51**	
Sentinel Rock	**64**	0	0	0	**0**	
Rahuinui	**75**	53	51	50	**51**	**32%**
Stewart Island	**26**	15	17	17	**16**	**37%**
Hunia Rock	**53**	31	31	30	**31**	**42%**
Blumine	**(9)***	4	5	4	**4**	
Ruakaka-Blackwood	**0**	5	5	5	**5**	
Tawhitinui	**43**	65	65	66	**65**	**+51%**
Total	**834****				**634**	
Decline 2015-2018					**200**	**24%**

Table 1. Average number of king shags assessed in the 2018 survey compared with 2015 baseline (*Blumine Island was not surveyed in February 2015 but 9 birds were at the roost in June 2015; **2015-baseline survey total of 839 birds is an omission and should have been 834).

Rahuinui, Stewart Island and Hunia Rock declined between 26-42% per colony (Table 1) (Fig. 3). No birds could be identified at Sentinel Rock. The Twins, at the entrance of the Queen Charlotte Sound, was re-occupied. Last attendance on the latter was recorded on 23 Sep 2006[6]. A small new roost was established at Ruakaka-Blackwood in the Queen Charlotte Sound. One colony, Tawhitinui, increased with 22 birds or 51% when compared with the baseline figures from 2015.

Aerial surveys were successful for the 2018 king shag survey. The images were affected by the non-optimal weather conditions but were suitable for the census purpose. Variability between the assessors through a coefficient of variation (CV) was low. The range in coefficients of variation among observers varied between 0% -13.3%. The CV for the biggest colonies with more than 50 birds was between 0.8% (White Rocks) and 3.0% (Rahuinui) (Table 2). The census and the established trend since the baseline in 2015 reflect an accurate status of king shags in 2018.

King shag Population, 2018							
	24th February 2018						
	Ass 1	Ass 2	Ass 3	MEAN	STDEV	CV	RANGE
Duffers Reef	213	206	218	212	6	2.8%	12
Trio Islands	130	128	128	129	1	0.9%	2
White Rocks	69	68	69	69	1	0.8%	1
Sentinel Rock	0	0	0	0	0		0
Rahuinui	53	51	50	51	2	3.0%	3
Stewart Island	15	17	17	16	1	7.1%	2
Hunia Rock	31	31	30	31	1	1.9%	1
Tawhitinui	65	65	66	65	1	0.9%	1
Twins	52	50	51	51	1	2.0%	2
Squadron Rock	0	0	0	0	0		0

[6] Bell, M. 2010. Numbers and distribution of New Zealand king shag (*Leucocarbo carunculatus*) colonies in the Marlborough Sounds, September-December 2006. Notornis Vol 57:33-36.

Ruakaka-Blackwood	5	5	5	5	0	0.0%	0
Blumine Island	4	5	4	4	1	13.3%	1
TOTAL	637	626	638	634	7	1.1%	12

Table 2. Coefficient of variation (CV) between the assessors.

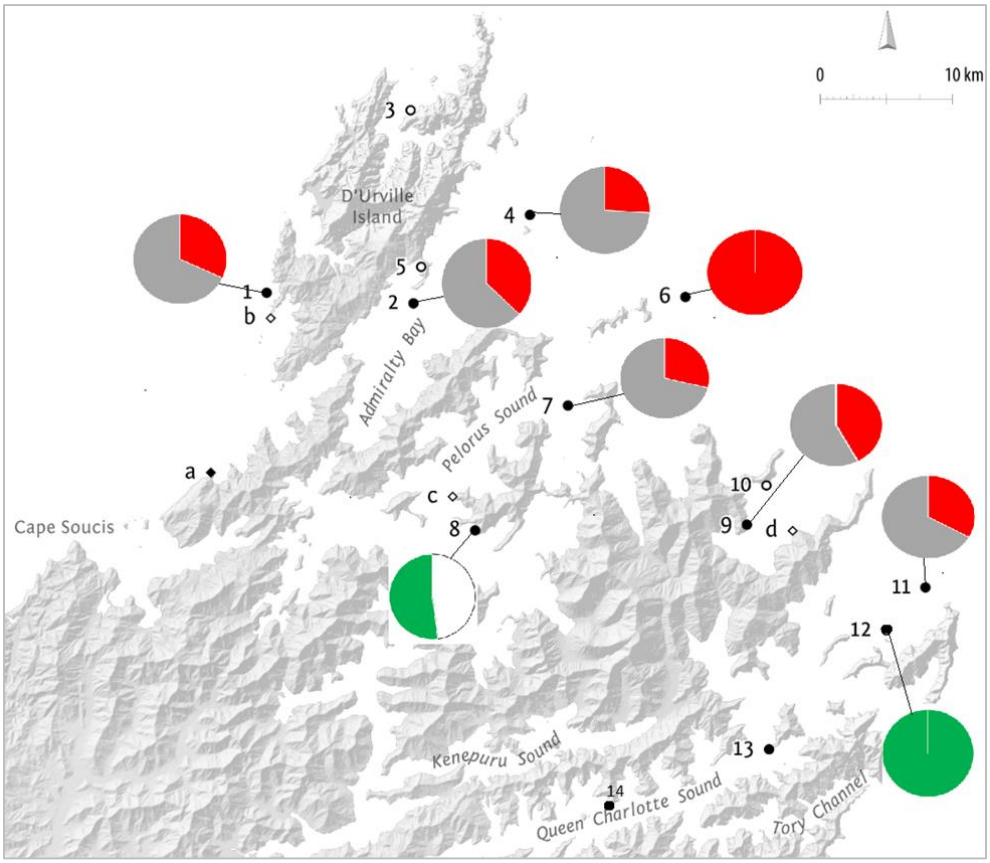

Fig. 3. Percentage of change of King shag population between 2015 (grey – 100%) and 2018 survey (red is % decline, green is % increase).

4 Population Trend

The decline of 24% of the king shag population is widespread, involving birds that feed in Tasman Bay (Rahuinui), Admiralty Bay (Trio Islands and Stewart Island), Pelorus Sound (Sentinel Rock, Duffers Reef and Tawhitinui) and Port Gore (Hunia Rock) (Fig.3). Also, White Rocks recorded a decline in numbers, but the overall number of birds feeding in the Queen Charlotte Sound went up from 112 in 2015 (103 White Rocks and 9 presumed at Blumine Island) to 129

(White Rocks, The Twins, Blumine Island and Ruakaka-Blackwood) in 2018. The total number of birds that feed in the Queen Charlotte appears to be stable or has shown a slight increase.

Based on the assumption of a stable population, a rudimentary four-stage population model was developed (MacKenzie 2014) to evaluate what range of values may be realistic for key demographic parameters. Fecundity was demonstrated to be a function of adult mortality. The annual adult mortality of king shags was likely in the approximate range of 0.10-0.15, an outcome has been referred to as the equilibrium model.

The 2015 and 2018 aerial surveys of king shag colonies and the breeding pairs that were assessed by plane in 2015, 2016 and 2017[7] have been integrated in the four-stage population model to evaluate what conditions may induce a 24% decline in the population[8].
The model used for the population trend was able to simulate the observed decline of King shags. When parameters of adult survival and fecundity were separately assessed, a 24% decrease of the population was reached when setting a lower survival probability of 96% of equilibrium or when fecundity drops to approximately 30% of equilibrium value. Alternatively, when adult mortality and fecundity are combined, the following scenarios mimicked a decline in the population as observed:

> *If equilibrium adult mortality is in the range of 0.10-0.15 (i.e., survival 0.85-0.90), then a 4% reduction in survival in combination with a 40% reduction in fecundity, could produce a 3-year decline of a similar magnitude to that observed. While if adult survival is 93% and fecundity is 90% of the equilibrium values, that could also result in a decline similar to that observed.*

A combined impact of fecundity and adult survival is the most likely scenario and if the decline is progressing like what have been observed since 2015, a '*sustained decline in the population size over the longer term'* can be expected. When such a decline of 24% as a result of lower adult survival and lower fecundity is extrapolated over a 10-year period to 2025, a loss of between

[7] Schuckard, R., Bell, M., Frost, P., Taylor, G. and Greene, T. 2018. A census of nesting pairs of the endemic New Zealand king shag (*Leucocarbo carunculatus*) in 2016 and 2017. Notornis Vol. 65: 59-66.
[8] MacKenzie, D.I. 2018. King Shag Population Modelling. Report for New Zealand King Salmon, Proteus Client Report: 2018-5. Proteus, Outram, New Zealand.

44%-68% is expected for those scenarios that resulted in a 19%-29% 3-year decline (nearest to the 24% observed). Important considerations from such an analysis are to maintain these results in a realistic scenario:

- Change in demographic parameters away from the equilibrium values was a one-time event with ongoing effects.
- Projected decline of the king shag population was assumed to be at an equilibrium in 2015.

5 Assessment and recommendations

The severity of the decline requires an immediate species management response. If however the wrong threat(s) are identified, proposed actions may fail to halt or reverse population declines. Identification of threats therefore needs to be a thorough process, subject to peer review wherever possible, involving critical analysis of the best available data. The threat analysis process also needs to be participatory, recognizing where appropriate how threats vary spatially and temporally. To the extent possible, data on the evidence that particular factors act as threats should be collated from different colonies and feeding areas[9].

Uncertainty whether the decline is caused by a one-off event or is caused by multiple key demographic parameters is partially caused by a historic underinvestment into the management of this species. If the cause of decline is multi-dimensional more uncertainty can be expected for this species compared to a one-off event. Shags require a high density of prey species where even moderate declines in prey density can have a profound impact on its viability[10]. King shag is dependent on access to deep benthic prey. The predominant prey species from a study in 2011 were: witch (*Arnoglossus scapha*), lemon sole (*Pelotretis flavilatus*) and opalfish (*Hemerocoetes sp.*)[11].

[9] IUCN/SSC. 2008. Strategic Planning for Species Conservation: A Handbook. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission.
[10] Grémillet D. and Wilson R.P. 1999. A life in the fast lane: energetics and foraging strategies of the great cormorant. Behavioral Ecology Vol.10 No.5: 516-524.
[11] Lalas, C., Schuckard, R., Melville, D.S. and Fisher, P. 2018. Prey analysis from two different feeding areas in 2011. In prep.

Knowledge about the distribution of the prey species and changes in the density of potential prey are essential components for a management response. How benthic changes through anthropogenic activities (trawling, dredging, marine farming, sediment run off, eutrophication, warmer water etc.) have influenced the distribution and accessibility of these prey species of king shag is fundamental for new additional research aimed at consolidating the species decline. Adaptability of king shag to environmental change is unknown but its effect may well be multi-dimensional. Expected environmental changes from climate change may well change both terrestrial (colony) and marine conditions. At colonies, further studies are required to determine host-parasite associations affecting biodiversity, population density and immune-competence[12]. High densities of ticks can act as vectors to cause numerous diseases and even can result in the death of seabirds. The occurrence of seabird ticks in New Zealand seabird colonies is most common in spring and summer, outside the breeding period of king shag[13]. Assessment of the scale of tick infestation (and that of other ectoparasites), could adversely affect king shag. During research that requires a landing, it is strongly recommended to integrate parasite surveys to be part of a multi scale threat assessment.

Where the decline of king shag is widespread throughout the Sounds, differences in the way of decline occur between geographically distinct areas of the sounds. In the Queen Charlotte Sound the number of birds at White Rocks also declined from 103 to 69 birds but a nearby colony at the Twins was reoccupied again by 51 birds. The total number of shags that forage in this part of the sounds is stable or may even have slightly increased.

During the month of February 2018, two cyclones passed through Central New Zealand. On the 1st February tropical cyclone Fehi approached Central New Zealand with winds in Wellington up to 140kmh combined with exceptional high tides. Between 20-21 February 2018, Cyclone Gita passed through Central New Zealand. Wind gusts at Stephen's Island of up to 144km/h were recorded on the 21st February. Rainfall in Blenheim was 83.0 mm. Before and after these events there was no indication this may have affected the number of birds at Duffers Reef. Before and after the storms 202 and 212 were counted respectively. Birds on Duffers Reef appear not to be

[12] Matinez, J., Merino, S. 2011. Host-parasite interactions under extreme climate conditions. Current Zoology 57(3): 390-405.
[13] Heath, A.C.G. 2006. Observations on Ixodes eudyptidis Maskell (Acari: Ixodidae), Ornithodoros capensis Neumann (Acari: Argasidae), and other tick parasites of sea birds in New Zealand. Systematic & Applied Acarology 11: 131–140.

affected by these two extreme weather systems. However, not all colonies may be affected in a same way by these adverse weather events due to geographical differences.

Wind data from 2018 have been more extreme when compared with wind data from the past. Between 1990 and 2001[14], at Stephens Island 4 weather events were combined with 51-60kt winds. Over the same period in Crail Bay (close to Tawhitinui colony), only one event was recorded with winds between 36-40kt. In February 2018, wind speed of almost 80kt was twice recorded from Stephens Island.

It appears that at least for Duffers Reef, adult birds can survive cyclonic winds. However, single stochastic events like adverse weather events combined with strong winds can still have a severe impact on king shag. In June 2015, 58% of the nests at White Rocks were lost due to a storm event during the breeding/chick rearing period in June 2015 (Schuckard *et al*. 2015).

The most sheltered colony occupied by the species, Tawhitinui, is the only site that has expanded over the last three years period. This colony also had a relative stable number of 12-15 nests over the period from 2015-2017 (Schuckard et al. 2018). Stable numbers at this colony were observed when the total breeding population declined and variable trends were recorded at all other colonies.

In contrast to Tawhitinui, desertion of birds from the most exposed colony, Sentinel Rock (Fig.3) is significant. Up to 78 birds have been recorded from this site in the past (14th April 1987). The birds have historically occupied the high ridge of the island, arguably the biggest exposure to winds from all directions when compared with other colonies and roosts.

If desertion of king shags from Sentinel Rock combined with an increase of birds at Tawhitinui is related to the exposure of severe winds, further research is required if alternative roosts can be found to mitigate this effect. Experiments with attracting the species in each foraging area to relative more sheltered sites may well be considered to counter measure potential weather related decline. All historic roosting sites (active and in-active) require a further assessment as

[14] Malinson, P. A. 2001. An Analysis of the Frequency of Wind Speeds by Direction for Stephens Island and Crail Bay in the Marlborough Sounds. Client report for Rob Schuckard. Meteorological Service on New Zealand.

suitable sites for potential relocation. Predator free status of potential sites may be an important parameter; however, Tawhitinui colony is connected to the mainland and is not free of predators.

Aerial population surveys will now need to be undertaken annually, starting in 2019. Uncertainty remain whether multiple key demographic parameters are responsible for the species decline. Information from annual surveys will likely allow to distinguish between a decline caused by a one-off event (no further decline is observed when adverse condition is not repeated) or the result of unknown parameters (further decline observed).

Additional research is required to explain a stable foraging population from the Queen Charlotte Sound compared with all other feeding. At this moment, a king shag research plan is being developed with input from Department of Conservation, Ministry of Primary Industries, Marlborough District Council, New Zealand King Salmon and Marine Farming Association. The topics of research that are advanced involve:

- Population monitoring
- Population dynamics
- Breeding biology
- Foraging ecology.

This approach is timely and likely essential for the future of the species. Additionally, with uncertainty about the cause of decline, the initial approach need to be as wide as possible. Parameters in water column monitoring need to be developed so to be relevant for the foraging conditions of a deep diving species like king shag. Uncertainties about the effect of the warmer sea conditions on thermal stratification and the response of HABs remain[15]. A warning system need to be in place when certain harmful algae occur that may particularly impact foraging seabirds. Impacts of toxic algae on seabirds reveal an array of responses ranging from reduced feeding activity, inability to lay eggs, and loss of motor coordination and death[16]. Bird deaths

[15] Wells, M.L., Trainer, V.L., Smayda, T. J., Karlson, B.S.O., Trick, C.G., Kudela, R.M., Ishikawa,A., Bernard,S., Wulffi, A., Anderson, D.M., Cochlan, W.P.. 2015. Harmful algal blooms and climate change: Learning from the past and present to forecast the future. Harmful Algae 49: 68–93
[16] Shumway, S.E., Allen, S.M., Boersma, P.D. 2003. Marine birds and harmful algal blooms: sporadic victims or under-reported events.? Harmful Algae 2, 1:1-17.

caused by HABs have been widely reported[17]. Some of the dinoflagellate produced foam destroys the waterproof layer of feathers that keeps seabirds dry, restricting flight and leading to hypothermia. One of these dinoflagellate *Akashiwo sanguinea* is regularly blooming in Opua Bay, Tory Channel[18] and further expansion of this algae into feeding habitats of the king shag need to be closely monitored.

6 Status of king shag

The International Union for Conservation of Nature and Natural Resources (IUCN) identified an 'unknown population trend' of king shags[19]. King shag has been assessed as 'VULNERABLE', where this *"species is facing a high risk of extinction in the wild in the medium-term future".* Due to the significant decline of the number of mature individuals of 24% in three years, the threatened status of the species needs to change. It is proposed to change the status to 'ENDANGERED' where it is considered to be facing a very high risk of extinction in the wild. This consideration is based on the following criteria:

- An observed, estimated, inferred, projected or suspected population size reduction of ≥ 50% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible.
    - When the decline of 24% as a result of lower adult survival and fecundity are extrapolated over a 10-year period to 2025, a decline between 44%-68% is expected for those scenarios that resulted in a 19%-29% 3-year decline.
- Population size is estimated to number fewer than 2500 mature individuals and a continuing decline is projected in numbers of mature individuals. The population structure has no subpopulation to contain more than 250 mature individuals and extreme fluctuations in number of mature individuals have been observed over three years.
    - The biggest colony is Duffers Reef with 218 mature individuals. A change in overall population of 24% over three years has been extreme.

[17] Lewitus, A.J., Horner, R.A., Caron, D.A., Garcia-Mendoza, E., Hickey, B.M., Hunter, M., Huppart, D.D., Kudela, R.M., Langlois, G.W., Largier, J.L., Lessard, E.J., RaLonde, R., Rensel, J.E.J., Strutton, P.G., Trainer, V.L., Tweddle, J.F. 2012. Harmful algal blooms along the North American west coast region: History, trends, causes and impacts. Harmful Algae 19:133-159

[18] L. McKenzie presentation Aquaculture review meeting 3 October 2016 (NIWA, Wellington)

[19] BirdLife International. 2016. *Phalacrocorax carunculatus*. The IUCN Red List of Threatened Species 2016: e.T22696846A95222664. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22696846A95222664.en. Downloaded on 18 May 2018.

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