

 <p>Agreement on the Conservation of Albatrosses and Petrels</p>	<p>Joint Twelfth Meeting of the Seabird Bycatch Working Group and Eighth Meeting of the Population and Conservation Status Working Group</p> <p><i>Lima, Peru, 8 August 2024</i></p> <p>Antipodean albatross multi-threat risk assessment</p> <p><i>Richard, Y.; Berkenbusch, K.; Crawford, E.; Tornquist, M.; Walker, K.; Elliott, G.; Tremblay-Boyer, L.</i></p>
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Attachment: Richard, Y.; Berkenbusch, K.; Crawford, E.; Tornquist, M.; Walker, K.; Elliott, G.; Tremblay-Boyer, L. 2024. Antipodean albatross multi-threat risk assessment. *New Zealand Aquatic Environment and Biodiversity Report No. 332*. 62 p. [Available for download here](#).

SUMMARY

The goal of this study was to investigate the causes of the Antipodean albatross decline which has undergone a considerable decline since 2005. The investigation included a literature review to collate information of the different threats to Antipodean albatross and similar species, followed by an analysis of data and modelling to assess the impacts of these threats.

The analysis included the development of a Bayesian model to estimate the principal demographic parameters of the population and how they varied over time to. The estimated parameters confirmed previous results that the population decline was a result of a decrease in survival rate, mostly of adult females, and in the breeding probability and breeding success.

Fishing threats within the New Zealand Exclusive Economic Zone were estimated for trawl, bottom and surface-longline fisheries. The estimation highlighted a peak in captures prior to 2005, and around 22 estimated captures per year across these fisheries thereafter.

The overlap in the spatial distribution between Antipodean albatross and international surface-longline fisheries showed an overall decrease around 2005, due to an overall decrease in fishing effort. Nevertheless, the overlap with fleets flagged to four states increased after 2007 and was negatively correlated with female annual survival. Varying the impact of different international fisheries individually, only one fleet could potentially explain both the change after 2006 and the female-biased impact. When the impact factor of this fleet was set to lead to around 1450 hypothetical deaths annually, the simulation showed a stabilisation of the population, and an even survival rate between both sexes, at around 97%. This relationship was not evident with other fleets.

Changes in oceanographic and climate parameters, and the overlap with plastic pollution in the Pacific Ocean did not explain the patterns in demographic parameters.

RECOMMENDATIONS

We recommend that SBWG and PaCSWG;

1. encourage and support further research on fisheries in the Tasman Sea in order to support an increased understanding of drivers of population declines of Antipodean albatross.
2. encourage and support the implementation of seabird bycatch measures to reduce the impact of fisheries on seabirds in Marine Areas Beyond National Jurisdiction (ABNJ) to address the Antipodean albatross decline.
3. note that some latent threats to the Antipodean albatross from New Zealand domestic fisheries still exist and will be addressed through continued implementation of the New Zealand NPOA-Seabirds.

Análisis de riesgo de múltiples amenazas para el *Diomedea antipodensis*

RESUMEN

El objetivo de este estudio fue investigar las causas del declive del *Diomedea antipodensis*, que ha sufrido una disminución de población considerable desde 2005. La investigación incluyó una revisión de la literatura para recopilar información sobre las diferentes amenazas para *Diomedea antipodensis* y especies similares, seguida de un análisis de datos y modelado para evaluar los impactos de esas amenazas.

El análisis incluyó el desarrollo de un modelo bayesiano para estimar los principales parámetros demográficos de la población y cómo variaron a lo largo del tiempo. Los parámetros estimados confirmaron los resultados previos de que la disminución de la población fue el resultado de una disminución en la tasa de supervivencia, principalmente de las hembras adultas, y en la probabilidad reproductiva y el éxito reproductivo.

Se estimaron las amenazas pesqueras dentro de la Zona Económica Exclusiva de Nueva Zelanda para las pesquerías de arrastre, y con palangre de superficie y de fondo. La estimación puso de relieve un pico de capturas antes de 2005 y, a partir de entonces, un estimado de 22 capturas por año en estas pesquerías.

En la superposición de la distribución espacial entre el *Diomedea antipodensis* y las pesquerías internacionales de palangre de superficie, se observa una disminución general alrededor de 2005, debido a una disminución general del esfuerzo pesquero. Sin embargo, la superposición con las flotas de cuatro estados del pabellón aumentó después de 2007 y se correlacionó negativamente con la supervivencia anual de las hembras. Variando el impacto de las diferentes pesquerías internacionales individualmente, a partir de una sola flota podría explicarse tanto el cambio después de 2006 como el impacto sesgado hacia las hembras. Cuando se estableció que el factor de impacto de esta flota provocaría alrededor de 1450 muertes hipotéticas al año, la simulación mostró una estabilización de la población y una tasa de supervivencia uniforme entre ambos sexos, en torno al 97 %. Esta relación no era evidente con otras flotas.

Los cambios en los parámetros oceanográficos y climáticos, y la superposición con la contaminación plástica en el océano Pacífico no explicaron los patrones en los parámetros demográficos.

RECOMENDACIONES

Se recomienda al GdTCS y al GdTPEC realizar las siguientes acciones:

1. Fomentar y apoyar nuevas investigaciones sobre pesquerías en el mar de Tasman con el fin de apoyar una mayor comprensión de los factores que impulsan la disminución de la población de *Diomedea antipodensis*.
2. Fomentar y apoyar la implementación de medidas de mitigación de la captura secundaria de aves marinas para reducir el impacto de las pesquerías en las aves marinas en las Zonas Marinas Situadas Fuera de la Jurisdicción Nacional (ABNJ) para hacer frente a la disminución de la población del *Diomedea antipodensis*.
3. Tomar nota de que todavía existen algunas amenazas latentes para el *Diomedea antipodensis* por parte de las pesquerías nacionales de Nueva Zelanda y que estas se abordarán mediante la implementación continua del PAN-Aves marinas de Nueva Zelanda.

Évaluation des risques multi-menaces pour le *Diomedea antipodensis*

RÉSUMÉ

L'objectif de cette étude était d'étudier les causes du déclin considérable de la population de *Diomedea antipodensis* depuis 2005. L'enquête comprenait une revue de la littérature visant à rassembler des informations sur les différentes menaces pesant sur le *Diomedea antipodensis* et d'autres espèces similaires, suivie d'une analyse des données et d'une modélisation pour évaluer les impacts de ces menaces.

L'analyse incluait l'élaboration d'un modèle bayésien pour estimer les principaux paramètres démographiques de la population et leur variation dans le temps. Les paramètres estimés ont confirmé les résultats précédents indiquant que le déclin de la population était le résultat d'une diminution du taux de survie, principalement des femelles adultes, ainsi que de la probabilité et du succès de la reproduction.

Les menaces liées à la pêche dans la zone économique exclusive de la Nouvelle-Zélande ont été estimées pour la pêche au chalut et la pêche à la palangre démersale et de surface. L'estimation a mis en évidence un pic de captures avant 2005 et environ 22 captures estimées par an dans ces pêcheries par la suite.

Le chevauchement de la répartition spatiale entre le *Diomedea antipodensis* et la pêche internationale à la palangre de surface a diminué globalement vers 2005, en raison d'une diminution générale de l'effort de pêche. Néanmoins, le chevauchement avec les flottes de quatre États de pavillon a augmenté après 2007 et était négativement corrélé à la survie annuelle des femelles. En variant l'impact des différentes pêcheries internationales

individuellement, une seule flotte pourrait expliquer à la fois le changement après 2006 et l'impact relativement plus élevé sur les femelles. Lorsque le facteur d'impact de cette flotte est fixé à environ 1 450 décès hypothétiques par an, la simulation indique une stabilisation de la population et un taux de survie égal entre les deux sexes, autour de 97 %. Cette relation n'était pas évidente avec les autres flottes.

Les changements dans les paramètres océanographiques et climatiques, ainsi que le chevauchement avec la pollution plastique dans l'océan Pacifique n'expliquent pas les tendances des paramètres démographiques.

RECOMMANDATIONS

Nous recommandons que le GTCA et le GTSPC ;

1. encouragent et soutiennent la poursuite de la recherche sur les pêcheries dans la mer de Tasman afin de mieux comprendre les facteurs du déclin des populations de *Diomedea antipodensis*.
2. encouragent et soutiennent la mise en œuvre de mesures sur la capture accessoire d'oiseaux de mer pour réduire l'impact de la pêche sur ces oiseaux dans les zones marines situées au-delà de la juridiction nationale afin de lutter contre le déclin du *Diomedea antipodensis*.
3. notent que certaines menaces latentes pesant sur le *Diomedea antipodensis* liées aux pêches nationales néo-zélandaises existent toujours et seront traitées par la poursuite de la mise en œuvre du Plan d'action national néo-zélandais sur les oiseaux de mer.

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.H\ZRUGV IRU HDFK WKUHDW ZHUH VHDFKHG LQGLYLGXDOO\ RU I
GHEULV LQFOXGHG VHDELUG SODVLF ~~GLHREULG B D EUDR FURVOD~~
LQJHVW 6RXWKHUQ +HPLVSKHUH 1HZ =HDODQG %URDGO\ GHII
QXPEHU RI UHVXOWV ZHUH QDUURZHG GRZQ E\ DGGLQJ RU H\FKD
ZDV UHSODFHG E\ 3URFHOODULLIRUP' RU 3DOEDWURVV'

,Q DGGLWLRQ WR WKH OLWHUDWXUH UHYLHZ LQIRUPDWLRQ IURP V
,QWHUQDWLRQDO ZHUH TXHULHG IRU HYLGHQFH RI SODVLF LQJ

:KHUH VSDWLDO LQIRUPDWLRQ ZDV DYDLODEOH WKH VSDWLDO H
WKH VXEVHTXHQW DQDO\VLV DQG YLVXDOLVDWLRQ

\$QWLSRGHDQ DOEDWURVV SRSXODWLRQ PRGHO

7KH \$QWLSRGHDQ DOEDWURVV FRORQ\ DW \$QWLSRGHV ,VODQG KDV
DQQXDOO\ VLQFH H[FHSWLQ VHH PRVW UHFHQW VXUYH\ UH
HW DO

7KH VXUYH\ GDWD ZHUH XVHG LQ SUHYLRXV SRSXODWLRQ PRGHO
GHYHORSHG E\ 5LFKDUG 7KLV PRGHO ZDV XSGDWHG IRU WKH
IURP WKH SHULRG EHWZHHQ DQG

7KH VWUXFWXUH RI WKH XSGDWHG PRGHO ZDV VLPLODU WR WKH SRSXODWLRQ
PRGHOOLQJ WKH WUDQVLWLRQ EHWZHHQ ODWHQW VWDWHV RI VX
VWDWHV UHFRUGHG LQ WKH ILHOG 7KHUH ZHUH QLQH ODWHQW VW
WKH VWXG\ DUHD DGXOWV EUHHGLQJ RXWVLGH WKH VWXG\ DUHD
QRQ EUHHGLQJ RXWVLGH WKH VWXG\ DUHD SUH EUHHGHUV LQVL
DUHD MXYHQLOHV LQVLGH WKH VWXG\ DUHD MXYHQLOHV RXWVLGH
SUREDELWLHV EHWZHHQ VXFFHVVLYH VWDWHV ZHUH VSHFLILH
ZHUH QLQH REVHUYHG VWDWHV DVVLJQH IURP WKH VWDWH RI W
LQVLGH WKH VWXG\ DUHD DGXOWV QRW EUHHGLQJ LQVLGH WKH V
RU QRW SUH EUHHGHU LQVLGH WKH VWXG\ DUHD SUH EUHHGHU
DUHD MXYHQLOH RXWVLGH WKH VWXG\ DUHD GHDGELUGV DQG Q
GHSHQGHQW RQ WKH ODWHQW VWDWH DQG WKH GHWHFWLRQ SURE

, Q WKH PRGHO MXYHQLOHV VWDWU DW WKH FRORQ\ WKHQ VSHQG
FRORQ\ DW WKH DJH RI ILUVW UHWXUQ ZKHQ WKH\ EHFRPH SUH EU
DJH RI ILUVW EUHHGLQJ ZKHQ WKH\ EHFRPH DGXOWV WKH\ EHFRP
\ HDU GHSHQGLQJ RQ WKH RXWFRPH RI WKHLU EUHHGLQJ DWWHPS
ZHUH SUHYLRXVO\ XQVXFFHVVIXO EUHHGHUV \$W DQ\ DQQXDO WLF
FODVV MXYHQLOH SUH EUHHGHU DGXOW IHPDOH RU DGXOW PDC

7KH PRGHO XVHG SUHYLRXVO\ E\ 5LFKDUG ZDV LPSURYHG LQ

‡ WKH SUREDELWLW\ RI EUHHGLQJ YDULHG DPRQJ\ HDUV DV LW ZD
‡ WKH DJH DW ILUVW UHWXUQ WR WKH FRORQ\ DQG DJH DW ILUVW
LQFUHDVLRQ OLQH DUO\ ZLWK DJH IURP JHUR DW D PLQLXP DJH
SUHYLRXV PRGHO WKLV FKDQJH FRQVWUDLQH WKH LQGLYLGD
DFHUWDLQ DJH OHDGLQJ WR D SRUWLRQ RI WKH SRSXODWLRQ W
‡ WKH GHWHFWLRQ SUREDELWLW\ RI SUH EUHHGHUV ZDV DOORZH
ODWHU WKDQ XVXDO WR DFRXQW IRU SUH EUHHGHUV WHQGGLQ
DGXOWV LQ DGGLWLRQ WKH\ PD\ EH VHHQ PRUH IUHTXHQWO\ GX
‡ WKH PRGHO FRGH ZDV UHIDFWRUHG VR WKDW WKH FDOFXODWLRQ
LQWR 5 WR UXQ VLPXODWLRQV PRUH TXLFNO\ DQG ZLWK WKH DVV
WR WKDW LQ WKH PRGHO PLQLPLVLQJ WKH FKDQFH RI HUURU

7KH 6WDQ PRGHO ZDV ILWWHG FURVWV WPH SDVND JH J FPGV
ODUNRY FKDLQ 0RQWH & DUOR 0&0& DOJRULWKPV)RXU 0&0& FKDL
DIWHU D ZDUP XS SHULRG RI LWHUDWLRQV

,PSDFW RI 1HZ =HDODQG ILVKHULHV

7KH QXPEHU RI DQQXDO IDWDOLWLHV RI \$QWLSRGHDQ DOEDWURV
GDWD RQ REVHUYHG FDSWXUHV DQG REVHUYHG ILVKLQJ HIIRUW F
UHSRUWHG HIIRUW DQG DW VHD ELUG GLVWULEXWLRQ PDSV 7KH
WR DQG DOO ILVKLQJ LQ WUDZO ERWRP ORQJOLQH DQG

%HFDXVH \$QWLSRGHDQ DOEDWURVV DUH GLILFXOW WR GLVWLQ
LQFOXGHG FDSWXUHV DQG GLVWULEXWLRQ DOEDWURVV
FDSWXUHV RI ZDQGHULQJ DOEDWURVV

7KH DW VHD GLVWULEXWLRQV IRU WKH WKUHH VSHFLHV ZHUH GH
DVVHVPHQW DW D GHJUHH UHVROXWLRQ IURP WUDFNLQJ GDWD
GLVWULEXWLRQ IRU DOO ZDQGHULQJ DOEDWURVV VSHFLHV ZDV R
WKUHH VSHFLHV

&DSWXUHV DQG ILVKLQJ HIIRUW ZHUH JULGGHG WR PDWFK WKH GL
DQG WKH ILVKLQJ HIIRUW ZDV FDWHJRULVHG LQWR IRXU JURXS V D

\$ %D\HVLQ PRGHO ZDV GHYHORSHG WR HVWLPDWH WKH YXOQHU
LQ ZKLFK WKH QXPEHU RI REVHUYHG FDSWXUHV LQ HDFK JULG FH
GLVWULEXWLRQ 7KH PHDQ QXPEHU RI FDSWXUHV ZDV PRGHOHG
ZHUH UHFRUGHG DW WKH VSHFLHV OHYHO RU DW WKH JHQXV OHYH
OHYHO HTXDWLRQ WKH ~~IRU D QXPEHU RI EDVH~~ SURGXFW
WKH RYHUODS EHWZHHQ WKH ILV\K\H\ JWRN SDQG XFKHRM SHULGHG
HIIRUW WKH YXOQHUDELOLW\ RI WKH ~~IRU D QXPEHU RI EDVH~~ SURGXFW
LGHQWLILHG DW WKH VSHFLHV OHYHO LQ FDSWXUHV L H FDSW
JHQHULF ZDQGHULQJ DOEDWURVV HTXDWLRQ WKH ~~IRU D QXPEHU RI EDVH~~ SURGXFW
WKH SUREDELOLW\ RI D FDSWXUHV ~~IRU D QXPEHU RI EDVH~~ SURGXFW
VSHFLHV RI WKH SURGXFW RI WKH RYHUODS DQG YXOQHUDELOLW\

$$.v_f = 3RLV(SRQ)_i$$
$$8_j = 3RLV(VRQ)_i$$

7KH PRGHO ZDV ILWWHG WR WKH FDSWXUH DQG HIIRUW GDWD EHWZ
UHOLDEOH EXW SUHGLFWLRQV ZHUH PDGH XVLQJ WKH UHSRUWLQ

7KH PRGHO ZDV ZULWWHQ XVLQJ WKH 6WDQ ODQJXDJH &DUSHQW
XVLQJ WKH SDFNDJH UVWDQ 6WDQ 'HYHORSPHQW 7HDP)
ZHUH UXQ RYHU LWHUDWLRQV ZLWK D ZDUP XS SHULRG RI
\$SSHQGL\$

)URP WKH ILWWHG PRGHO WKH WRWDO QXPEHU RI REVHUYDEOH F
WKHQ SUHGLFWHG E\ GUDZLQJ UDQGRPO\ IURP D 3RLVVRQ GLVWUL
YXOQHULF ~~IRU D QXPEHU RI EDVH~~ SURGXFW LQ WKH PRGHO DQG E\ WKH WRWDO RYHU

,PSDFW RILQWHUQDWLRQDO ILVKHULHV

6XLWDEOHGDWDRQREVVHUYHGFDSWXUHV DQG REVVHUYHG ILVKLQJ
IRUWKLVDVVHVVPHQW VRWKDW DQHVWLPDWLRQRIFDSWXUHV L
WKHSUHVHQWVWXG\LQFOXGHG DQH[DPLQDWLRQRIRWKHYDULDE
FODVVHV ZKLFK ZDV UHODWHG WRWKHYDULDELOLW\RIGHPRJUD

6SDWLDOOD\HUV RILQWHUQDWLRQDO VXUIDFH ORQJOLQH ILVKL
5HJLRQDO)LVKHULHV ODQDJPHQW 2UJDQLVDWLRQV 5)02V JUL
DQG 7KHVHJULGV ZHUHUH VDP SOHG WRD GHJUHHUHVROXW
\$QWLSRGHDQDOEDWURVV GLVWULEXWLRQOD\HUVGHULYHGE\5L
ZDVLUVVFRQYHUWHG WRGHQVLWLHV WDNLQJLQWRDFFRXQWV
WRKRRNVDIWHUHU SURMHFWLRQ

7KH\$QWLSRGHDQDOEDWURVV GLVWULEXWLRQPRGHOOHQJE\5LF
OD\HUIRUHDFKFODVV MXYHQLOH SUH EUHHGHU QRQ EUHHGLQ
DQGIRUHDFKVH[PDOHDQGIHPDOH +HUHDIWHU WKHFRPELQDV
IRUVLPSOLFLW\

7KHWRWDO RYHUODS EHWZHHQ HDFK SRSXODWLRQ FODVV DQG
VXPPLQJWKHSURGXFWRIWKHELUGGHQVLW\DQGWKHILVKLQJH
HQWLUHJULG 7KH ELUG GHQVLWLHV ZHUHILUVVQRUPDOLVHG V
GHQVLW\DQGFHOODUHDZDVRQH

7KHFRUHHODWLRQ EHWZHHQ RYHUODS DQG \HDOO\ HVWLPDWHV
JUDSKLFDQO\DQGE\FDOFXODWLQJWKH3HDUVRQIVFRUHHODW
ZLWKRXW WKH %RQIHUURQLFRUHFWRQIDFWRU 'XQQ IR
SRSXODWLRQFODVV

&RPSDULVRQRIFDWFKDELOLWLHV IURPVXUYLYDOUDWHV D

\$QRYHO DSSURDFK ZDV GHYHORSHG WRDVVHVZKHWKHU FKDQJ
EHWZHHQWKHSUH DQGSRVW SHULRGV ZHUHVXIILFLHQW W
VH[HVDQGEHWZHHQSHULRGV 7KHDSSURDFKZDVDSSOLHG WRH
IDFWRUV WREHFRQVWDQW

7KHWRWDODQXPDIWKHWRWDOEHWZHHQDQGEH H[SUHVHVG DVWKHVXP
LQWKHJUDSKLQWKHDQXDORPUPDQDORWKHFDXVHV LQFOXGLQJ
KXPDQ UHODWHG FDXVHV

$$P = P_j + P_{\bar{j}}$$

\$VVXPLQJWKDWWKHQDWXUDO PRUWDOLW\DQGWKHPRUWDOLW
LVWKHVDPHEHWZHHQPDOHV DQGIHPDOHV WKHQ

$$P \quad P_j = P \quad P_j :$$

%HFDXVH WKHDQXDOPRUWDOLW\UDWH BVDRQHVPKQPRUWKEDQW
ILVKLW\WKHSURGXFWJRLQDWKFKIDFKHLDQGDQGWKHSHU FDSLWDRY
DQGWKH2LVKDWLRQ EHFRRPHV

$$(\quad 3) \quad T_j \quad 2_j = (\quad 3) \quad T_j \quad 2_j :$$

\$VVXPLQJ WKDW WKH FDWFKDELOLW\ RT, P D O H V D Q G I H P D O H V L V W

$$T_J = \frac{3}{2_J} \frac{3}{2_J} :$$

)ROORZLQJ D V L P L O D U U H D V R Q L Q J X V L Q J W K H G L I I H U H Q F H L Q V X U Y L Y D O U D W H V E H W Z H H Q P D O H V D Q G
D Q G D V V X P L Q J W K D W F D W F K D E L O L W \ Q D W X U D O P R U W D O L W \ D Q G
S H U L R G T Y I R U H D F K V H [L V

$$T_J = \frac{3_{S U H} 3_{S R V, W}}{2_{J S U H} 2_{J S R V W}}$$

8 V L Q J W K H G L I I H U H Q F H L Q V X U Y L Y D O U D W H V E H W Z H H Q P D O H V D Q G
W K H W Z R S H U L R G V I R U H D F K V H [D Q G W K H L U D V V R F L D W H G R Y H U O I
F D W F K D E L O L W \ W K H L F K B Q J H L Q W K H J L W H W O D S Z L W K \$ Q W L S R G H D Q D
V X U Y L Y D O U D W H V W K H Q W K H W K U H H H V W L P D W H V R I F D W F K D E L O L
H V W L P D W H V X V L Q J W K L V D S S U R D F K Z H U H F D O F X O D W H G I R U H D F K

7 K H S O D X V L E L O L W \ R I W K H F D W F K D E L O L W \ H V W L P D W H V Z D V D V V H Y
I U R P 1 H Z = H D O D Q G I L V K H U L H V 7 K H O D W W H U Z D V H V W L P D W H G G L U
W K H 1 H Z = H D O D Q G I O H H W D Q G L W V R Y H U O D S Z L W K \$ Q W L S R G H D Q D
I L V K H U \ L V W K H S U R G X F L W R I R W H U F O D S Z K D E K W K G W R W W D O Q X P E H U R I
S R S X O D W K H Q = 21 7 K H Q X P E H U R I R E V H U Y D E O H F D S W X U H V H V W L P D
X Q G H U H V W L P D W H W K H W R W D O Q X P E H U R I I D W D O L W L H V E H F D X V H
R E V H U Y D W L R Q V L Q V X U I D F H O R Q J O L Q H I L V K H U L H V L W Z D V H V W L
R Q E R D U G R I I L V K L Q J Y H V V H O V % U R W K H U V H W D O 7 K H H V W L
= H D O D Q G V X U I D F H O R Q J O L Q H I L V K H U L H V Z D V W K H U H I R U H G R X E

, P S D F W R I F O L P D W H

8 V L Q J W K H E L U G G H Q V L W \ O D \ H U V E \ S R S X O D W L R Q F O D V V I U R P 5 L F
F O L P D W L F Y D U L D E O H V Z D V F D O F X O D W H G I R U H D F K \ H D U D Q G S R S X
F R X O G H [S O D L Q W K H Y D U L D E L O L W \ L Q G H P R J U D S K L F S D U D P H W H U

7 K H V H F O L P D W H Y D U L D E O H V Z H U H L Q F O X G H G L Q W K H D Q D O \ V L V
\$ W P R V S K H U L F \$ G P L Q L X W L Q D W K H Q = 21 \$ S D S D S P E H U O D L Q

‡ V H D V X U I D F H W H P S H U D W X U H 6 6 7 D Q G D Q R P D O \ P R
³ 1 2 \$ \$ B ' + : B P R Q W K O \ B / R Q
‡ Z L Q G V S H H G D Q G G L U H F W L R Q P R Q W K O \ (5 ' ' \$ 3 G D W D V H W ³ H U G O
‡ D L U W H P S H U D W X U H V H D O H Y H O S U H V V X U H V X U I D F H / L I W H G , Q C
Y H U W L F D O P R W L R Q U H O D W L Y H K X P L G L W \ G D L O \ (5 ' ' \$ 3 G D W D V

7 K H F O L P D W L F D Q G D W P R V S K H U L F O D \ H U V Z H U H F R Q Y H U W H G W R J
W K H V D P H H [W H Q W D Q G U H V R O X W L R Q D V W K H E L U G G H Q V L W \ O D \ H

7 K H D Q Q X D O Z H L J K W H G D Y H U D Z B R W K H Q L P D O F L X F O D W H L G E O S I R S X O D
W K H V X P R Y H U D O O J U L G F H O O V R I W K H S B R G O F W R D O K H F O L P D W L
W K H F O D W L Y L G H G E \ W K H W R W D O R I Q X P E H U R I E L U G V L Q W K H F O D

$$P = \frac{P \cdot \cdot \cdot G}{\cdot \cdot \cdot G}$$

KWWSV FRDVWZDWFK SIHJ QRDD JRY HUGGDS

,Q DGGLWLRQ WKH PRQWKO\ 6RXWKHUQ 2VFLOODWLRQ ,QGH[62
SHULRGV RI (O 1LxR RU /D 1LxD SKDVHV DQG ZDV REWDLQHG IURP 6

7KH FRUUHODWLRQ EHWZHHQ FOLPDWLF YDULDEOHV DQG GHPRJ
JUDSKLFDQ\ DQG E\ FDOFXODWLQJ WKH 3HDUVRQ¶V FRUUHODW
FRUUHFWLRQ IDFWRU 'XQQ 7KH GHPRJUDSKLF SDUDPHWHUV
UDWHIRU HDFK RI WKH WHQ SRSXODWLRQ FODVVHV EUHHGLQJ SU

0DQDJPHQW VFHQDULRV

7R H[SORUH WKH LPSDFW RI GLIIHUHQW VFHQDULRV RQ WKH \$QWLS
DOVR LQFOXGHG WKH GHYHORSPHQW RIDQLQWHUDFWLYH DSSOL

7KH DSSOLFDWLRQ DOORZV XVHUV WR VLPXODWH WKH SRWHQWLD
EHLPSRUWHG IURP DYHFWRU RU UDVWHUILOH RUGUDZQ PDQXDC
UDVWHULVHG DXWRPDWLFDOO\ WR WKH H[WHQW SURMHFWLRQ D
7KH XVHFDQ VSHFLI\ WKH ELUG FODVVHV DQG VH[HV WKDW PD\ E
YDOXH ZKLFK UHSUHVHQWV WKH SUREDELOLW\ WKDW DIDWDOLW

2QFH WKH VSDWLDO WKUHDW LV GHILQHG ZLWK WKH LPSDFWHG FC
WKH GLVWULEXWLRQ IURP 5LFKDUGHW DO RI WKH LPSDFWH
PXOWLSO\LQJ WKHELUG GHQVLW\ DQG WKH WKUHDW GHQVLW\LQH
YDOXH WR GHULYH WKH QXPEHU RIDWDOLWLHV VSDWLDOO\ 7KH
LV WKHQ UHSRUWHG

)RU WKUHDWV WKDW KDYH QR VSDWLDO H[WHQW RUIRU ZKLFK VS
EH GHILQHG DV DQ RYHUOO QXPEHU RIDWDOLWLHV RUDVDFKD
GLUHFWO\ VXUYLYDO UDWH RIMXYHQLOHV SUH EUHHGHUV DGX
EUHHGLQJ VXFFHV

,Q WKH VFHQDULR H[SORUHU ERWK VSDWLDO RU QRQ VSDWLDO W
)RU SRWHQWLDO WKUHDWV WKH LPSDFW LV DGGHG DQG GHFUHD
SRWHQWLDO WKUHDW VKRXOG EH FKRVLQJ ZKHQ DVVHVVLQJ WKH
QHZ SROOXWLRQ VRXUFH)RU H[LVWLQJ WKUHDWV UHPRYLQJ WK
DQLQFUHDVHLQ WKHYDOXHVRIGHPRJUDSKLF SDUDPHWHUV 7KL
D WKUHDW RULWV HIIHFW RQ WKH FXUUHQW SRSXODWLRQ G\QDPL
RU WR DVVHVVLIDJLYHQ LPSDFW LV UHDOLVWLF

:KHQ WKH LPSDFW RID WKUHDW LV GHILQHG DV D QXPEHU RIDW
VXUYLYDO UDWH RI WKH LPSDFWHG FODVVHV LV FDOFXODWHG E\ F
UDWH 7KLV PRUWDOLW\ UDWH LV WKH UDWR RIDWDOLWLHV WR W
LQLWLDO JOREDO SRSXODWLRQ

)RU WKH LQLWLDO SRSXODWLRQ LQ WKH VLPXODWLRQV WKH VWU
VLPXODWLQJ HDFK LQGLYLGXDO RYHU WLPXVLQJ WKH WUDQVLV
IURP WKHLU ILUVV VLJKWLQJ DIWHU WR 7KH SUHGLFWHG V
WKHLU DFWXDO VWDWXV DV UHFRUGHG LQ WKH ILHOG ZKHQ LW ZD
DQG VH[ZDV WKHQ VFDOHG WR WKH JOREDO SRSXODWLRQ E\ GLYL
SRSXODWLRQ WKDW LV ZLWKLQ WKH VWXG\ DUHD

0XOWLSOH WKUHDWV FDQ EH FRQVLGHUHG LQ DVLQJOH VFHQDULR
FDOFXODWH WKH DVVRFLDWHG FKDQJHLQ GHPRJUDSKLF SDUDPH

KWWSV VWDWLWLVFVQ] VKLQ\DSSV LR HQVRBRFW

\$QWLSRGHDQ DOEDWURVV PXOWL WKUHDW ULVN DVVHVVPHQW

)LJXUH 6FUHHQVKRW RIWKH RQOLQH DSSOLFDWLRQ WR VLPXODWH VFH
\$QWLSRGHDQ DOEDWURVV

)LVKHULHV 1HZ =HDODQG

\$QWLSRGHDQ DOEDWURVV PXOWL

7KH FRQVHTXHQFH RI HDFK VFHQDULR RQ WKH SRSXODWLRQ G\QDF
RYHU \H DU V WKH GHIDXOW YDOXH

7KH LQWHUDFWLYH WRRO SURYLGHV VHYHUDO SUH ORDGHG VSDW

‡ DQQXDO ILVKLQJ HIIRUW IRU WUDZO ERWWRP ORQJOLQH VXUID
WKDW WRJHWKHU FRQWULEXWHG RYHU RI WKH WRWDO RYHUOD

E

‡ VSDWLDO GLVWULEXWLRQ RI RFHDQ SODVWLFV IURP (ULNVHQ HV

‡ VHD VXUIDFH WHP SHUDWXUH DQRPDO\ IRU WKH SHULRGV ±

±

5(68/76

/LWHUDWXUH UHYLHZ WKUHDWV WR \$QWLSRGHDQ DOEDWURV

\$QWLSRGHDQ DOEDWURVV DUH H[SRVHG WR D UDQJH RI GLYHUVH
VHYHUH ZHDWKHU HYHQWV SODVWLF DQG RWKHU SROOXWLRQ H
7KH VSDWLDO H[WHQW RI WKHVH WKUHDWV PD\ EH ORFDOLVHG H
KDYH DQ H[WHQVLYH VSDWLDO H[WHQW H J LPSDFWLQJ WKH IRU

6RPH RI WKH WKUHDWV PD\ KDYH VLPLODU UHSHUFXVVLRQV IRU H[
LQJHVWLRQ RI SODVWLF GHEULV SUHYHQWLQJ WKH XSWDNH RI IR
ILVKLQJ H J *Up PLOOHW HW DO RU E\FOLPDWH FKDQJH W
RULQIRUDJLQJ HIILFLHQF\ H J &DUSHQWHU .OLQJHW DO
WKUHDWV PD\ EH VHTXHQLDO RU DGGLWLYH H[DFHUEDWLQJ WK
HW DO

)LVKHULHV

7KUHDWV SRVHG E\ ILVKHULHV LQFOXGH SRSXODWLRQ LPSDFWV IL
LQWHQWLRQDO WDNH RU NLOOLQJ DW VHD \$OIDUR 6KLJXHWR HW

5HFRUGV RI \$QWLSRGHDQ DOEDWURVV E\FDWFK LQ 1HZ =HDODQG Z
ERDUG FRPPHUFLDO ILVKLQJ YHVVOV)RU H[DP SOH UHFHQW REY
RI ILYH \$QWLSRGHDQ DOEDWURVV IRXU PRUWDOLWLHV LQ VXUID
DQG WKH VDPH QXPEHU RI FDSWXUHV ILYH PRUWDOLWLHV LQ ±
2EVHUYHG FDSWXUHV LQ WUDZO ILVKHULHV DSSHU WR EH UDUH
DQG ±

\$QDO\HV RI WUDFNLQJ GDWD DQG VSDWLDO ILVKLQJ LQIRUPDWL
E\FDWFK WKUHDW SRVHG E\ SHODJLF ORQJOLQH ILVKHULHV LQ WK
%RVH 'HEVNL ,PSDFWV IURP RWKHU ILVKHULHV ZHUH F
ODFN RI RYHUODS ERWWRP ORQJOLQLQJ MLJJLQJ RUIHZ REVHU
=HDODQG ZDWHUV

5HFHQW PRGHOOHQJ RI \$QWLSRGHDQ DOEDWURVV GLVWULEXWLR
DQG VXUIDFH ORQJOLQH IOHHWV SDUWLFXODUO\LQ WKH 7DVPDQ
RIIWKH &KLOHDQ FRDVW 5LFKDUG HW DO

7DEOH 2YHUYLHZ RINH\ ULVNV DQG DVVRFLDWHG WKUHDWV WR \$QWLSRGHDQ DOEDWURVV FRQVLGHUHG LQ

5LVN 7KUHDW 4XDQWLWDWLYH VSDWLDO GDWD 5HIHUHQFH

)LVKHULHV %\FDWFK PRUWDOLW\ 9HVVHO OR% BWH R QH VREL VHUY HDQGD SLW KD H G HWUDON

GLVWULEXWLRQ PRGHOOHQJ

,QWHQWLRQDO WDNH NLOOLQJDW VHD 'DWD IRU RWKHU SURFHOODULLIRUPHV VSHFL

5HVRXUFH FRPSHWLWLRQ QXWULWLRQDO VWUHVV 'DWD IRU RWKHU VSHFLHV

&OLPDWH FKDQJH \$YDLODELOLW\ 6RPHLQVWIDEXWIRWOKHU VSHFLHV 4XHLUyV HW DO

IRUDJLQJ EHKDYLRXU ERG\ FRQGLWLRQ DQG 3LQDXG :HLPHUVNLUFK

UHSURGXFWRQ

6HYHUH ZHDWKHU HYHQW\W DRIDJRLQKHKIDVSHFDWV :ROIDDUGW HW DO 9H

LPSDFWV QHVWLQJ VXFFHV

3ROOXWLRQ 3ODVWLF GHEULVDWPRIRWDROLKHU VSHFLHV VRDMIGHDWDMDO \$QWLSRGHDQ HW DO

FRQGLWLRQ EUHHGLQJ VDGEBWVRVV

2LOVSLOOV PRUWDOLW\ DWSDRWWRKHHVSHFLHV LQFOXGLQJ LQ 1= ZDWHUV /HLJKWRQ

FRQGLWLRQ IRUDJLQJ

&RQWDPLQDQWV H J PHD\DU\IRU RWKHU VSHFLHV *RQWRH QW DQ VHDUF&KHUHO HW DO

'HSDUWPHQW RI &RQVHUYDWLRQ

'LVHVDVH \$YLDQ LQIOXHQJD DYD\Q FRURDWKBUVR\SHW DQVW\ /HRWWD HW DO -DHJ

UHGXFHG FRQGLWLRQ

2WKHU ILVKHU\ LPSDFWV PD\ DULVH IURP WKH LQWHQWLRQDO W
FRPSHWLWLRQ DIIHFWLQJ WKH DYDLODELOLW\ RI SUH\ 0RUWDOL
WDNH RI DOEDWURVVHV KDV EHHQ UHSRUWHG ~~3 KRWH RDKMULDSHFUR~~
RII WKH FRDVW RI 3HUX \$OIDUR 6KLJXHWR HW DO 6LPLODU
VHYHUH LQMXULHV KDV DOVR EHHQ UHSRUWHG IRU HLJKW VSHF
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JHQHUDOO\ ODFNLQJ LQFOXGLQJ IRU \$QWLSRGHDQ DOEDWURVV

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YDULHW\ RI RFHDQLF VTXLG DQG RFWRSRG VSHFLHV LQ DGGLWLR
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UHSRFXVVRQV IURP UHGXFHG SUH\ DYDLODELOLW\ DQG ORZH
FRQGLWLRQ DQG QXWULWLRQDO VWUHVV ZKLFK LQWXUQ PD\ OHD

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DOEDWURVV 1HYHUWKHOHV SUHYLRXV PRGHOOHQJ RI \$QWLSR
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GHFOLQH (GZDUGV HW DO

&OLPDWH FKDQJH

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SURGXFWLYLW\ RI HFRV\ VWHPV ZLWK UHSRFXVVRQV IRU UHVL
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DUH DPRQJ WKH ZRUOG¶V UHJLRQV PRVW LPSDFWHG E\ FOLPDWH
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WKH UHJLRQ &DFFDYR HW DO

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RI WKH GLHW RI \$QWLSRGHDQ DQG *LEVRQ¶V DOEDWURVVHV FOLP
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WKH LQIOXHQFH RI RFHDQRJUDSKLF FRQGLWLRQV RQ EUHHGLQJ
DYDLODELOLW\ ELUGV UHWXUQHG WR WKHLU QHVW ZLWK ORZHU
ZHUH PRUH OLNHO\ WR FHDVH EUHHGLQJ 3LQDXG :HLPHUVNLUFK

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VHYHULW\RI ZHDWKHU HYHQWV FDXVHG E\FOLPDWH FKDQJH KDYH
FRORQLHV :ROIDDUGW HW DO 9HQWXUD HW DO (IHFV
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SRVVLEOH WKDW RWKHU LPSDFWV IURP VHYHUH ZHDWKHU HYHQW

3ODVWLF SROOXWLRQ

3ODVWLF SROOXWLRQ KDV EHFRPH D VLJQLILFDQW FRQVHUYDWL
DFFXPXODWLRQ RI LQFUHDVLQJ DPRXQWV RI SODVWLF GHEULV SR
HW DO *DOO 7KRPSVRQ)RU VHDELUGV ULNVV DVVRF
HQWDQJOHPHQW DQG LQJHVWLRQ RI SDUWLFOHV OHDGLQJ WR GL
ILOOLQJ RU EORFNDJH RI GLJHVWLYH RUJDQV UHGXFLQJ WKH DEL

7KH ODWWHU LV DOVR UHOHYDQW IRU EUHHGLQJ ELUGV WKDW UHJ
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WKDW DUH SDUW RI WKH SURGXFWLRQ RI SODVWLF L H DGGLWLY
PDULQH ZDWHUV \$UWKXU HW DO <DPDVKLWD HW DO

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RQ WKH &RQVHUYDWLRQ RI \$OEDWURVVHV DQG 3HWUHOV \$JUHH
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ZDQGHULQJ IRUHQHURVH KEDQ HW DO DQG EROXVHV IURP \$Q
DOEDWURVVHV ;DYLHU HW DO

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NLOOHG LQ 1HZ =HDODQG ILVKHULHV 5REHUWVRQ HW DO

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VKLS 09 5HQD QHDU 7DXUDQJD LQ 2FWREHU 'LRPHGHVHQXODQ
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2WKHU FRQWDPLQDWLRQ ULVNV IRU \$QWLSRGHDQ DOEDWURVV DU
H J PHUF XU\ FDGPLXP OHDG SHUVLVWHQW RUJDQLF SROOXW
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ELRDFFXPXODWLRQ RI WR[LQV WKURXJK WKH FRQVXPSWLRQ RI SU
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H[DPSOH UHVLHZV E\ 7KRPSVRQ +DPHU 3KLOOLSV HW DO
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'LVHDTVHV

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JHHVH VKRUHELUGV WHUQV JDQQHWV DQG VNXD DFURVV D ZLG
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KLJKOLJKW LWV SRWHQWLD O ULVN WR \$&\$3 OLVWHG VSHFLHV L
DFFLGHQWDO LQWURGXFWRQ YLD KXPDQV 8KDUW HW DO ,
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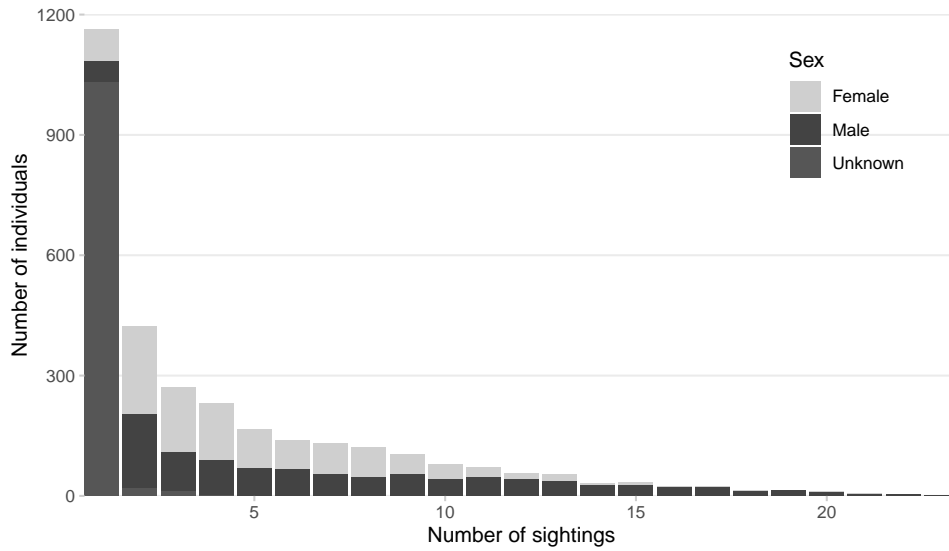
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RI QHVWV UHFRUGHG ZLWKLQ WKH VWXG\ DUHD)LJXUH %RWK V
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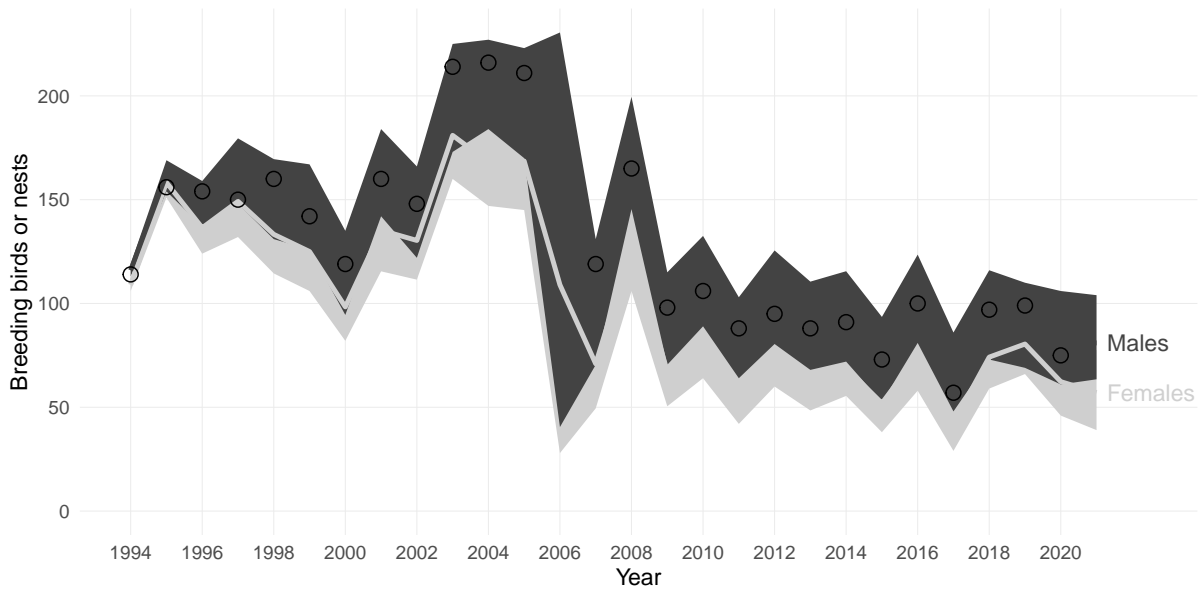
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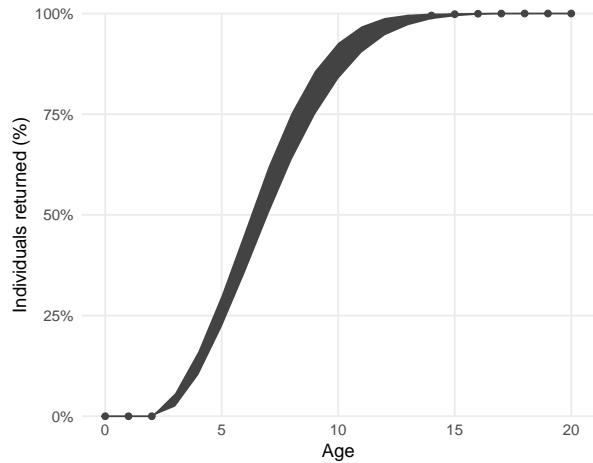
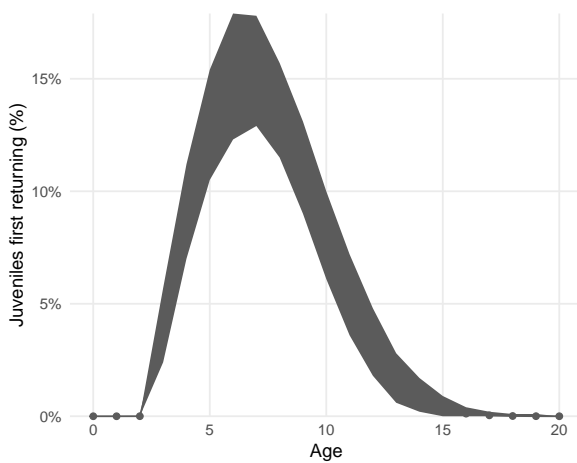
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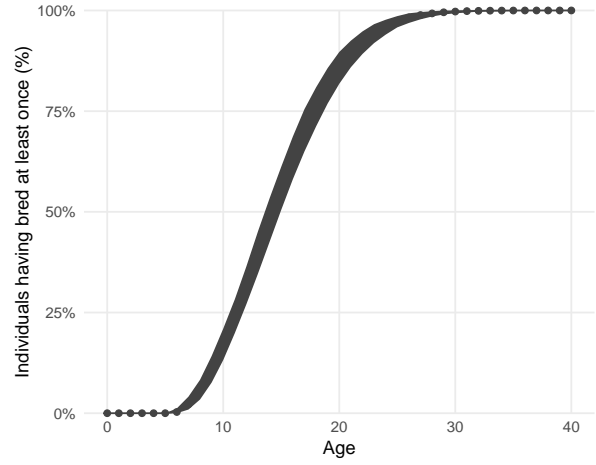
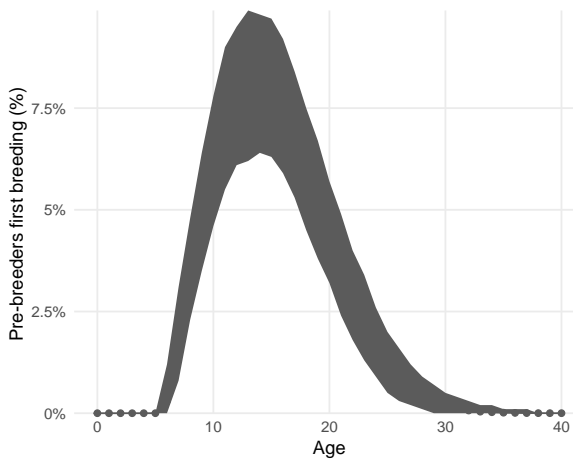
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 'HDG
 \$OO



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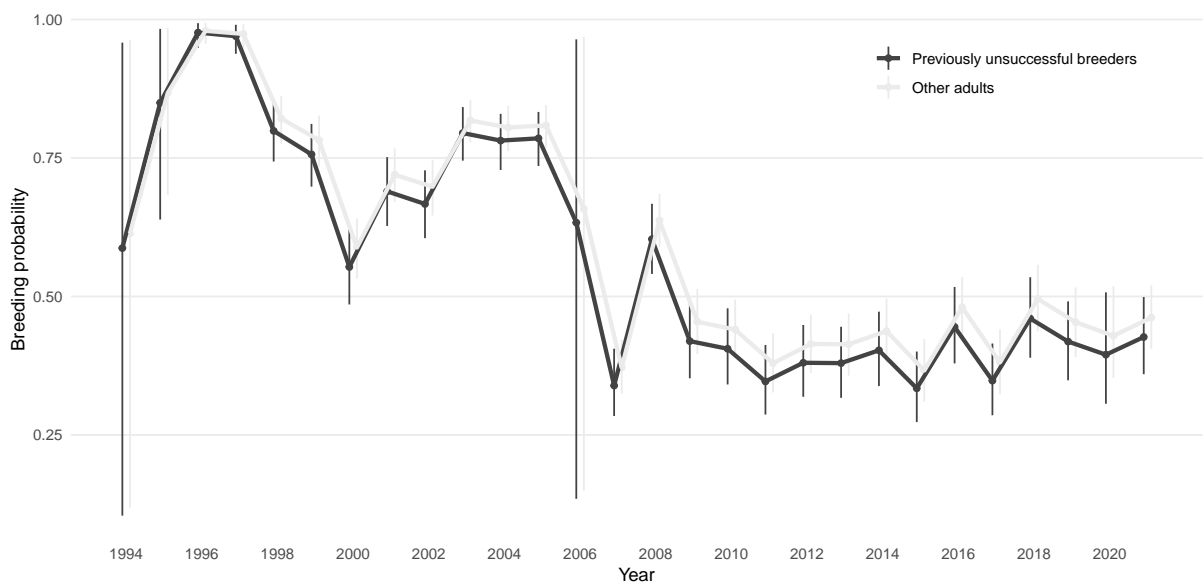
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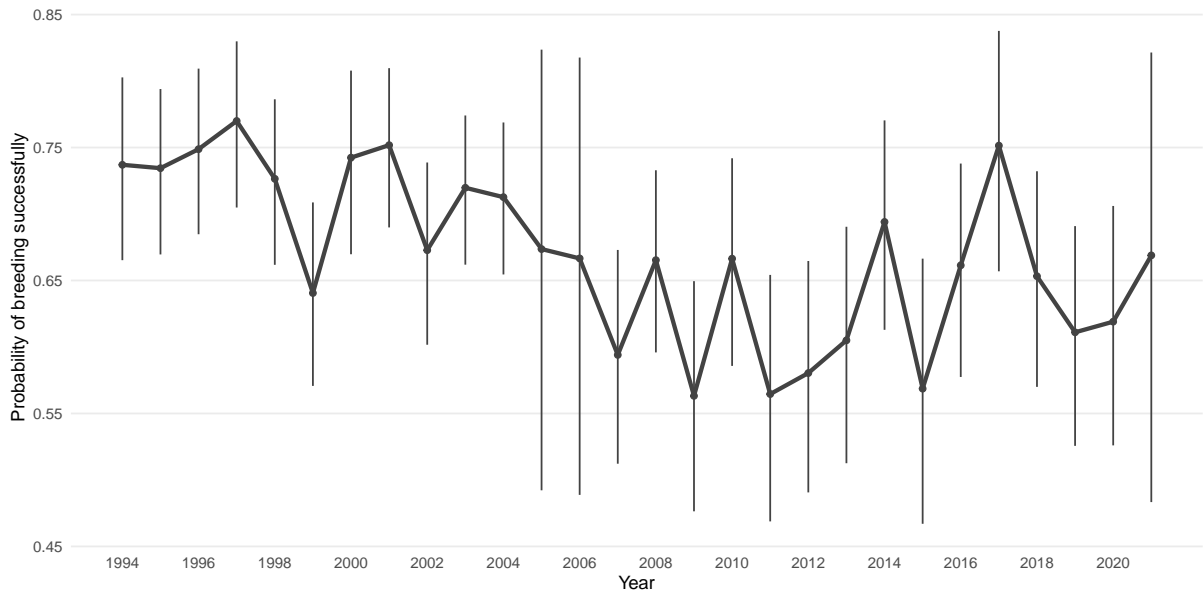
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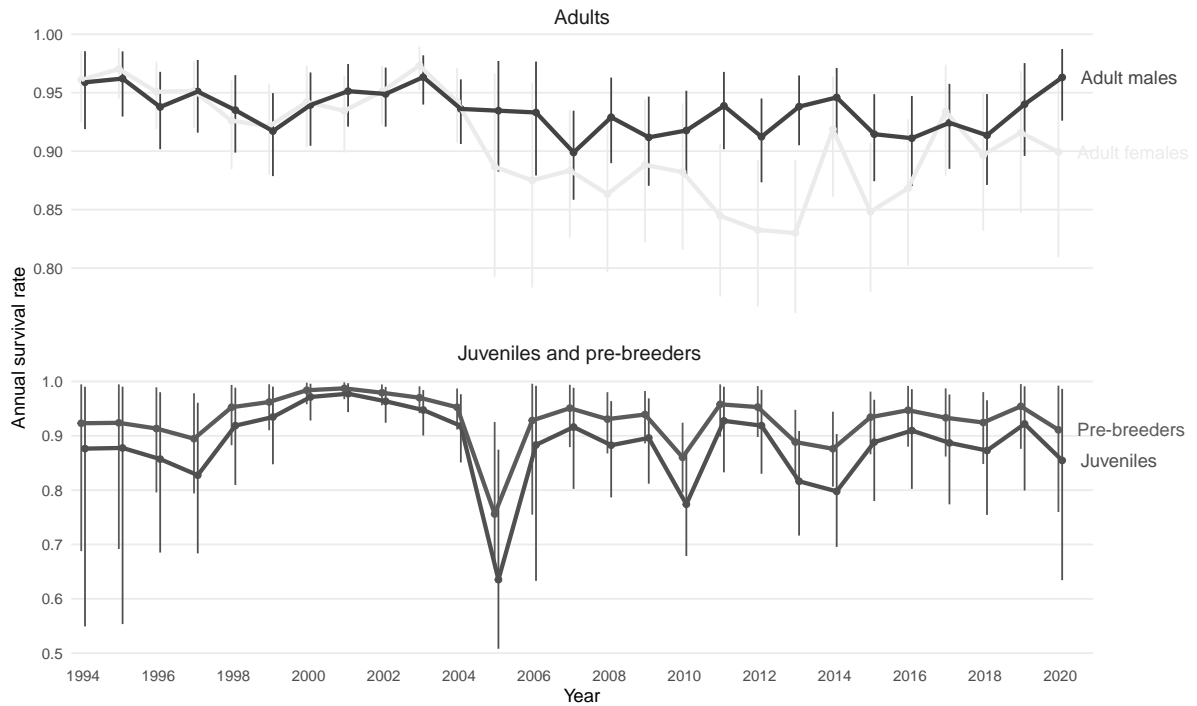


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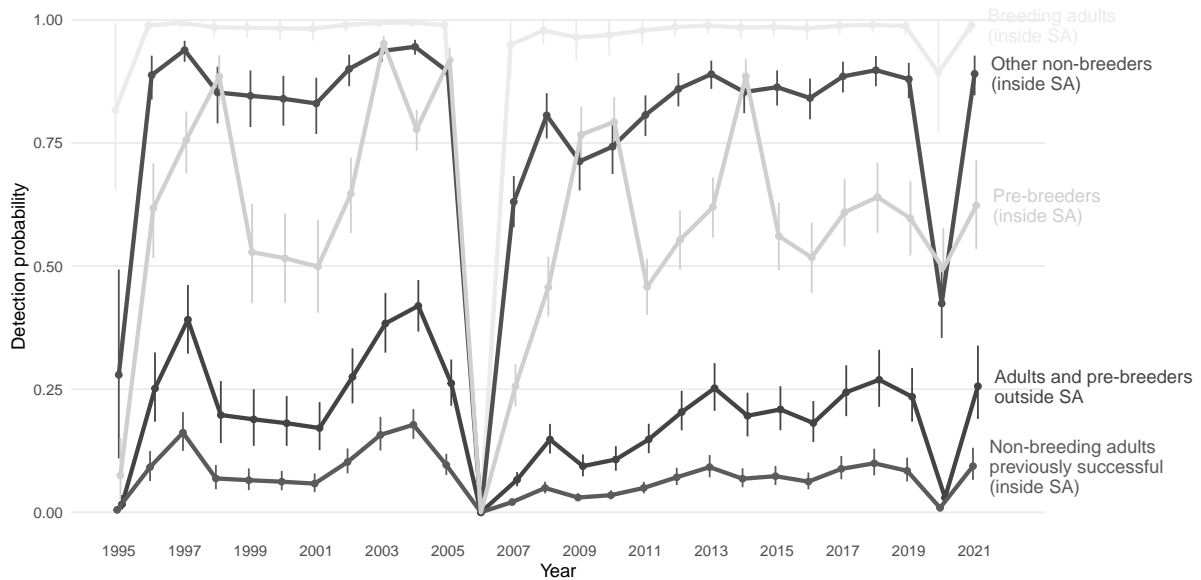
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 DIWHU 7KH ILQGLQJ GRFXPHQWHG WKDW WKH SRSXODWLRQ
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 IRUDGXOWPDOHV IURPDPHDQRI FL ± WRDPHDQ
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 WRDPHDQRI \HDUV

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 VDPH DQQXDO YDULDELOLW\ LQ GHWHFWLRQ SUREDELOLW\ ZDV DS
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 UHVSHFWLYHO\

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 UHWXUQ WR LW WR DFFRXQW IRU SRWHQWLDO ELDVHV LQ VXUYLY
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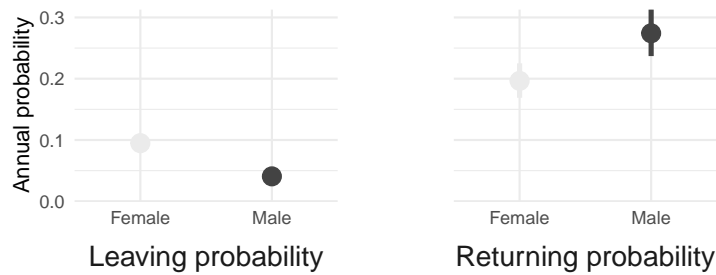


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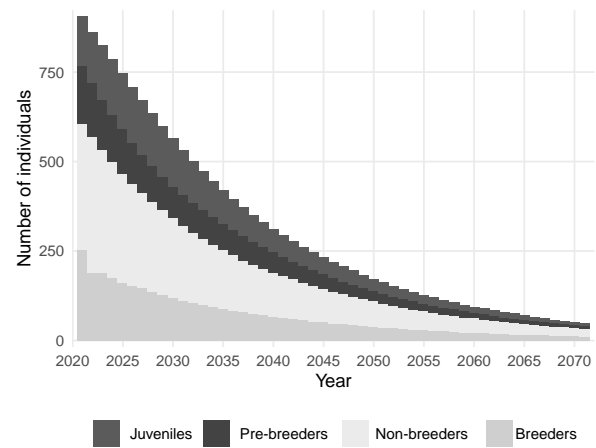
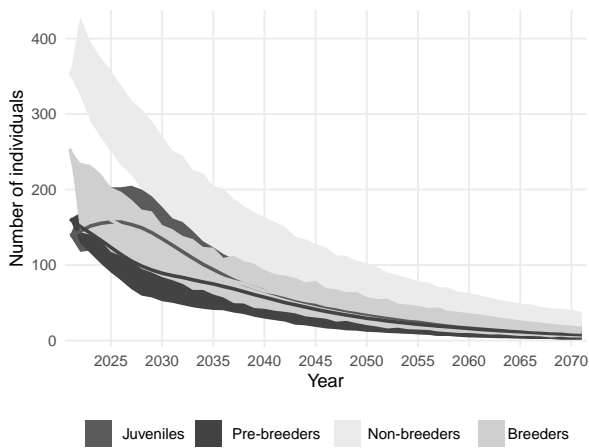
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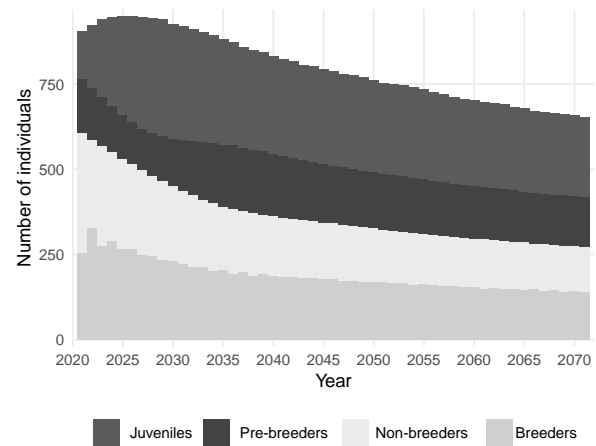
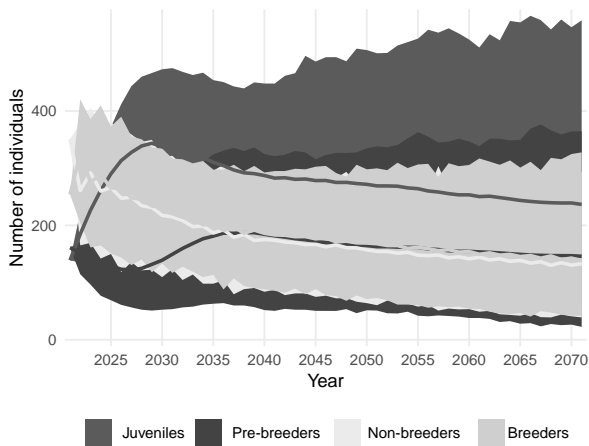
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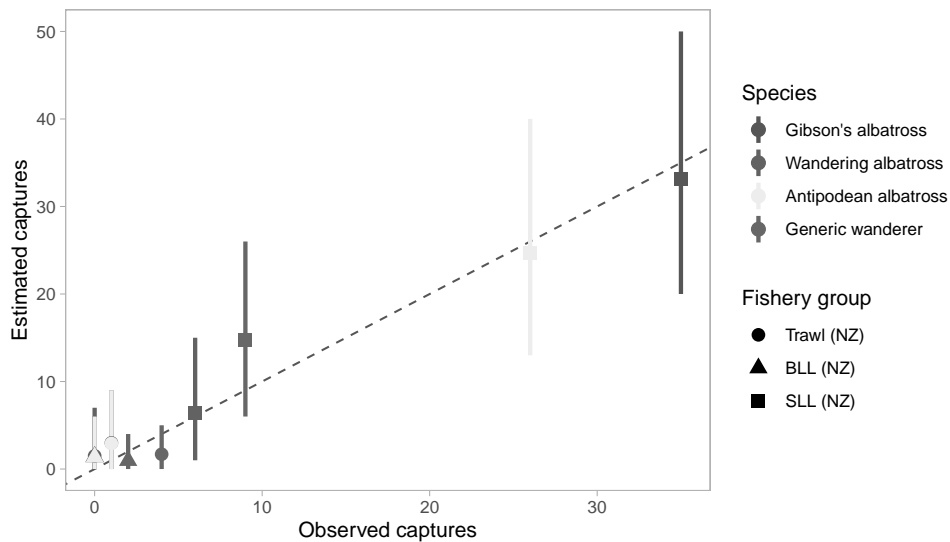
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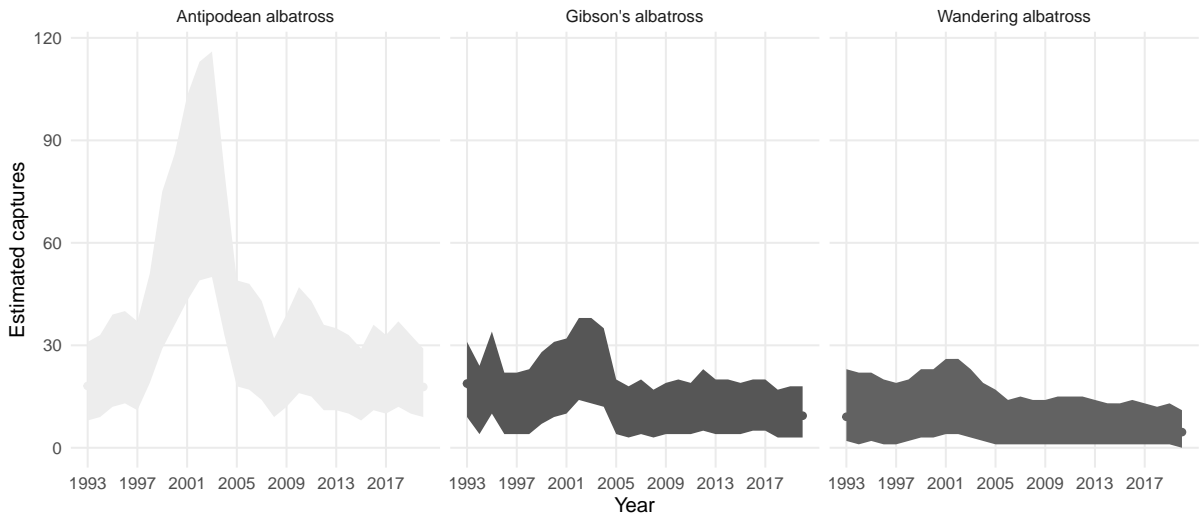
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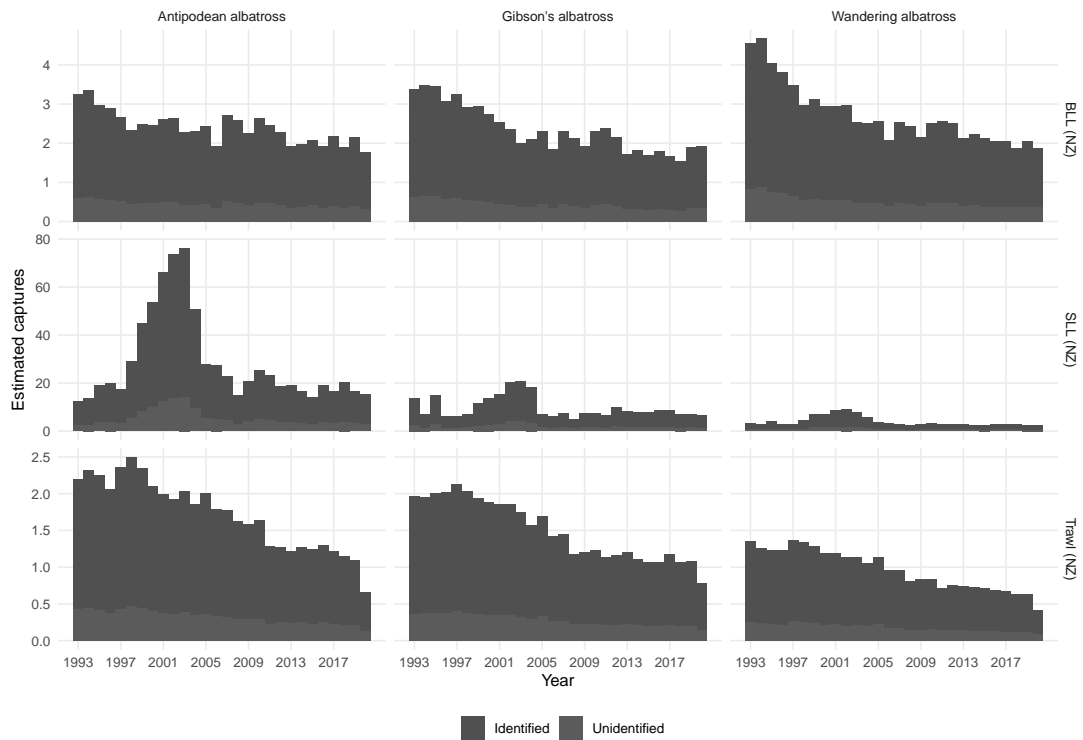
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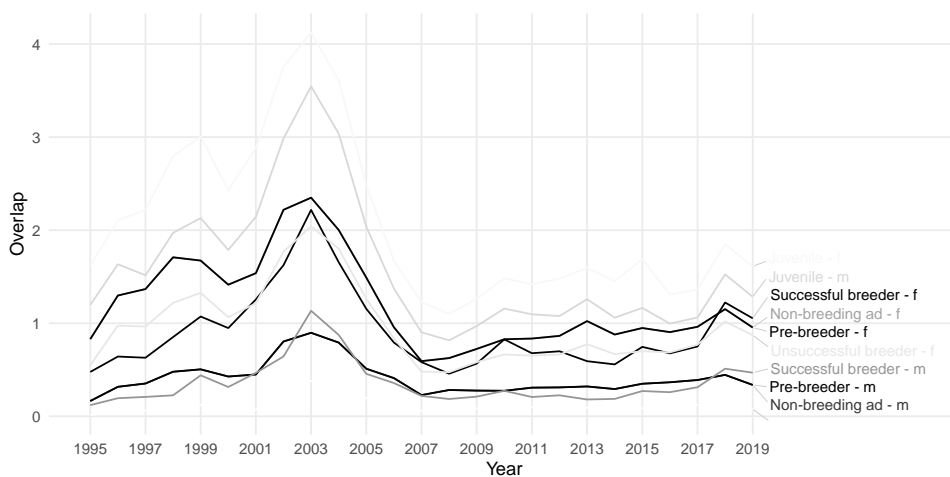
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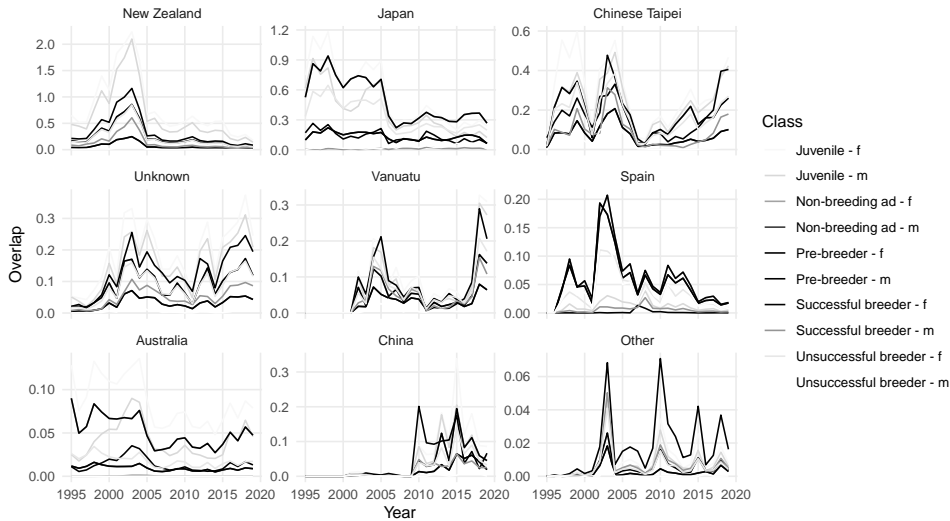
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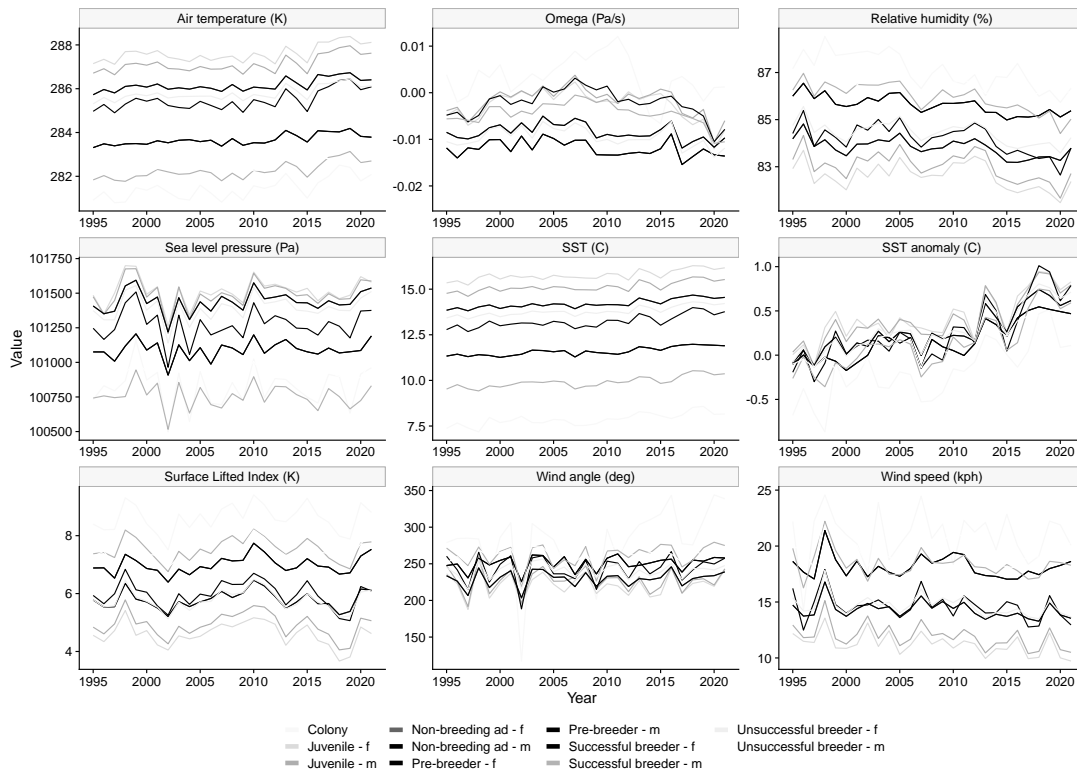
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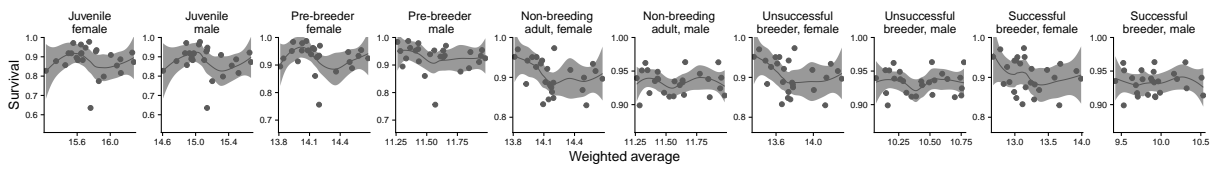
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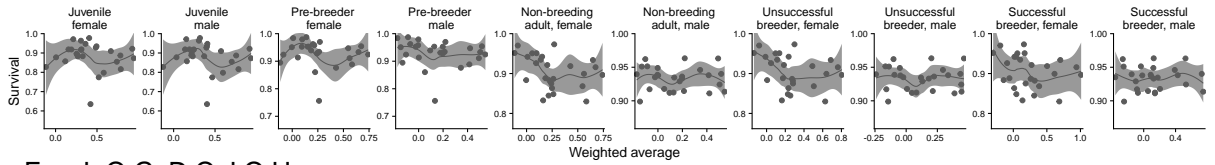


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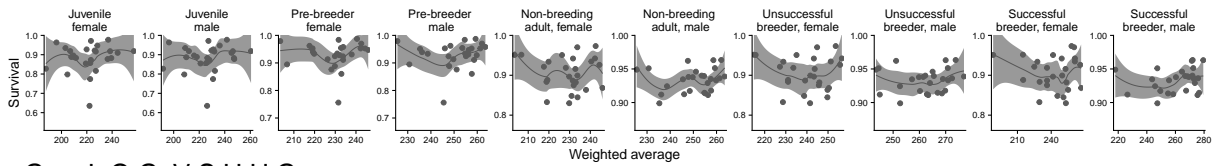
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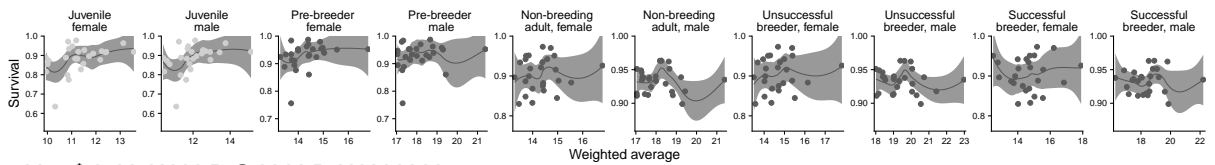
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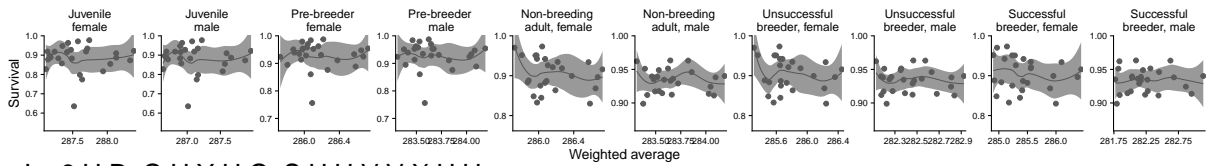
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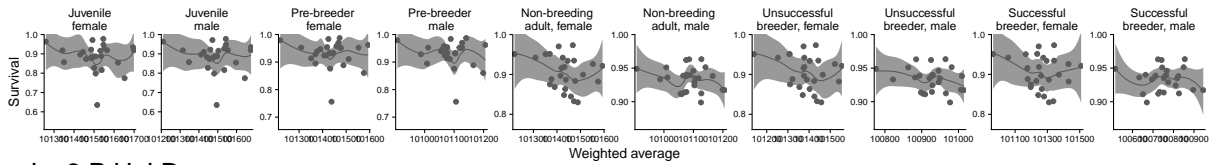
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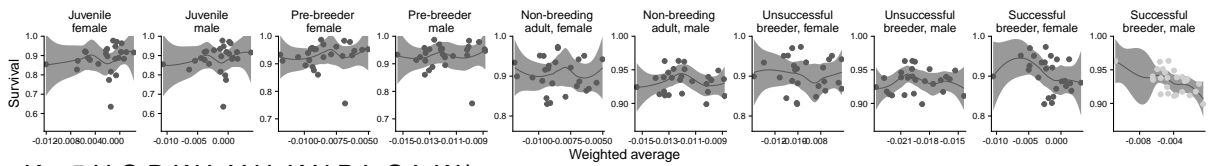
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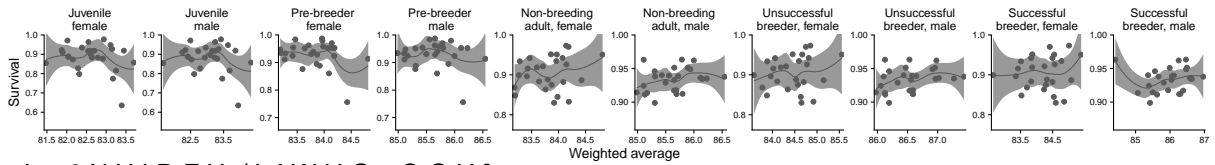
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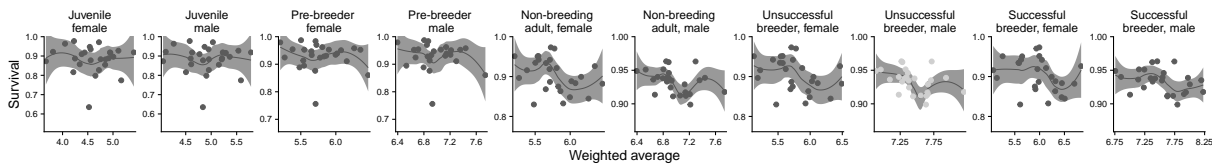
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L 6XUIDFH /LIWHG ,QGH\



)LJXUH 5HODWLRQVKLS EHWZHHQ WKH DQQXDO YDULDELOLW\ LQ FOLP
 YDULDELOLW\ LQ WKH HWLPDWHG VXUYLYDO UDWHRU HDFK SRSXODWL
 3RLQW ZLWK D VLJQLILFDQW 3HDURQ KRZ QHODWRQ HDWQGLQ SXUSO

\$QWLSRGHDQ DOEDWURVV PXOWL WKUHDW ULVN DVVHVPHQW

