Hector’s & Māui dolphin TMP risk assessment
Risk assessment process & progress
MRAG Mar 2018

Jim Roberts, Krista Hupman, Kim Goetz, Ian Doonan, Charles Edwards (all NIWA),
Wendi Roe (Massey), Simon Childerhouse (Blue Planet Marine),
D’Arcy Webber (Quantifish)
Acknowledgements

Dolphin experts consulted to date
People that have agreed to share data, code & model outputs with the TMP risk assessment...
• Darryl MacKenzie & Deanna Clement
• Rochelle Constantine & Scott Baker
• Jody Weir, Manue Martinez, Stefan Bräger & Sam DuFresne
AEWG, MRAG, independent expert reviewers
Structure of presentation

1. TMP risk assessment methodology
2. TMP risk assessment process
3. Details & progress with project components
4. What next?
Evolution of the Hector’s Māui TMP

2007 TMP Māui & Hectors
• PBR for 4 genetic sub-populations
• Quantitative assessment of set-net mortalities (Davies et al. 2008)
• Qualitative assessment of other threats

Four genetic sub-populations

Hamner et al. 2012
Evolution of the Hector’s Māui TMP

2007 TMP Māui & Hectors
• PBR for 4 genetic sub-populations
• Quantitative assessment of set-net mortalities (Davies et al. 2008)
• Qualitative assessment of other threats

2012 TMP Māui only
• PBR for Māui
• Expert threat characterization – spatial & magnitude (Currey et al. 2012)
• Basic assessment of spatial overlap of threats with Māui

2017 TMP Māui & Hector’s
• Spatially-explicit risk assessment (SEFRA) with seasonality
• Multiple threats on 4 genetic sub-populations simultaneously
• Related to a PST (inspired by though different to PBR approach)
TMP risk assessment methodology (1)

Extension of SEFRA Risk Atlas tool (Webber: MPI contracts PRO2016096 & SEA2016-30, in progress), building on initial outputs of the Marine Mammal risk assessment (Dragonfly DataScience: MPI contract PRO2014-01) and method development by Sharp (2017) and Webber & Sharp (in progress)

Calculation of **Population Suitability Threshold (PST)** – annual mortality that will allow population recovery or stabilization to [X] % of \( K \) with [Y] certainty, including inter-annual stochasticity

\[
PST = \frac{1}{2} \cdot \varphi \cdot r_{\text{max}} \cdot N
\]

This will be related to **threat-specific annual potential fatalities (APF)**, given overlap between the **spatial distribution of Hector’s & Māui dolphins** and **spatial threat intensity**

The TMP risk assessment will estimate all inputs in blue
TMP risk assessment methodology (2)

Demographic assessment
• Review life history info for Rmax
• Current adult survival
• Small population-size effects

Threat characterisation
• Identification of threats
• Spatial distribution of threat intensity
• Method for estimation of annual threat mortality

Hector’s & Māui seasonal spatial distribution
• Predictive modelling of summer/winter dolphin distribution from aerial surveys (e.g. MacKenzie & Clement 2016)
• Integration of info from C-POD, boat-based surveys, etc
TMP risk assessment methodology (3)

Modifications to SEFRA model
- To bring in multiple threats
- Population specific demographics
- Other custom.. E.g. use of public and/or fishery observer sightings to inform spatial distribution of Māui & Hectors

Workshop
- Review SEFRA model inputs
- Implement SEFRA tool
- Estimate/illustrate effects of alternative management scenarios on risk
- Workshop reporting

Risk assessment reporting
# Māui/Hector’s TMP risk assessment process

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AEWG

Draft

Final
Timeline of review opportunities

- **Aug 2017** – Technical WG, introduction & extending SEFRA for TMP
- **Sep 2017** – risk assessment begins
- **Nov 2017** – Toxoplasmosis workshop at Massey
- **Nov 2017** – AEWG, risk assessment process & progress update
- **7 Mar 2018** – AEWG Demographic assessment
- **26 Mar 2018** – MRAG, progress update (Auckland)
- **17 Apr 2018** – AEWG Threat characterization (MPI, Wellington)
- **30 May 2018** – AEWG Māui/Hector’s spatial distribution (NIWA, Wellington)
- **Jul 2018** – SEFRA workshop
- **Sep/Nov 2018** – TMP risk assessment draft & final reporting
Demographic assessment
Summary of 7th March AEWG

- Hector’s/Māui $r_{max}$ (*Presented by Charles Edwards*)
- Small population effect on growth rate (*Ian Doonan*)
- Population-specific survival (*Jim Roberts*)
Previous Māui TMP $r_{max}$

- 0.018 used as base case by previous TMP (Currey et al. 2012), based on longevity of 20 years... though ~15% survived to age 20+ by 2006...
- No updated longevity information is available for this assessment

![Histogram showing minimum age in 2006](Gormley 2009)
Cetacean $r_{max}$

- $r_{max} = 0.018$ is inconsistent with estimates from other mammals given first reproduction at age 8 (Slooten 1991)

- Approx. half the next lowest estimated for a cetacean (Bowhead whales: longevity $>100$ years with $r_{max} \geq 0.036$; Givens et al. 2013)
Cetacean $r_{\text{max}}$

- Direct estimation requires long time series of abundance/demographic rates of populations growing at maximum rate
- Default $r_{\text{max}}$ of 0.04 is used in 153 of 163 stock assessments due to lack of data;
- Of the remainder:
  - 9 assume $r_{\text{max}} > 0.04$ (e.g. humpback whales)
  - $r_{\text{max}}$ 0.035 is used for one orca population
Rmax estimation from Hector’s life history

Follows that of Moore (2015) and Dillingham et al (2016)

RATIONAL

- STEP 1 generates samples for $\ln(\lambda_{max})$ consistent with demographic theory
- STEP 2 ensures these samples are consistent with allometric theory
- These contrasting paradigms are biased in opposite directions by uncertain adult survivorship
- Their combined use should intuitively reduce the bias overall
Maximum growth rate estimates
rmax estimate for Hector’s/Māui

- $r_{max} \approx 0.05$
- Plausible given probable age at first reproduction
- Will update with new age data when available
Estimating the age at first breeding

- An informative prior was developed following a meta-analysis which shows a relationship between asymptotic length and the length at maturity

\[ \frac{L_\alpha}{L_\infty} \approx 0.95 \]
## Population size bias on pop. growth rate

- IBM model population simulations using VORTEX software – simulates demographic stochasticity & other low population size problems

- Input demographic rates consistent with \( r_{\text{max}} = 0.04 \)

- Has environmental variation & inbreeding depression

- Realised population growth lower than input \( r_{\text{max}} \)

- Can be considered for \( r_{\text{max}} \) used for Māui

- Note increased extinction rate below 20 individuals

<table>
<thead>
<tr>
<th>Start N</th>
<th>Deterministic ( r_{\text{max}} )</th>
<th>Stochastic ( r_{\text{max}} )</th>
<th>SD Stochastic ( r_{\text{max}} )</th>
<th>Probability extinction (% within 200yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>0.04</td>
<td><strong>0.033</strong></td>
<td>0.067</td>
<td>0</td>
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<td>40</td>
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<td>30</td>
<td>0.04</td>
<td>0.028</td>
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<td>25</td>
<td>0.04</td>
<td>0.026</td>
<td>0.072</td>
<td>2.1</td>
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<td>20</td>
<td>0.04</td>
<td>0.023</td>
<td>0.075</td>
<td>4.5</td>
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<td>15</td>
<td>0.04</td>
<td>0.019</td>
<td>0.081</td>
<td>11.4</td>
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<td>10</td>
<td>0.04</td>
<td>0.011</td>
<td>0.093</td>
<td>36.1</td>
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<tr>
<td>5</td>
<td>0.04</td>
<td>-0.001</td>
<td>0.131</td>
<td>88.3</td>
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</table>
Annual survival

Adult survival

- A constraint on cumulative mortality
- By genetic sub-population (though low info for some e.g. WCSI & SCSI)
- Demographic assessment of mark-resighting data using NIWA’s SeaBird
- We have or will obtain:
  - **Māui genetic & photo mark ID 2001-2017** (from Rochelle & Scott)
    Progress with Māui assessment under DOC project (DOC307002)
  - **Hector’s Kaikoura photo ID 2013-2017** (from Jody Weir)
    Will obtain latest years over next few weeks
  - **Hector’s Banks Peninsula photo ID 1985-2002** (Sam DuFresne thesis)
    Obtaining similar results to DuFresne (2004)

Open demographic assessment presentations...
Threat characterisation
Which threats will be considered?

Threats deemed to affect Māui population (Currey et al. 2012)...

Indirect effects were bundled into natural mortality & addressed by rmax

Shortlist from previous TMP...

<table>
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<tr>
<th>THREAT CLASS</th>
<th>ESTIMATED MORTALITIES</th>
<th>RISK RATIO</th>
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<tbody>
<tr>
<td></td>
<td>MEDIAN</td>
<td>95% CI LOWER</td>
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<tr>
<td>Fishing</td>
<td>4.97</td>
<td>0.28</td>
</tr>
<tr>
<td>Mining and oil activities</td>
<td>0.10</td>
<td>0.01</td>
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<tr>
<td>Vessel traffic</td>
<td>0.07</td>
<td>&lt;0.01</td>
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<tr>
<td>Pollution</td>
<td>0.05</td>
<td>&lt;0.01</td>
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<tr>
<td>Disease</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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<tr>
<td>Total</td>
<td>5.27</td>
<td>0.97</td>
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</table>
Which threats will be considered?

• Plus key threats affecting Hector’s only from 2007 TMP assessment (if any)
• Plus threats not specifically addressed by previous TMPs, e.g.:
  • Toxoplasmosis
    • Main cause of death at necropsy – Roe et al. 2013
    • Subject of recent workshop held at Massey
  • Prey availability
    • Fishing effects deemed influential by 2012 TMP, but not climate
    • Red cod the main prey – short lived & presumed responsive to SST
• Potential future threats, e.g.
  • Iron sand mining
  • Changes in spatial extent of threats, e.g. oil & gas
Modelling approach varies by threat

Approach taken will depend on:
• Available information (e.g. spatial threat intensity?)
• Whether threat is demonstrably lethal

Full SEFRA (estimating deaths within model)
• Commercial set net & trawl
• Recreational fishing (e.g. using vulnerability from commercial)

Partial SEFRA (estimating deaths outside of model)
• Other threats known to be lethal & with spatial threat intensity
• E.g. toxoplasmosis

PBR type approach
• Lethal threats for which no spatial threat intensity

Will obtain risk ratios for these
Modelling approach varies by threat

Spatial overlap
• Threats for which no demonstrable evidence of lethal effects, though we have a spatial threat intensity

Qualitative assessment
• All other threats

No risk ratios for these, though still useful for qualitative assessment of risk & spatial management
Spatial threat intensity

Project team is developing methods for estimating spatial threat intensity

Methods will be reviewed by AEWG WG in Wellington, 17th April

Approach will vary with nature of threat & data

E.g. based on:
- Precise locational data, e.g. commercial fishery
- Distance from point source, e.g. noise from oil & gas seismic or iron sand
- Model outputs, e.g. hydrological & cat density for spatial toxoplasmosis
- *Ad hoc* methods for less well-informed threats
Annual mortality by threat

For lethal threats other than fishing, will use SEFRA model to estimate sub-population mortality based on:

• Attributing estimated mortality for a sub-population (1-survival) to...
• ...Proportional cause of death at necropsy (Wendi is producing updated list with consistent methodology through time – since 2008)
• Detection probability by threat.. Probably lack data, though sensitivities can be done
Māui/Hector’s spatial distribution
Hector’s Māui spatial distribution

- Annual variation in Māui distn from boat & aerial surveys – composite used for previous TMP risk assessment
- Seasonal variation (Hector’s & Māui?)

Currey et al. 2013

Mackenzie & Clement 2016
Hector’s Māui spatial distribution

Abundance by genetic sub-population
- From Hector’s aerial survey
- Māui abundance from genetic mark-recapture

Spatial distribution
Hector’s dolphin
- From Hector’s aerial survey (by MacKenzie & Clem
- Using their GAM smooth; and
- Estimated from habitat preference model, e.g. dep

Māui dolphin
- Estimated from Hector’s dolphin habitat preferenc
- From public sightings and fishery observer records
- Distributions from previous aerial & boat-based su
- Ongoing year-round CPOD & sound trap deployment (NIWA) and analysis (Univ. Auckland)
  - Four deployments: May done & Nov in water
  - 2 more trips deployments in Feb and May
Use of observer/public sighting data

Observer sighting data since 2009...

Also gives us spatial density of fishing v non-fishing vessels
Intend to use as spatial effort layer to relate to respective public sightings
Use of observer/public sighting data

Public sighting data...

- Subset by sighting ‘platform’
- Subset by validation category
Seasonal habitat preference – e.g. turbidity

Rakaia River
Satellite turbidity proxy

Hector’s aerial survey

Satellite turbidity proxy

Cawthron Eye winter 2016

Rakaia
Satellite turbidity proxy

Time Averaged Map of Remote Sensing Reflectance at 645 nm (Rrs) monthly 4 km [MODIS-Aqua MODISA_L3m_RRS v2018] sr^-1 over 2016-05-01 00:10:01Z - 2016-11-01 02:30:00Z, Region 165.8057E, 47.6016S, 179.4287E, 33.627S

- Selected date range was 2016-May - 2016-Oct. Title reflects the date range of the granule.
Satellite turbidity proxy

Time Averaged Map of Remote Sensing Reflectance at 645 nm (Rrs) monthly 4 km [MODIS-Aqua MODISA_L3m_RRS v2018] sr^-1 over 2016-05-01 00:10:01Z - 2016-11-01 02:30:00Z, Region 172.3535E, 39.3311S, 174.9463E, 34.1895S

- Selected date range was 2016-May - 2016-Oct. Title reflects the date range of the granules that went into making this result.
Habitat preference – e.g. prey

Hector’s dolphin aerial survey
Mackenzie & Clement
SEFRA modelling
Integrating SEFRA model inputs

• Updating/extending SEFRA model to include:
  • Updated life history parameters
  • Spatial threat intensity maps
  • Spatial dolphin distribution maps
  • Deaths for known lethal threats other than fishing

• Sensitivities anticipated

• SEFRA model outputs including overlap will not be shown before the SEFRA workshop in July
SEFRA Workshop (3 days in July)

- Overview of all model inputs
- Model outputs
  - RRs for all lethal threats by sub-population
  - Spatial overlap for others
- Relating risk ratios to population models
  - are they consistent?
  - Population effects of threats?
- Illustrative management scenarios, e.g. effects of threat management on risk ratio/population growth
- Workshop report summarising outputs for the TMP
What next?

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- **Mar 2018** – AEWG Demographic assessment
- **26th Mar 2018** – MRAG, progress update (Auckland)
- **17th Apr 2018** – AEWG Threat characterization (MPI, Wellington)
- **30th May 2018** – AEWG Māui/Hector’s spatial distribution (NIWA, Wellington)
- **Jul 2018** – SEFRA workshop
- **Sep/Nov 2018** – TMP risk assessment draft & final reporting
End of presentation
Previous Hector’s demographic assessments
All Univ. Otago


• CJS demographic assessment in MARK, exploring: area, age, year & mark quality effects on non-calf survival (basic MR data in Appendix)
• Single-area non-calf survival estimate of 0.904 (0.882-0.923)
Previous Hector’s demographic assessments
All Univ. Otago


• Multi-area model not most parsimonious though results indicate this model structure might be appropriate if enough data...

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<th>Area</th>
<th>Survival</th>
<th>SE</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
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<tr>
<td>North</td>
<td>0.8519</td>
<td>0.0443</td>
<td>0.7428</td>
<td>0.9197</td>
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<tr>
<td>East</td>
<td>0.8920</td>
<td>0.0743</td>
<td>0.6455</td>
<td>0.9740</td>
</tr>
<tr>
<td>Akaroa</td>
<td>0.9230</td>
<td>0.0327</td>
<td>0.8296</td>
<td>0.9672</td>
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<tr>
<td>South</td>
<td>0.9225</td>
<td>0.0555</td>
<td>0.7221</td>
<td>0.9820</td>
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Used in rmax assessment
Previous Hector’s demographic assessments
All Univ. Otago


• Age effect on survival, though only adults identified with confidence, after 5+ years of sighting (presumed 2+ at first sighting)
• Therefore “Juvenile” will include some adults

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<th>Stage-class</th>
<th>Survival</th>
<th>SE</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
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<td>Juvenile</td>
<td>0.9429</td>
<td>0.0145</td>
<td>0.9069</td>
<td>0.9656</td>
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<tr>
<td>Adult</td>
<td>0.8661</td>
<td>0.0175</td>
<td>0.8280</td>
<td>0.8968</td>
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Previous Hector’s demographic assessments
All Univ. Otago


- Bayesian CJS demographic assessment with individual heterogeneity in recapture probability, exploring: 1998 sanctuary effect on survival and population growth
- Changes in recapture effort through time though reasonably consistent since 1990/91
- Post-sanctuary non-calf survival estimate of 0.917, though:
  - Does not account for movement & area effect on recapture effort (might lead to underestimate)
  - Data from 2003-2006 not available
Previous Hector’s demographic assessments

All Univ. Otago

• No Banks Peninsula assessment using data collected since 2009
• Is survival likely to have changes since given...
  • Extension of sanctuary in 2008;
  • Changes in habitat; and
  • Potential changes in other threats?
Previous Hector’s demographic assessments
All Univ. Otago


Population outside of marine mammal sanctuary though fishing area restrictions

- Intend to use Māui dolphin model structure to estimate non-calf survival for this population.
- Small population, so not appropriate to use in SEFRA model with 4 genetic sub-populations
  ...though valuable context for assessing sub-population/threat effects on survival
Sub-population survival to use for SEFRA

Given data issues, I am looking for guidance from the WG...

• **WCNI** (Māui) – we can update SeaBird model with latest photo ID?
• **ECSI** – we could use Gormley (2009) estimate, unless there is something using more recent data?
• **SCSI** - ??
• **WCSI** - ??
Spatial correlation with prey

Spatial/seasonal correlation with red cod, their main prey (Eleanor Miller 2014)
Satellite turbidity proxy
Commerson’s dolphin

Dellabianca et al 2016
Satellite turbidity proxy
Heaviside’s dolphin
Satellite turbidity proxy
Vaquita