Estimating local limit reference points for highly migratory sea turtles

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Motivation
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Loggerhead BPUE 2000-2009, DFO 2010

dfo-mpo.gc.ca
Motivation

Kobe phase plot and trajectory for North Atlantic swordfish. ICCAT 2014
Motivation
Concept: Limit Reference Points (LRPs)

(Curtis et al 2015a, modified from Moore et al 2013)
Concept: LRP Estimators

\[ PBR = 0.5 \times R_{\text{max}} \times N_{\text{min}} \times F_r \]

- \( 0.5 \times R_{\text{max}} \) - growth rate at MNPL in logistic model;

- \( N_{\text{min}} \) – lower percentile of population estimate that ensures meeting management objectives

- \( F_r \) - recovery factor; 0.1 to 1; to account for potential biases; or ensure time to recovery not unduly extended
Concept: LRP Estimators

(Curtis et al 2015a)

Are abundance data fishery-independent?

No

See in-text references for guidance on catch LRP for fishery-dependent data (e.g., catch series)

Yes

Is mortality age-selective and does reproductive value depend strongly on age?

No

Total population abundance

Preferred estimator = PBR-like

Yes

What abundance information is available?

Abundance for a single age class

Preferred estimator = Modified PBR-like

Preferred estimator = RVLL-like

Catch LRP estimator (basic form):

(b R_max N f)_{min}

Notes:

N = abundance scaled by reproductive value

Indicator:

Removals scaled by reproductive value

Data requirements:

Life table data to construct a population transition matrix corresponding to optimal population-growth conditions; estimates of abundance for a particular age or stage class (e.g., reproductive adults); age- or stage-specific estimates of human-caused removals

Estimates of \(R_{max}\) (from life table or other methods), survey estimates of total population abundance, estimates of human-caused removals

Estimates of \(R_{max}\) (from life table or other methods), survey estimates of \(\eta\), demographic parameters to convert \(\eta\) to \(N\); estimates of human-caused removals
Concept: Local LRP

- Proportional to local abundance

(Curtis et al 2015a)
Concept: LRP

Strengths of reference points:

- Tie population impacts to population outcomes in probabilistic framework
- Comparability among species, regions
- Relevant to cumulative impacts from all sources
- Can explore sensitivity to different types of uncertainty or bias
- Easy to re-evaluate given new information, e.g. about life history
- If used to set limits, encourage transparent, a priori discussion and decisions about objectives and risk tolerances
Objectives: S&T Toolbox Funding Years 1/2

• Further development of reference point estimators (RVLL and PBR) and management strategy evaluation tools

• Case study(s) to demonstrate application of reference point estimation to sea turtles
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Methods

LRP estimation steps

1. Specify conservation objectives
   - population unit
   - population thresholds, risk tolerances, and time horizons
2. Choose LRP estimator
3. Estimate maximum potential population productivity
4. Estimate local abundance
5. Tune LRP estimator for uncertainty, defined risk tolerances
Methods: 1.a. Management Unit

(Curtis et al 2015b)
Methods: 1.b. Conservation objectives

1. Avoid exceeding $F_{\text{MNPL}} (<5\% \text{ risk})$
2. Avoid exceeding $F_{\text{collapse}} (<2.5\% \text{ risk})$
3. Recover to productive state (MNPL)
   - Within percent time difference from unimpacted population (PBR under MMPA)
4. Maintain current # adults

Evaluation time horizon: two generations (40 years)
Methods: 2. Choose LRP Estimator

(Curtis et al 2015)

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Catch LRP estimator (basic form):

\[(b R_{\text{max}} N_f)_{\text{min}}\]

Notes:

\(N = \text{abundance scaled by reproductive value}\)

Indicator:

Removals scaled by reproductive value

Data requirements:

Life table data to construct a population transition matrix corresponding to optimal population-growth conditions; estimates of abundance for a particular age or stage class (e.g., reproductive adults); age- or stage-specific estimates of human-caused removals

\(N = \text{total abundance across ages}\)

Removals

Estimates of \(R_{\text{max}}\) (from life table or other methods), survey estimates of total population abundance, estimates of human-caused removals

\(\eta = \text{abundance for an age class; } g(\eta) \text{ is a function to obtain total abundance from } \eta\)

Removals

Estimates of \(R_{\text{max}}\) (from life table or other methods), survey estimates of \(\eta\), demographic parameters to convert \(\eta\) to \(N\); estimates of human-caused removals
Methods: 3. Estimate Productivity

\[ PBR = [0.5R_{\text{max}}N_L f_a]_{\text{min}} \]

- \( R_{\text{max}} \sim \text{U}(0.04, 0.06) \), inferred from other populations
Methods: 4. Estimate Local Abundance

\[ PBR = [0.5R_{max}N_L f_a]_{min} \]

\[ \hat{N}_{fem,USWCEEZ} = \frac{\text{days in WCEEZ}}{365} \times \text{proportion using WCEEZ} \times (\hat{R}_I - 1) \hat{n}_{2014} \]

\[ \hat{N} = \frac{1}{\text{proportion adults}} \frac{1}{\hat{P}F} \hat{N}_{fem,USWCEEZ} \]
Methods: 5. Management Strategy Evaluation

- **Biological/Operating Model**: Applied to entire population, age-structured “theta-logistic”, non-selective bycatch mortality.

- **Observation Model**: Sample nesting females.

- **Management Model**: Estimate and apply LRP, only outcome uncertainty in discard mortality.

Additional parameters: 10% K starting population, all stages equally density-dep.
Methods: 5. Management Strategy Evaluation

Tool development

1. Systematic error in abundance estimation
2. Uncertainty in population productivity
3. Uncertainty in discard mortality
4. Mapping percentiles of final LRP distribution to risk
Sensitivity Trials

- **F:** double F at constant $R_{max}$
- **A:** underestimate $P_{\text{adult}}$
- **J:** varying $P_{\text{juv}}$ more steeply
- **M:** Underestimated AFR (True AFR=20, estimated AFR still 10)
- **U:** Pessimistic unstable starting age structure
- **K:** Currently at 20%K instead of 10%
Results: Hypothetical LRPs

(A) Risk of falling below $N_{\text{MNP}}$ (%) for different $f_a$ values: $f_a = 1$ (black) and $f_a = 0.6$ (gray).

(B) Population status at 40 years (%) for $f_a = 0.6$.

(C) Risk of decreasing adults (%) for different $f_a$ values: $f_a = 1$ (black) and $f_a = 0.6$ (gray).

(D) Increase in time to $N_{\text{MNP}}$ (%) for Different Adjustment Factors: $\%\text{ile} = 15$.

(Curtis et al 2015b)
Results: Hypothetical LRP

(A) Risk of falling below $N_{MNP}$.
- $f_a = 1$
- $f_a = 0.6$

(B) Pop status at 40 y ($\%N_{MNP}$).
- $f_a = 0.6$

(C) Risk of decreasing adults ($\%$).
- $f_a = 1$
- $f_a = 0.6$

(D) Increase in time to $N_{MNP}$ ($\%$).
- %ile = 15

(Curtis et al 2015b)
Results: Hypothetical LRPs

(Curtis et al 2015b)
Results: Hypothetical LRP

Limit (AE or indiv.)

LRP percentile

- Naive, $f_a = 0.6$
- Naive, $f_a = 0.1$
- Survey, $f_a = 0.6$
- Survey, $f_a = 0.1$
- Tag, $f_a = 0.6$
- Tag, $f_a = 0.1$

(Curtis et al 2015b)
Results: Risk Assessment

(Curtis et al 2015b)
Results: Risk Assessment

(Curtis et al 2015b)
Results: Risk Assessment II

(Moore and Curtis, in press)
Results

• Publication of case study in *PLoS ONE* with code for MSE

• Dialogue and collaboration with region (WCRO)
  • pre-publication
  • post-publication
Ongoing and Future Work

• Comparability among regions important feature of LRPds so conducting additional case study
• Further development of RVLL tool
• Continued/expanded dialogue
Potential Management Applications?

Leveling playing field for U.S. fishermen:

• Can add value to jeopardy analysis in conjunction with current approaches
• Can support ecosystem-based fisheries management under MSA
• Can facilitate comparison of impacts on PLMR in international fisheries to our own
• Can provide standard for sustainability certification
Potential Management Applications?

WORK IN PROGRESS!!!
Acknowledgments

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A whole lot of help and advice from a whole lot of people