Risk equivalency: a general approach to account for environmental variation and change in scientific advice for fisheries

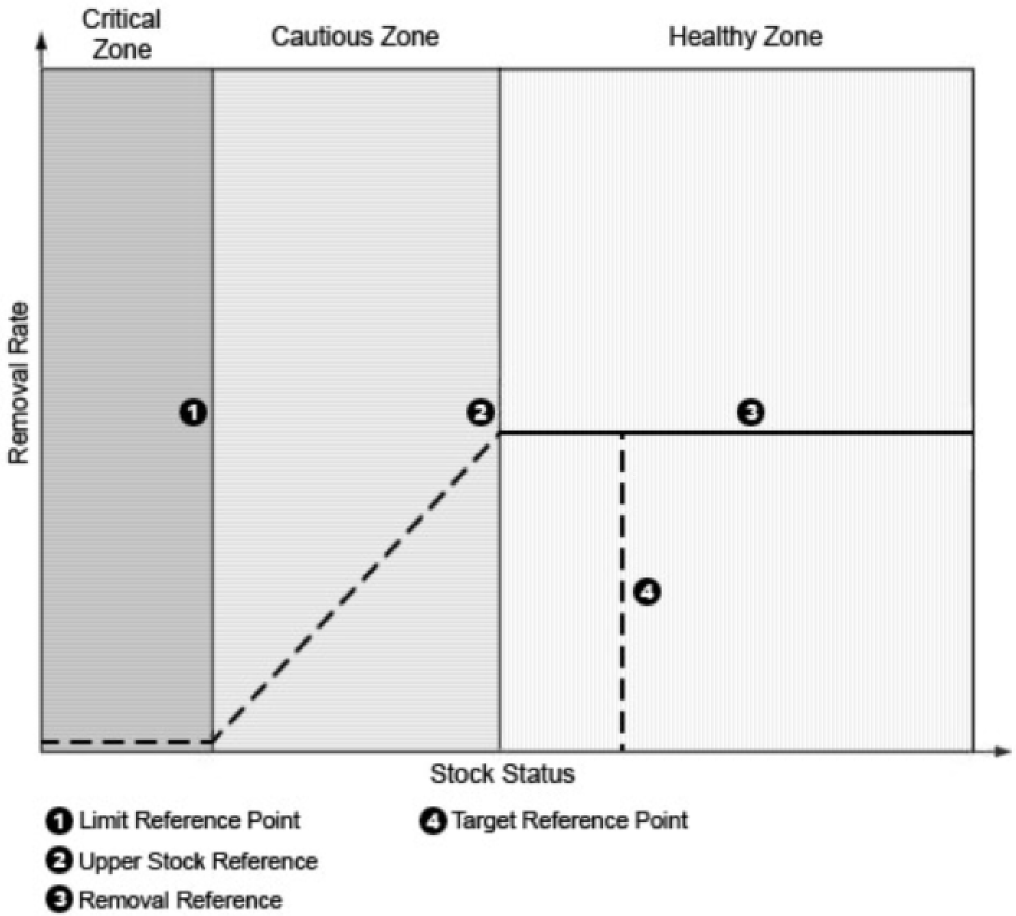
Marie-Julie Roux, Daniel Duplisea, Karen Hunter, Jake Rice

Online seminar, EAFM Working Group
June 2020

Objectives:

- Gain a shared understanding of the risk equivalency framework.
- Identify potential contributions of the EAFM WG to advancing the risk equivalency framework, and how the risk equivalency framework may contribute to shaping the EAFM initiative.
- Discuss opportunities and challenges for the application of the risk equivalency framework within the context of an EAFM.
- Explore potential EAFM case studies that could be used to apply the risk equivalency framework.
- Identify next steps/future sessions on this topic.

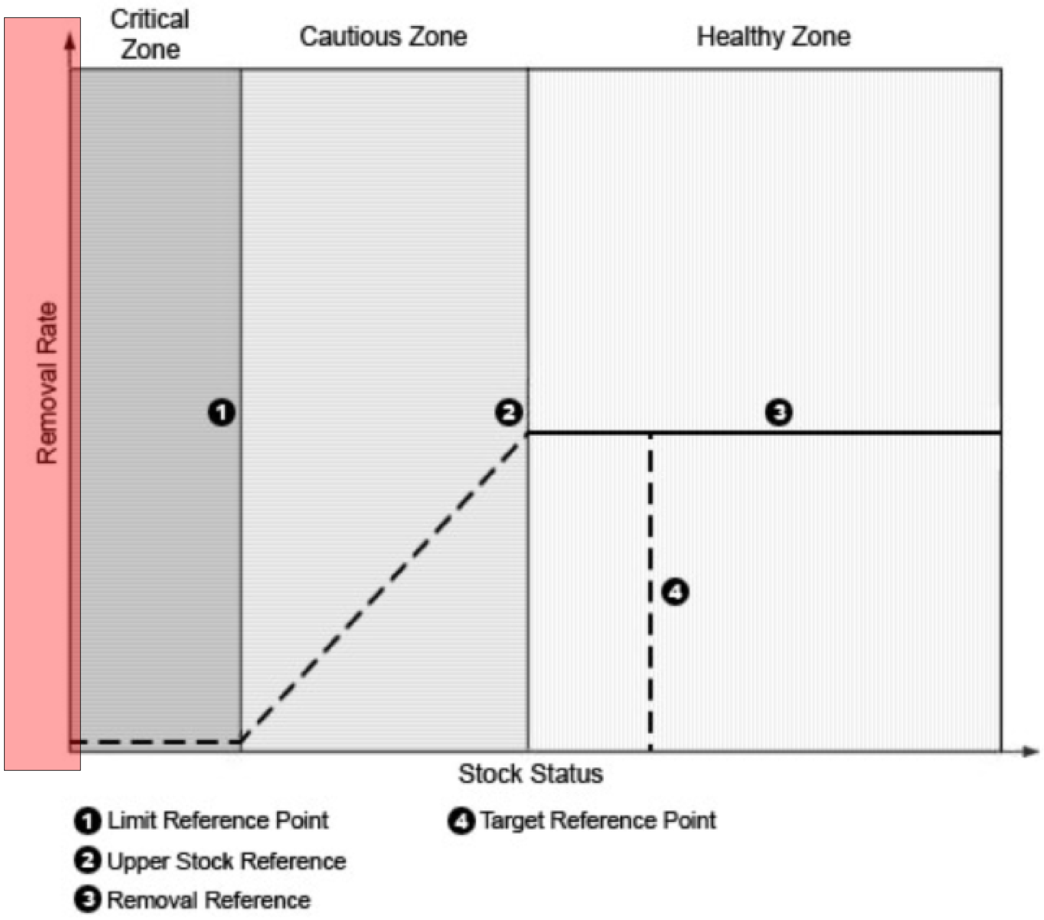
This is a risk management framework



RISK = (EXPOSURE x SENSITIVITY) x CONSEQUENCE

This is a risk management framework

EXPOSURE = the human pressure (threat) that can be managed



RISK = (EXPOSURE x SENSITIVITY) x CONSEQUENCE

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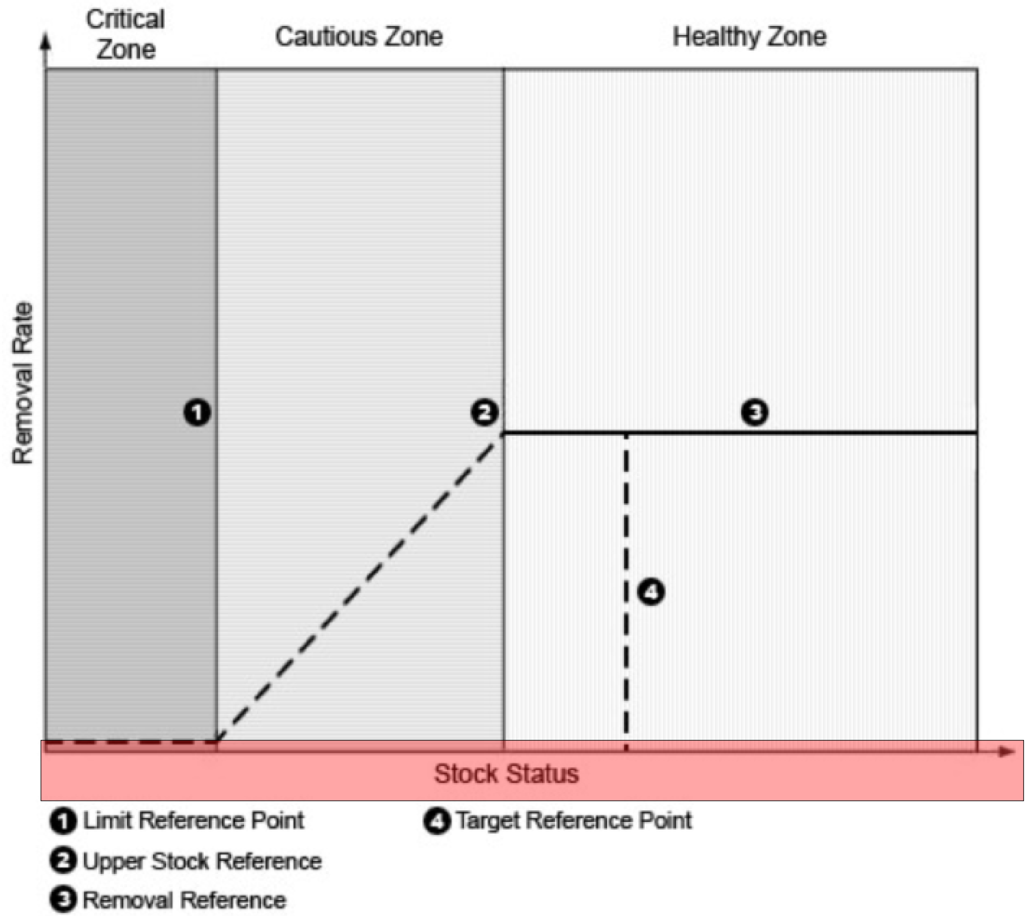
SENSITIVITY = stock-specific productivity/ ability to compensate for fishing-induced mortality



RISK = (EXPOSURE x SENSITIVITY) x CONSEQUENCE

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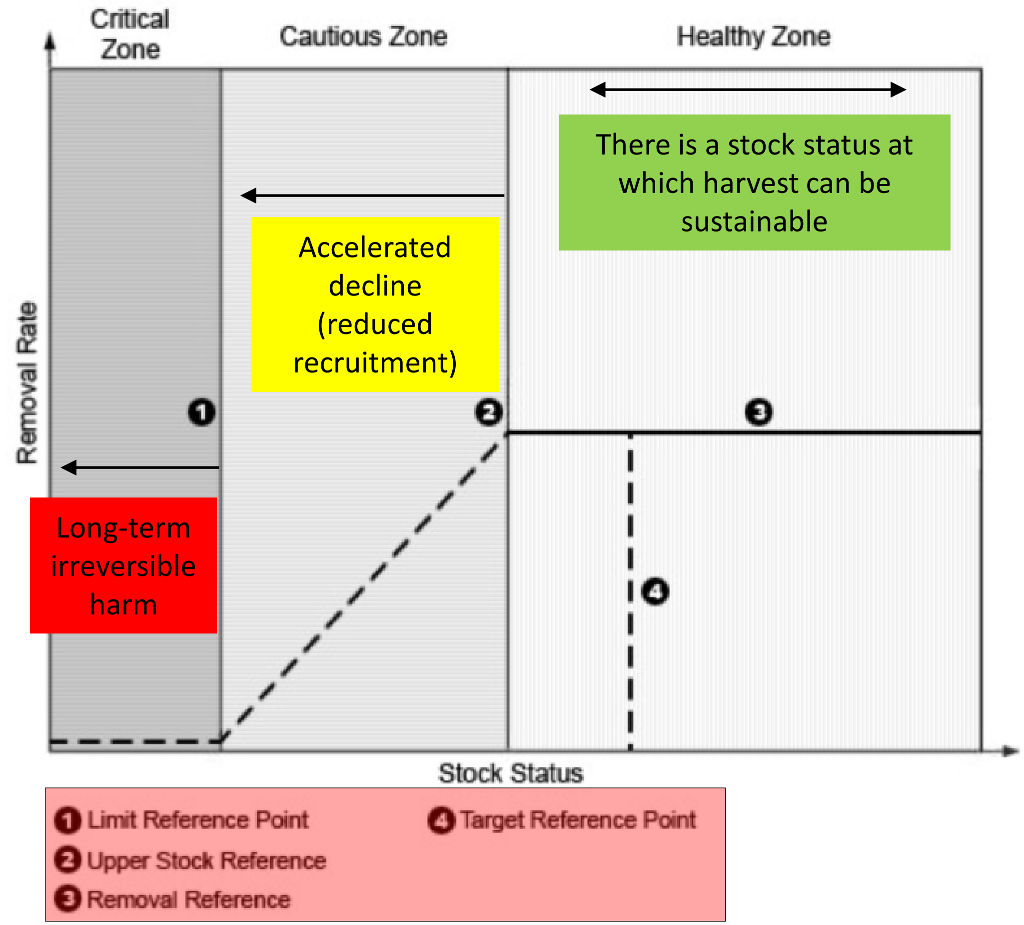
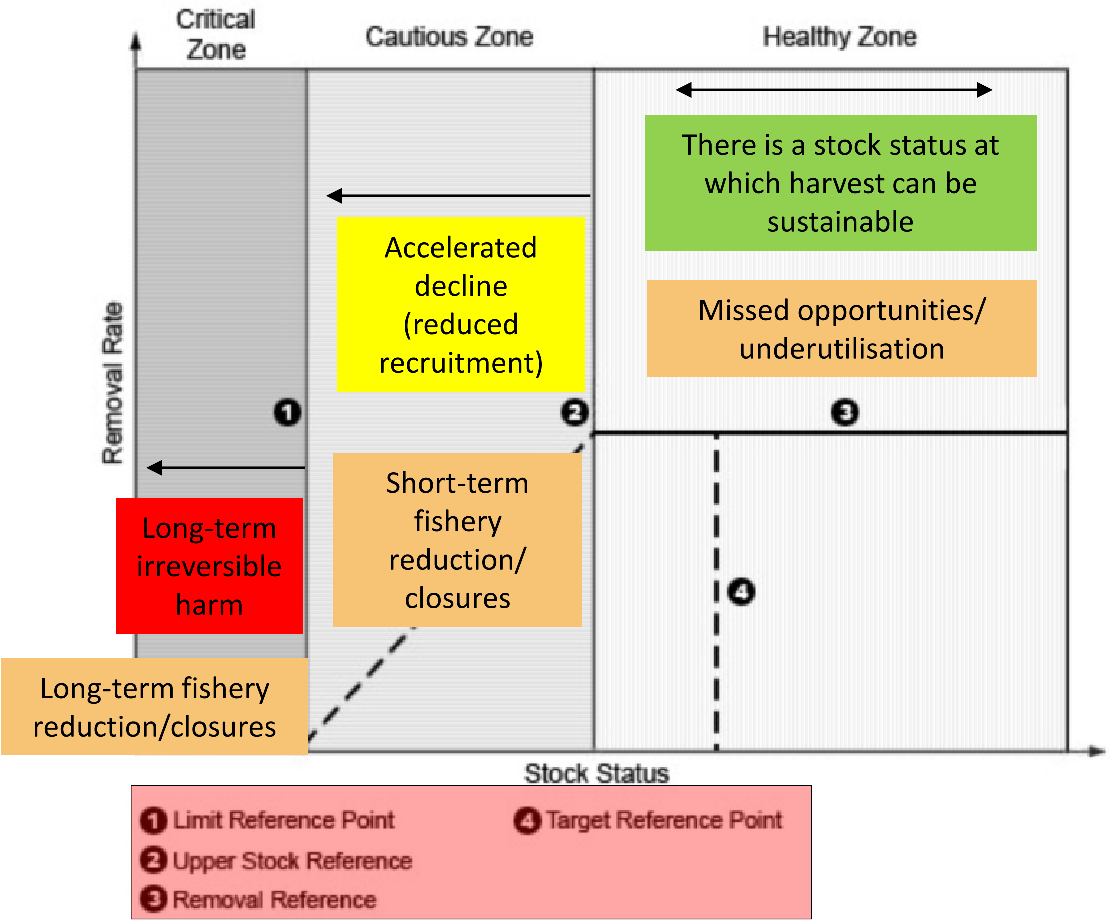
CONSEQUENCE is defined by the reference points which represent thresholds for biological outcomes



RISK = (EXPOSURE x SENSITIVITY) x CONSEQUENCE

This is a risk management framework

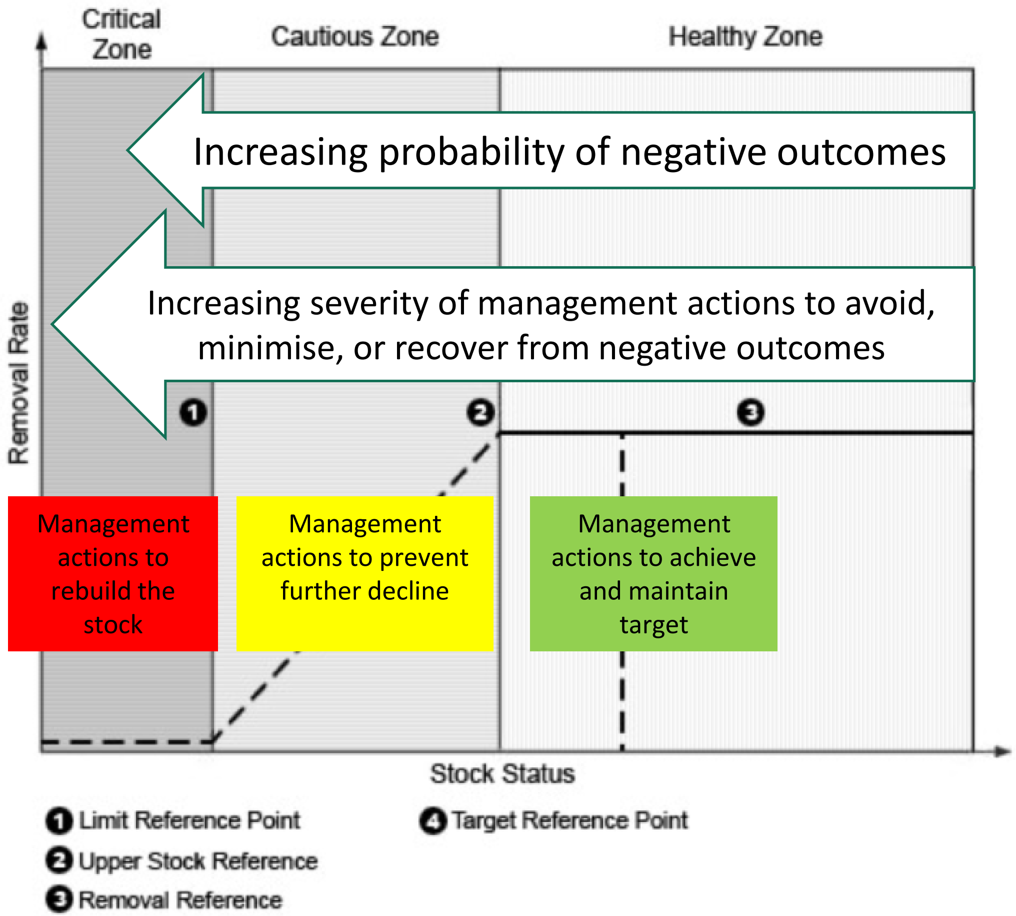
CONSEQUENCE is defined by the reference points which represent thresholds for **biological outcomes** and **fishery outcomes**



RISK = (EXPOSURE x SENSITIVITY) x CONSEQUENCE

This is a risk management framework

- Allows for the formulation of scientific advice in a way that conveys the possible consequences of uncertainty (risk assessment*)
- Provides criteria for the severity of management actions that can be taken to scale resource use (EXPOSURE) to resource state (SENSITIVITY) in a way to minimise the probability of negative outcomes = taking uncertainty into account when making management decisions (risk management*)



*definitions by Francis and Shotton 1997

RISK = (EXPOSURE x SENSITIVITY) x CONSEQUENCE

Risk is accounting for uncertainty

Which uncertainty?

Types of uncertainty that contribute risk in fisheries (Francis & Shotton 1997):

- Observation uncertainty
- Process uncertainty
- Model and estimation uncertainty
- Institutional and implementation uncertainty

"Risk" in fisheries management: a review

R.I.C.C. Francis and R. Shotton

Can. J. Fish. Aquat. Sci. **54**: 1699–1715 (1997)

Which uncertainty?

Types of uncertainty that contribute risk in fisheries (Francis & Shotton 1997):

- Observation uncertainty – quantifiable and reducible
- Process uncertainty – partly quantifiable, irreducible
- Model and estimation uncertainty – partly quantifiable and reducible
- Institutional and implementation uncertainty – possibly quantifiable and reducible

“Risk” in fisheries management: a review

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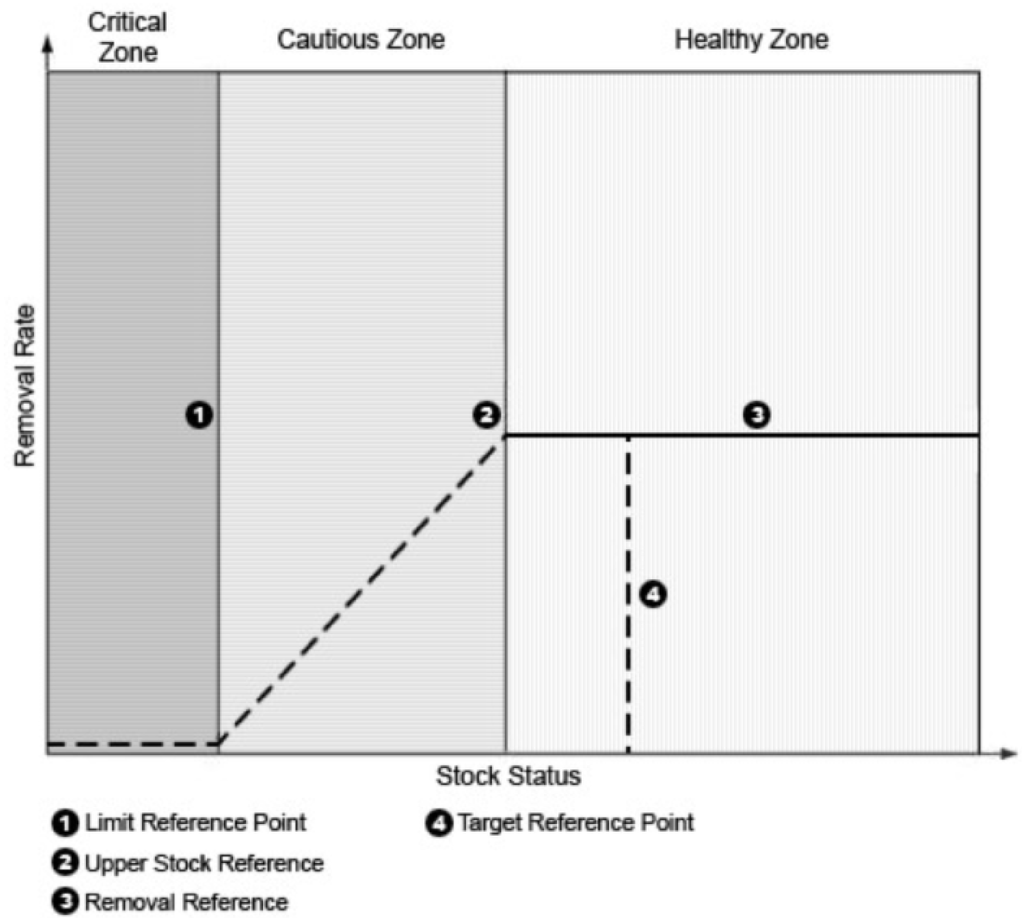
Which uncertainty?

Focus on <u>quantifiable scientific uncertainty</u> in PA framework

From PA guidance:

- *Uncertainty should be incorporated in the calculation of stock status and biological reference points.*

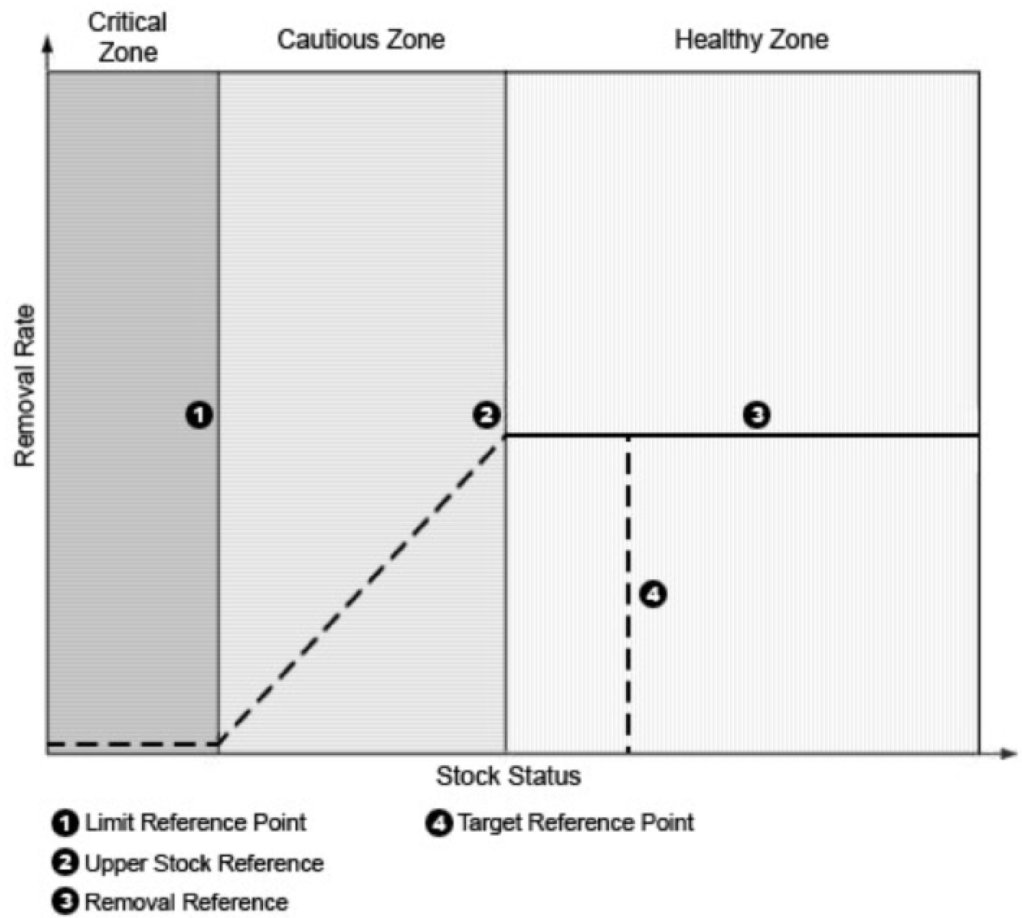
- *It is desirable that scientific uncertainty be quantified to the extent possible and used to assess the probability of achieving a target or of a stock falling to a certain level under a specific management approach (...)*



Which uncertainty?

Focus on quantifiable scientific uncertainty in PA framework

…which does not mean that institutional and/or implementation uncertainty have gone away, nor that other 'unquantifiable' sources of uncertainty are absent…



Unquantifiable uncertainty is always present

Unquantifiable uncertainty and the need for consistency in practice when accounting for uncertainty:

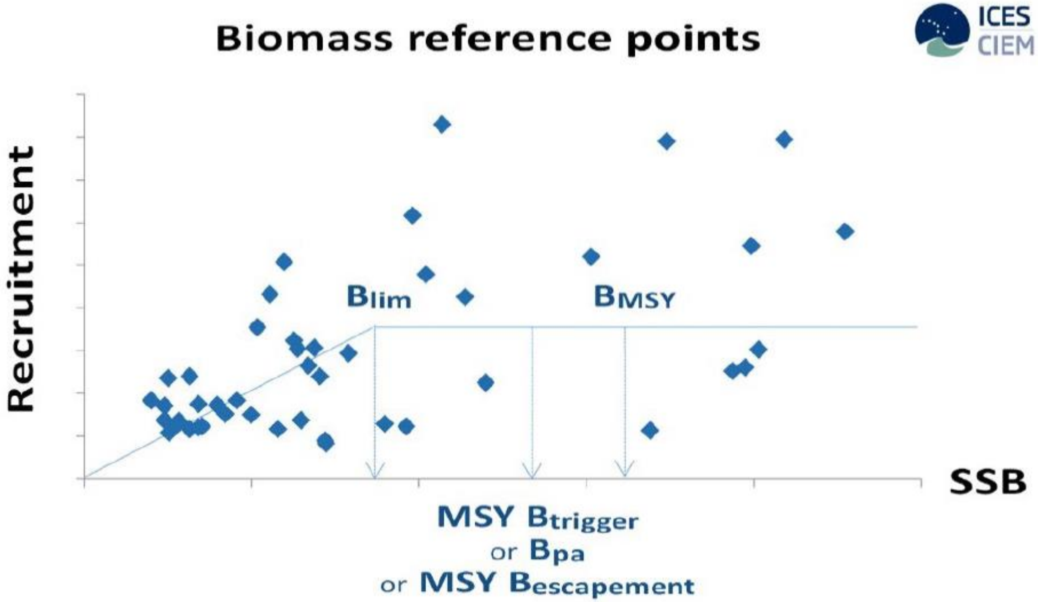
risk equivalency

Principle: Ensure that evidence-based scientific advice for fisheries will result in functionally similar outcomes (e.g., comparable low probabilities of SSB being reduced to unproductive sizes) despite:

- Stock by stock differences in productivity dynamics
- Stock by stock differences in data and knowledge availability
- Stock by stock differences in assessment methods
- Etc.

Risk equivalency: accounting for uncertainty arising from stock by stock differences in productivity dynamics

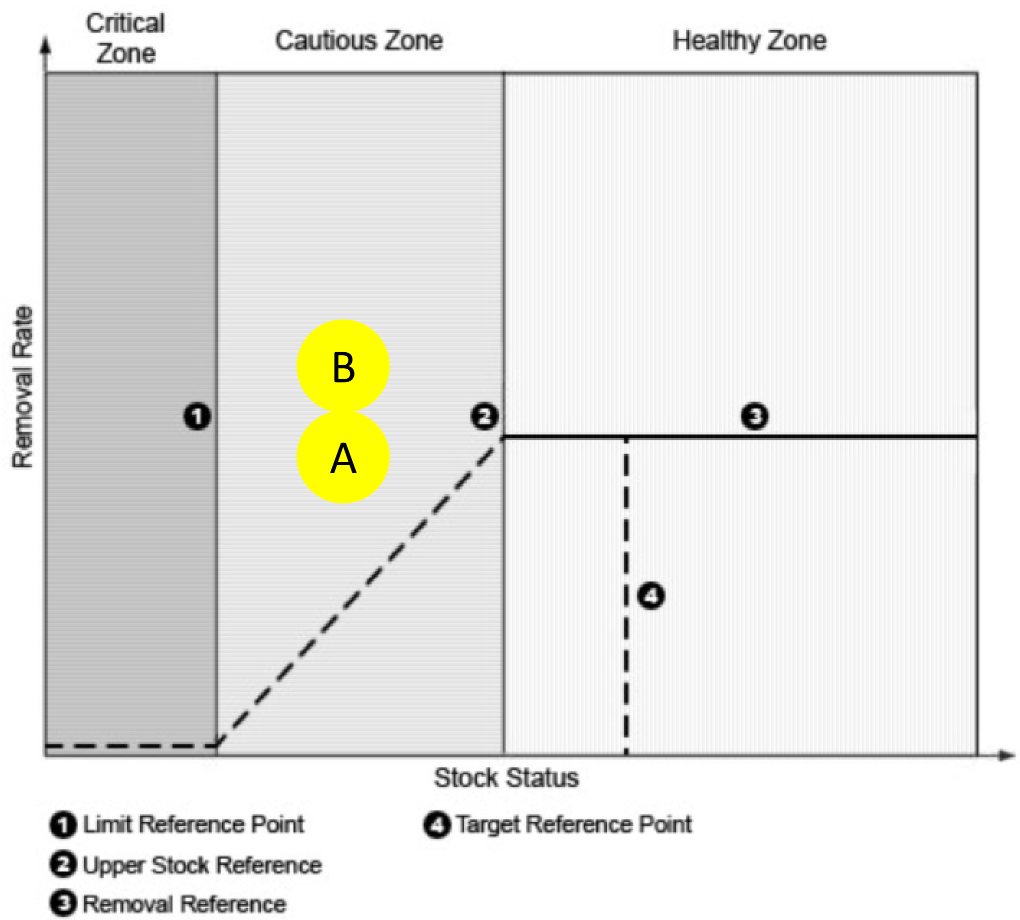
- ICES advice for long-lived vs short-lived category 1 and 2 stocks
- Advice for long-lived stocks aimed at F≤FMSY while maintaining the stock above Blim with at least 95% probability
- Advice for short-lived stocks is capped (Fcap) to limit exploitation rate when biomass is high and maintain a high probability of achieving a minimum biomass left to spawn (Bescapement - which includes a biomass buffer to account for uncertainty in the assessment)



- Ensure functionally equivalent outcomes: low risk of impaired recruitment despite large fluctuations in biomass in short-lived stocks and a higher sensitivity to recruitment = Risk equivalent advice

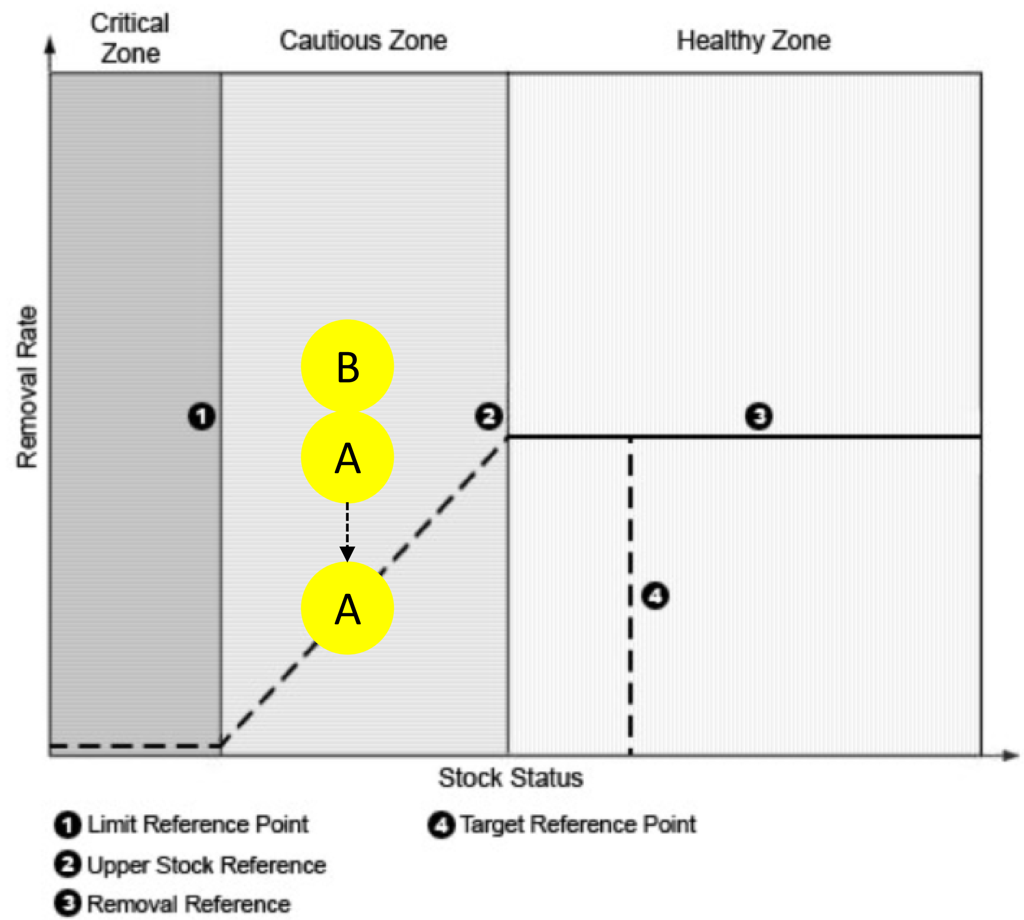
Risk equivalency: accounting for uncertainty arising from differences in data availability and/or assessment type

- A is a data-limited stock with a survey index (indicator-based assessment)
- B is a data-rich stock with estimated SSB (analytical assessment)
- Both have similar status under current exploitation rates
- Probability of decline below LRP is A>B because A is more uncertain



Risk equivalency: accounting for uncertainty arising from differences in data availability and/or assessment type

- A is a data-limited stock with a survey index (indicator-based assessment)
- B is a data-rich stock with estimated SSB (analytical assessment)
- Both have similar status under current exploitation rates
- Probability of decline below LRP is A>B because A is more uncertain
- **Risk equivalent advice**: adjust exploitation rate for A to account for higher (but not explicitly quantified) scientific uncertainty and ensure comparable risk (i.e., functionally equivalent outcomes of PA application) in both stocks



Risk equivalency: examples from other jurisdictions

- Definition and application of **buffers** to the advice in order to maintain a level of risk consistent with the *level considered acceptable* (to avoid true B< Blim and true F> Flim)

$$\boxed{\text{Buffer}} = \frac{ADVICE_{[adjusted\ for\ uncertainty]}}{ADVICE_{[status\ quo]}}$$

$$\boxed{\text{Buffer}} = \frac{ABC}{OFL}$$

Accepted biological removals

Overfishing level

- US, AUS & ICES: buffers applied to equalise risk among tiers/stock categories characterised by similar data availability and/or harvest control rules

- Buffers = precautionary reduction in catch advice in high risk data poor assessments to reflect potential bias and uncertainty in the assessment method

Risk equivalency: examples from other jurisdictions

- AUS: buffer size based on assessment method (semi-arbitrarily defined with no formal evaluation) (Stobutzki et al. 2011)
- US: buffer size based on assessment uncertainty (estimated considering among assessment variation (Ralston et al. 2011)
- Buffer performance evaluated in simulations assuming a range of life histories and information content (single-specie (Punt et al. 2012)) and in a multi-species context (Fulton et al. 2016)

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journal homepage: www.elsevier.com/locate/fishres

ELSEVIER

Developing risk equivalent data-rich and data-limited harvest strategies

Elizabeth A. Fulton[a,*], André E. Punt[a,b], Catherine M. Dichmont[c,d], Rebecca Gorton[a], Miriana Sporcic[a], Natalie Dowling[a], L. Richard Little[a], Malcolm Haddon[a], Neil Klaer[a], David C. Smith[a]

ICES Journal of Marine Science

ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2012), 69(4), 624–634. doi:10.1093/icesjms/fss047

Evaluating the impact of buffers to account for scientific uncertainty when setting TACs: application to red king crab in Bristol Bay, Alaska

André E. Punt[1*], M. S. M. Siddeek[2], Brian Garber-Yonts[3], Michael Dalton[3], Louis Rugolo[3], Diana Stram[4], Benjamin J. Turnock[3], and Jie Zheng[2]

Risk equivalency: examples from other jurisdictions

Buffers are at least partly, arbitrary

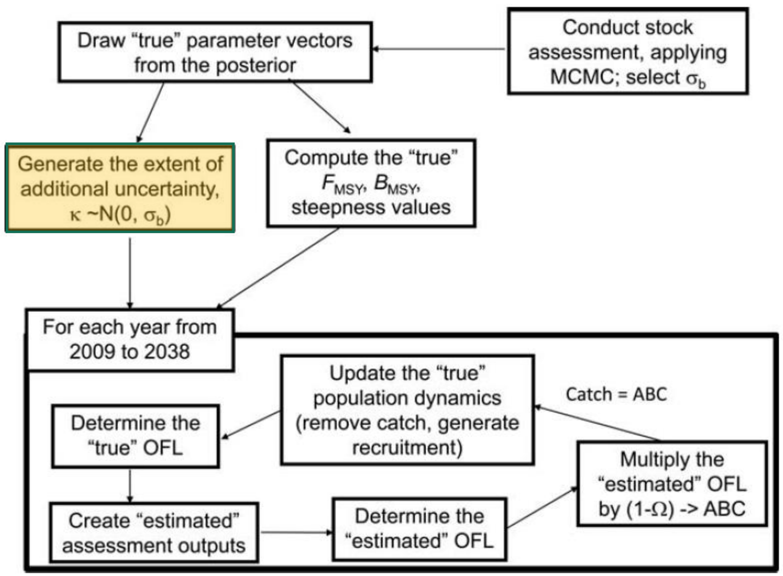

Figure 2. Flowchart of the algorithm used to evaluate the medium- and long-term implications of the alternative choices for the buffer.

Punt et al. 2012

uncertainty quantified using the stock assessment

\+

unquantifiable uncertainty
(specified based on expert opinion and comparisons with other stocks)

Simulations: used to demonstrate that the assumption of σ_b =0 is clearly invalid (Punt et al. 2012)

Risk equivalency = consistency in practice

when accounting for uncertainty in scientific advice for fisheries

Risk equivalency = consistency in practice when accounting for uncertainty arising from:

- ✓ Stock by stock differences in productivity dynamics
- ✓ Stock by stock differences in data and knowledge availability
- ✓ Stock by stock differences in assessment methods

- ➢ Changes in ecosystem/environmental (E) conditions affecting stock status and productivity

Risk equivalency to account for uncertainty arising from ecosystem/environmental (E) variation and change

Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2019/044

National Capital Region

Resource management under climate change: a risk-based strategy to develop climate-informed science advice

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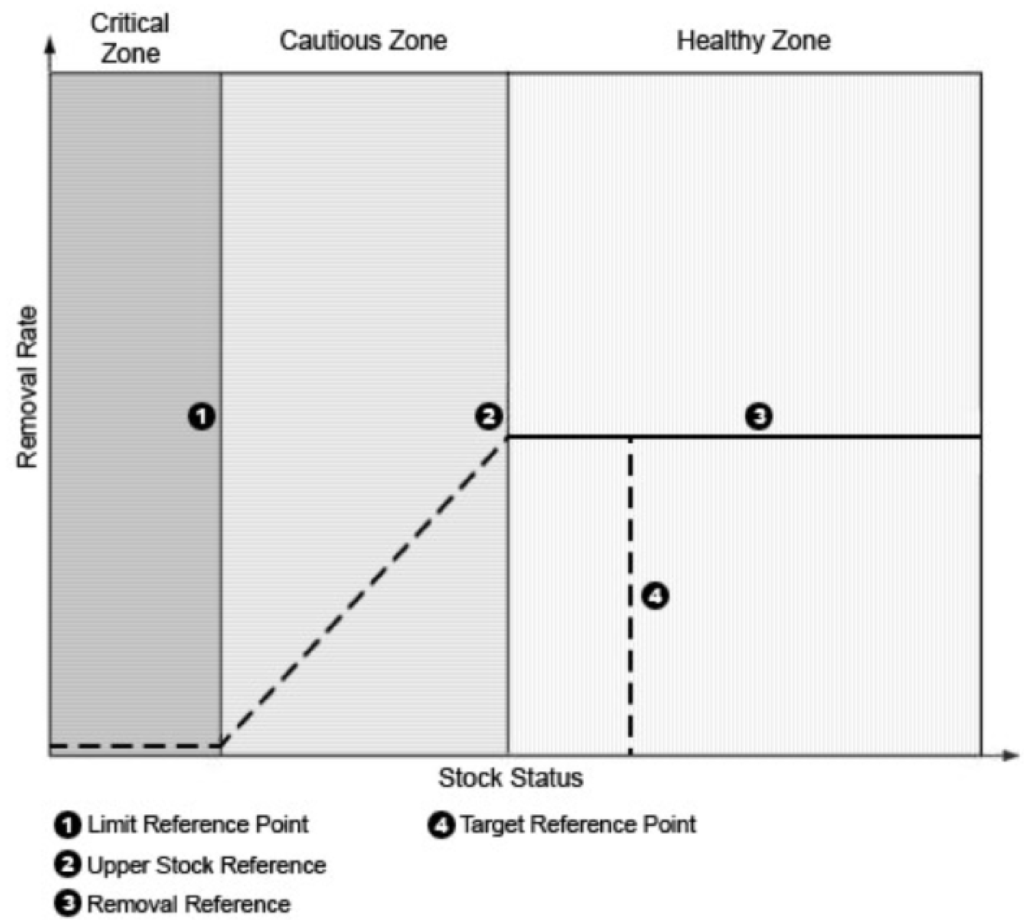
Where is the ecosystem/environment in the PA framework?

- Vague mention of potential E effects on associated species when status falls below Blim (PA guidelines)

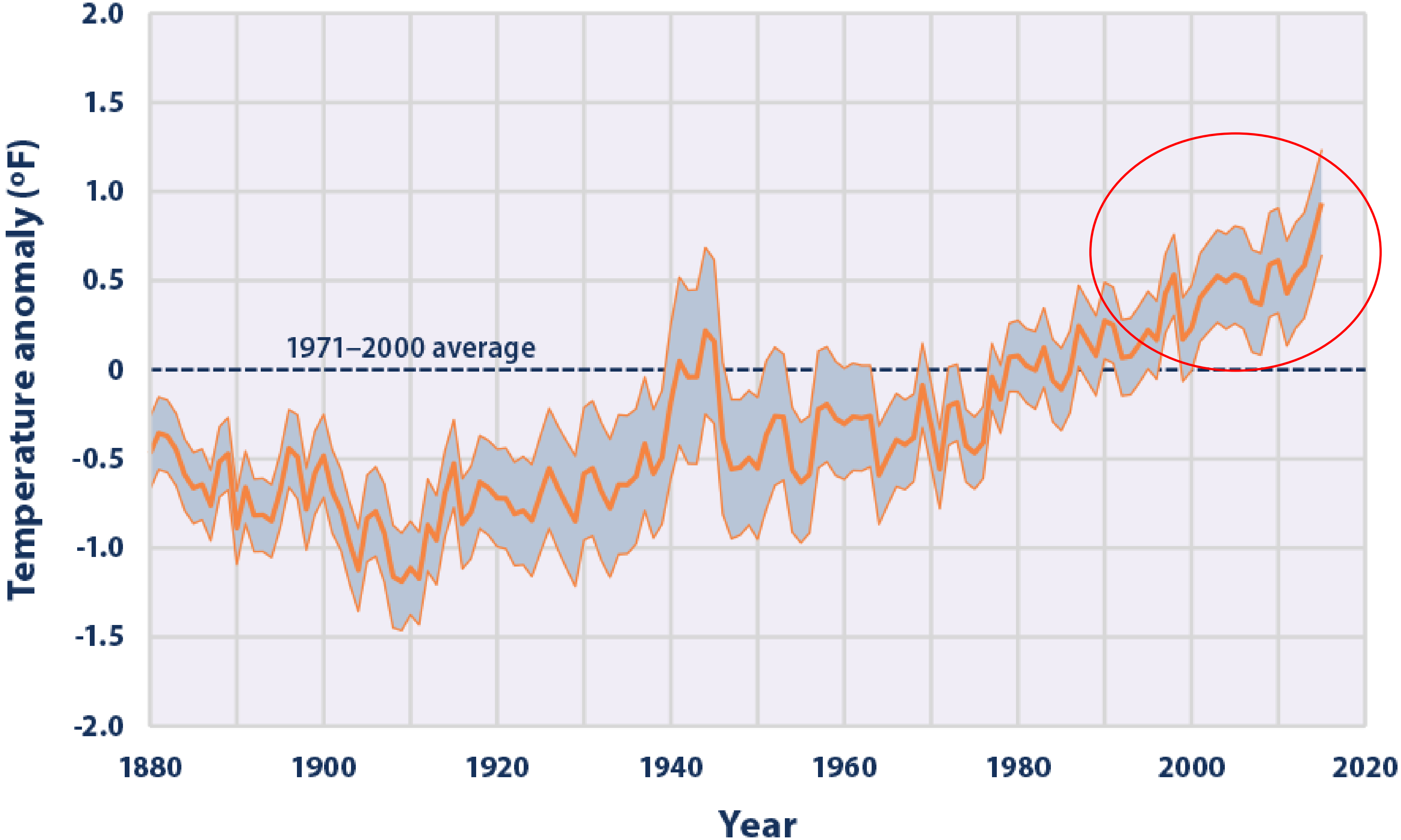
- The invisible, third axis: **assumed constant or randomly varying about some historical scatter and/or previously observed conditions**

- Reference points are defined based on the assumption of average environmental conditions ($E_{baseline}$)

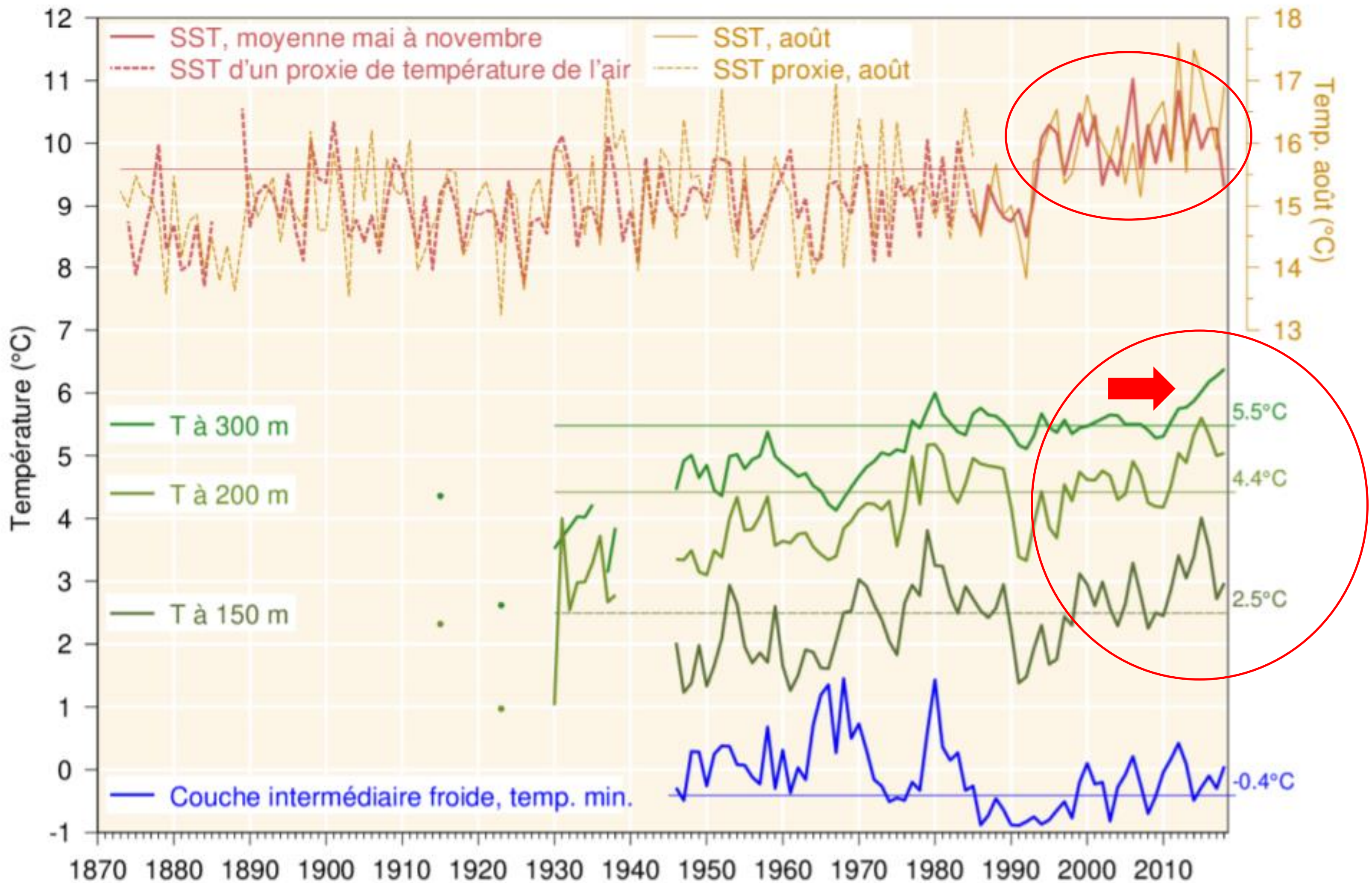


E is always included, though not explicitly

Violation of constant/random E assumption



Violation of constant/random E assumption



Galbraith et al. 2019

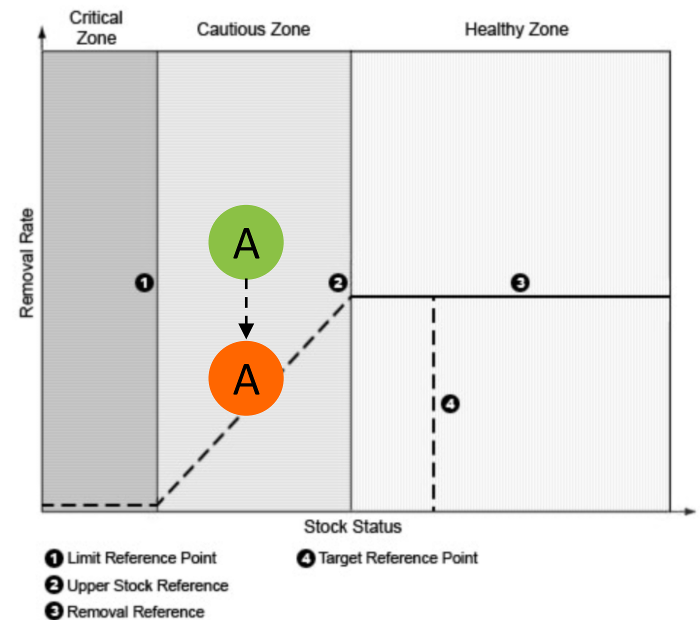
Violation of constant/random E assumption in PA framework

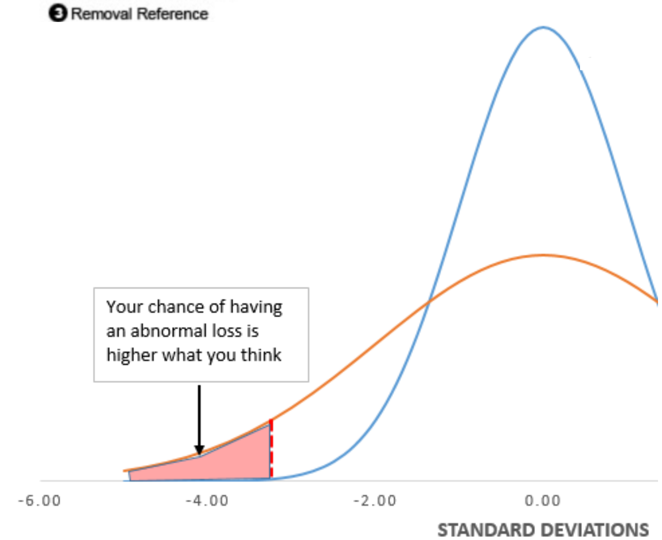
- E departure from baseline conditions: potential bias and additional uncertainty in the assessment

- Consider stock A under **E=Ebase** vs stock A under **E>Ebase** (unfavourable conditions for stock productivity)

- Probability of stock A falling below LRP higher under **E>Ebase** conditions (heavier left tail)

- Risk equivalent advice: adjust exploitation rate to account for uncertainty contributed by (unfavorable) environmental conditions





Risk equivalency to account for uncertainty arising from environmental variation and change

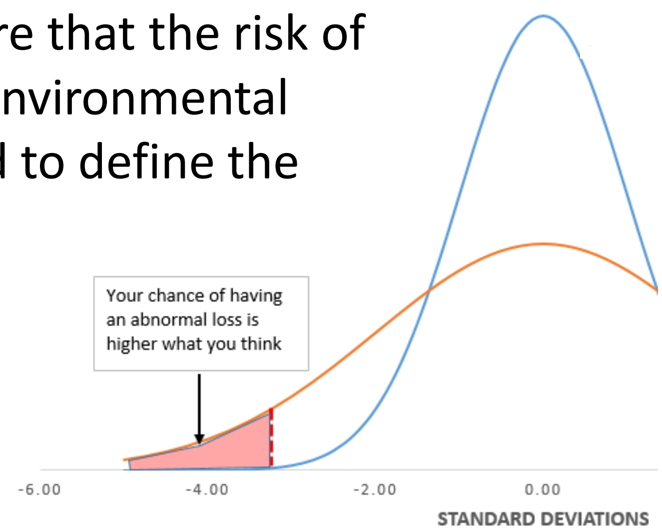
Buffers are used to equalise risk among assessment types

+ Data and knowledge availability -

Model-based assessments

Indicator-based assessments

E-conditioning factors (CF) can be used to ensure that the risk of achieving objectives remains comparable when environmental conditions shift outside the long-term mean used to define the reference levels.



Risk equivalency to account for uncertainty arising from environmental variation and change

E-conditioning factors (CF)

P = Probability of achieving an objective as a function of F given model uncertainty

*P**= Probability of achieving an objective as a function of F given model uncertainty and additional uncertainty related to changes in E

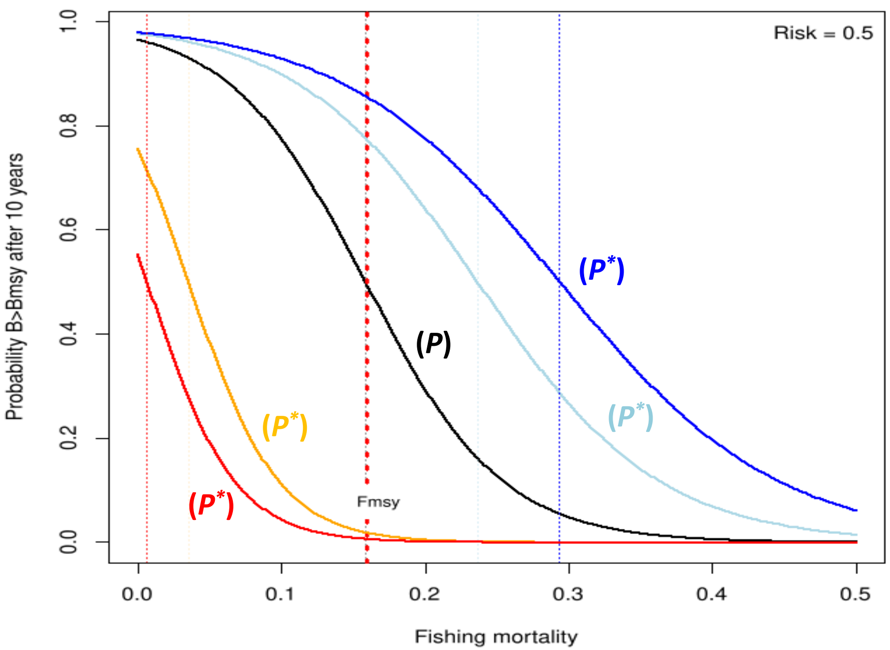
Example for P = 0.4^:

$F_{P*}/F_P = 0.11 =$ CF

$F_{P*}/F_P = 0.28 =$ CF

$F_{P*}/F_P = 1.50 =$ CF

$F_{P*}/F_P = 1.90 =$ CF



P P** = Favorable E conditions

P P** = Unfavorable E conditions

^objective is to maintain a 40% probability that true B is > Bmsy under shifting productivity

Risk equivalency to account for uncertainty arising from environmental variation and change

E-conditioning factors (CF)

Advice on fishing opportunities is

↓ when E conditions are unfavorable
(higher probability of negative outcomes)

↑ when E conditions are favorable
(lower probability of negative outcomes)

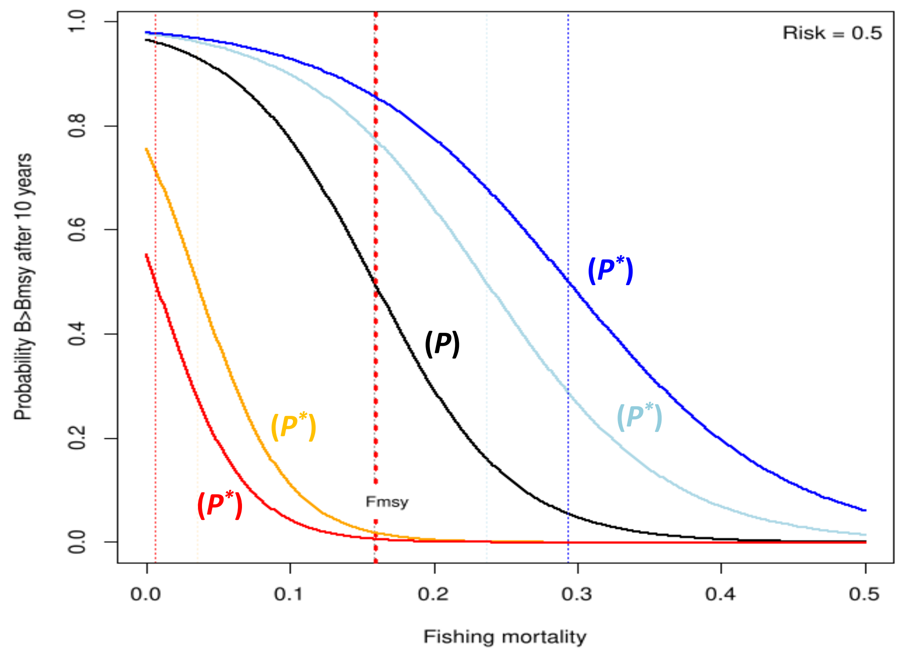
Example for P = 0.4^:

$F_{P^*}/F_P = 0.11 =$ CF

$F_{P^*}/F_P = 0.28 =$ CF

$F_{P^*}/F_P = 1.50 =$ CF

$F_{P^*}/F_P = 1.90 =$ CF



P^* P^* = Favorable E conditions

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^objective is to maintain a 40% probability that true B is > Bmsy under shifting productivity

E-contributed uncertainty is process uncertainty

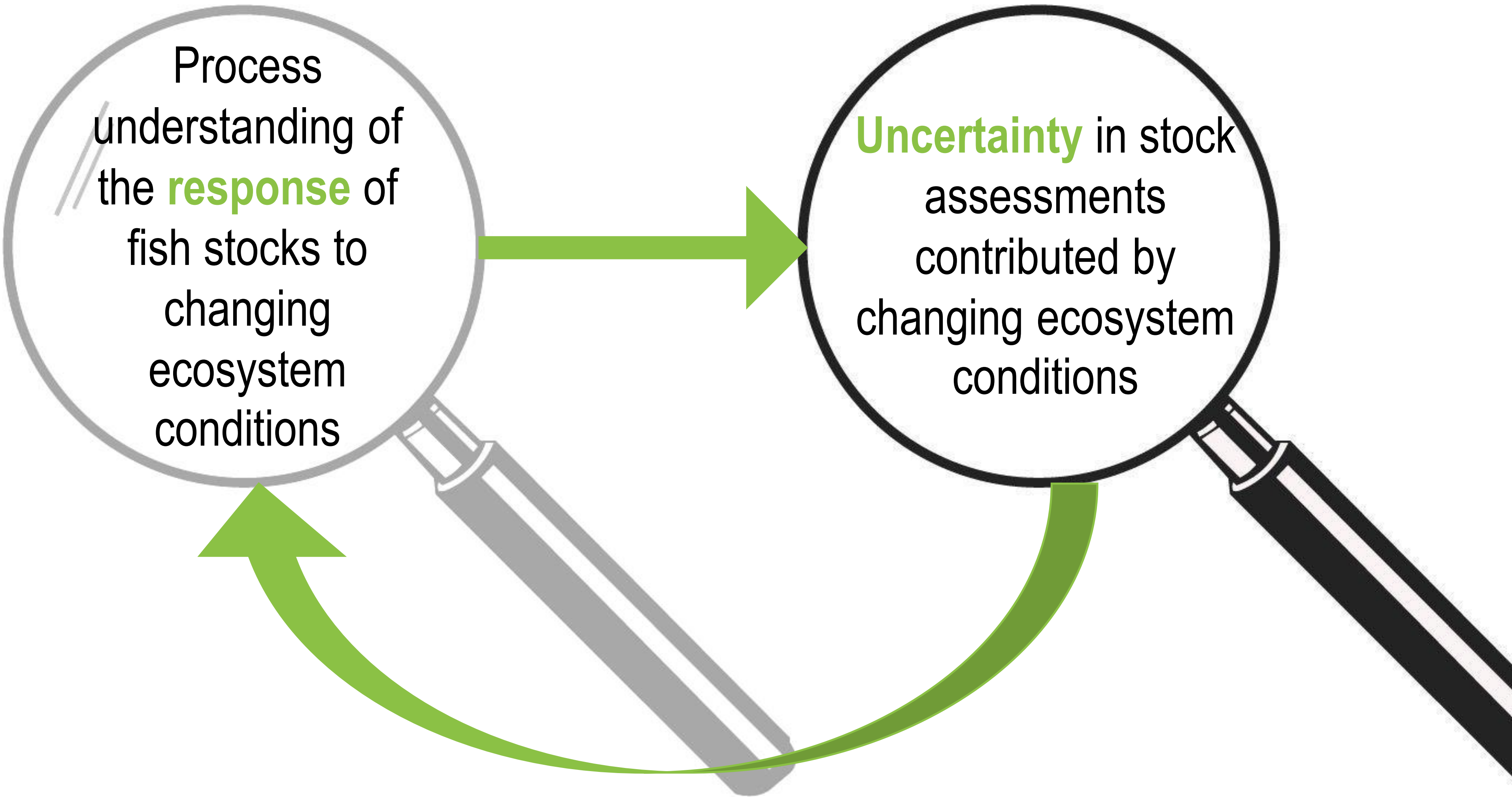
Types of uncertainty that contribute risk in fisheries (Francis & Shotton 1997):

- Observation uncertainty – quantifiable and reducible
- Process uncertainty – partly quantifiable, irreducible
- Model and estimation uncertainty – partly quantifiable and reducible
- Institutional and implementation uncertainty – possibly quantifiable and reducible

E-contributed uncertainty can be quantified and estimated however in most cases it can only be approximated based on the best available scientific information to ensure it is included in the advice

A risk-based approach is applicable across the data and process knowledge continuum

A risk-based approach implies a change in focus



Objective: risk-based conditioning of advice for E-effects

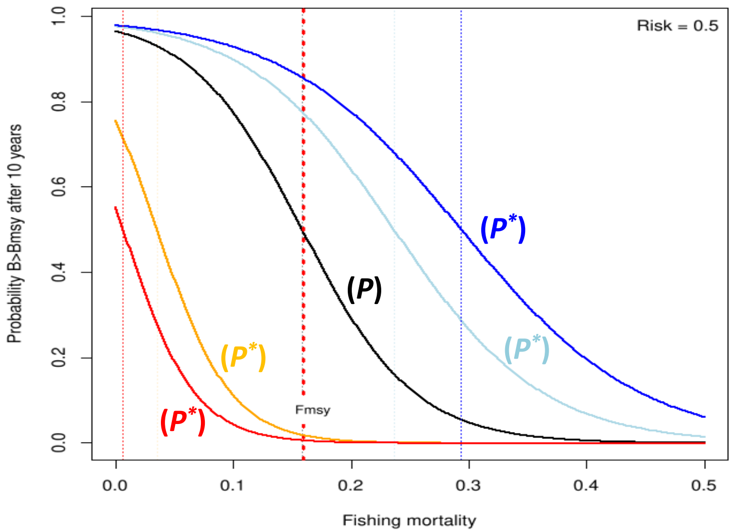
+ Data and knowledge availability -

CF estimation (model-based)

CF approximation (scoring-based)

E.g., stock response to F and changing E is known (there is an analytical model with E variable(s) or time-varying productivity parameter(s) with underlying E hypotheses

E.g., stock response to F is known or approximated and response to changing E is unknown but can be investigated using empirical modeling



Objective: risk-based conditioning of advice for E-effects

+ Data and knowledge availability -

CF estimation (model based)

CF approximation (scoring-based)

E.g., stock response to F and changing E is unknown and data are insufficient for quantitative modeling

Risk-based conditioning of advice: GSL case study examples

+ Data and knowledge availability -

CF estimation (model-based)

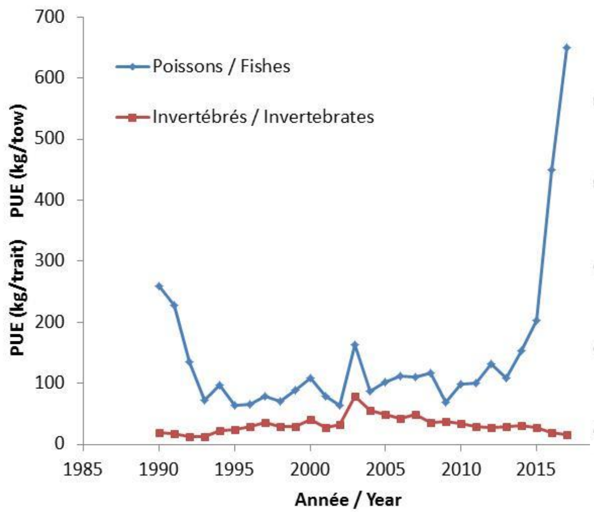
CF approximation (scoring-based)

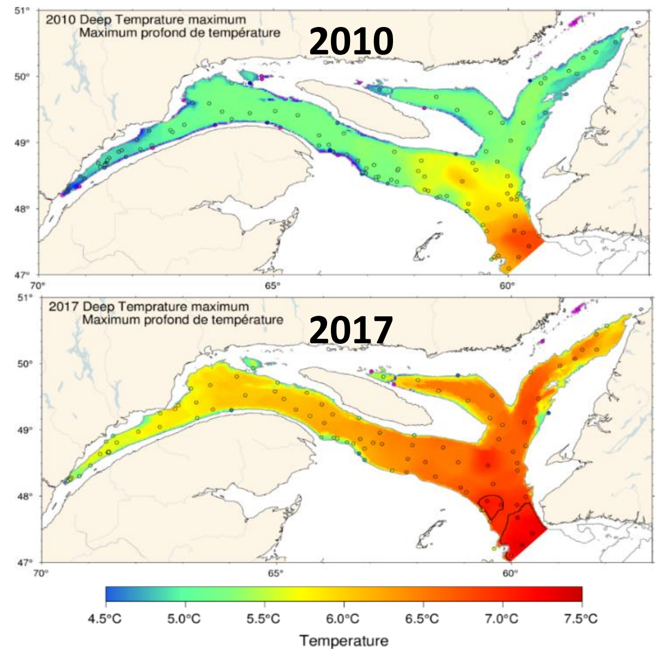
Northern shrimp: stock response to F is approximated in HCR and stock response to E is unknown

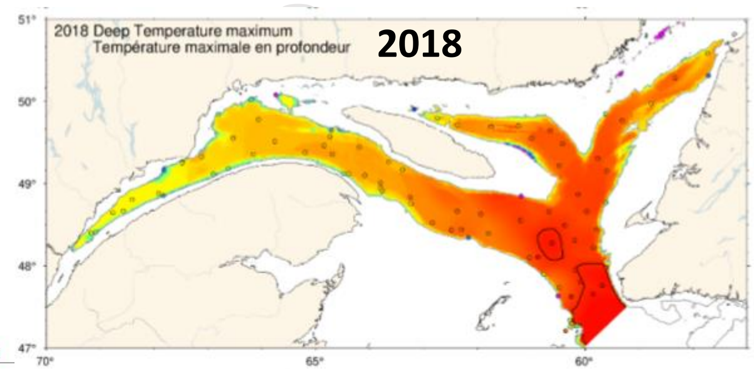
Greenland halibut: stock status and trajectory assessed using survey-based indicators and stock response to E is unknown

Risk-based conditioning of advice: GSL case study examples

- Cold-water adapted species subject to increasing bottom water temperature and changing community composition
- Declining biomass trends since approx. 2015







Three steps to developing risk-equivalent advice
accounting for ecosystem/environmental conditions:

1. Definition of risk-based ecosystem (E) hypotheses and identification of E variable(s) and baseline E conditions (Ebase)
2. Advice conditioning based on <u>magnitude of change</u> in E
3. Advice conditioning based on <u>frequency and recurrence</u> of E deviation from Ebase (tactical vs strategic considerations)

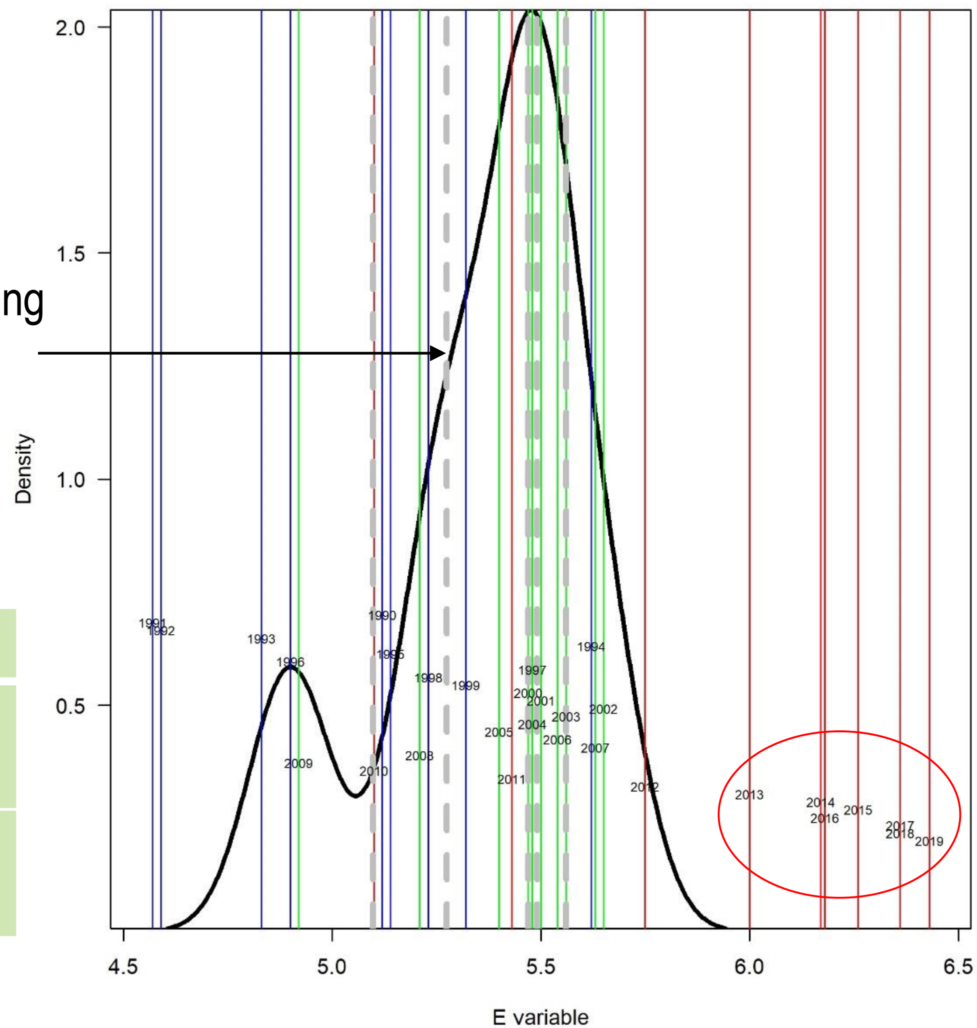
Three steps to developing risk-equivalent advice
accounting for ecosystem/environmental conditions:

1. Definition of risk-based ecosystem (E) hypotheses and identification of E variable(s) and baseline E conditions (Ebase)

E variable = bottom water temperature

Distribution of annual values during baseline period (1996-2002)

1990-1999 2000-2009 2010-2019



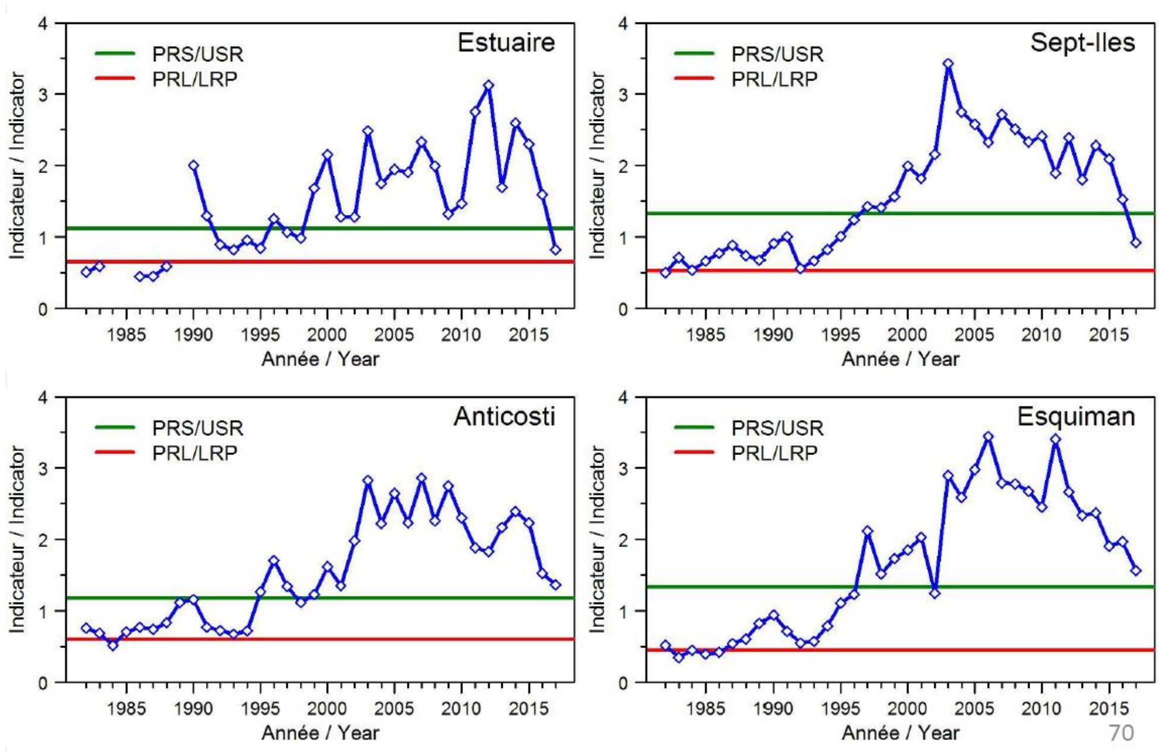
	Risk-based hypothesis
H0	Increasing bottom water temperature has no impact on stock productivity
H1	Increasing bottom water temperature negatively affects stock productivity

Three steps to developing risk-equivalent advice
accounting for ecosystem/environmental conditions:

1. Definition of risk-based ecosystem (E) hypotheses and identification of E variable(s) and baseline E conditions (Ebase)
2. Advice conditioning based on magnitude of change in E


Things to consider:

- 4 stocks/management units for northern shrimp in the GSL
- No quantitative stock assessment
- There is an operational PA framework with reference points and a harvest control rule (developed using data from 1990-2010)



E-conditioning of advice: data-limited scoring method

+ Data and knowledge availability -

CF estimation (model based)

CF approximation (scoring method)

$$CF_{ij} = (S_i * E/E_{base}) * k_j$$

Sensitivity (species *i*)

Exposure (magnitude of current E deviation from Ebase)

Scaling factor (consequence *j*)

E-conditioning of advice: data-limited scoring method

SENSITIVITY = potential to recover from adverse effects, migrate towards more favourable conditions and/or adapt to new conditions

$S_i = U(S_{min}, S_{max})$ with $S_{min} = 3.0/4.0$ and $S_{max} = 3.8/4.0$

Productivity attributes

Experimental data

$$CF_{ij} = S_i * E/E_{base}$$

NOAA's Northeast Fish and Shellfish Climate Vulnerability Assessment (CVA)

https://www.fisheries.noaa.gov/national/climate/climate-vulnerability-assessments

Northern Shrimp – *Pandalus borealis*

Overall Vulnerability Rank = High

Biological Sensitivity = High
Climate Exposure = High
Data Quality = 83% of scores ≥ 2

	Pandalus borealis	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	3.6	1.4	
	Other Stressors	2.3	2.0	
	Population Growth Rate	1.2	2.8	
	Spawning Cycle	3.1	3.0	
	Complexity in Reproduction	2.8	2.2	
	Early Life History Requirements	2.9	1.8	
	Sensitivity to Ocean Acidification	2.2	2.6	
	Prey Specialization	1.7	2.4	
	Habitat Specialization	2.6	3.0	
	Sensitivity to Temperature	3.2	3.0	
	Adult Mobility	1.7	2.6	
	Dispersal & Early Life History	2.1	2.2	
	Sensitivity Score	High		

Low
Moderate
High
Very High

E-conditioning of advice: data-limited scoring method

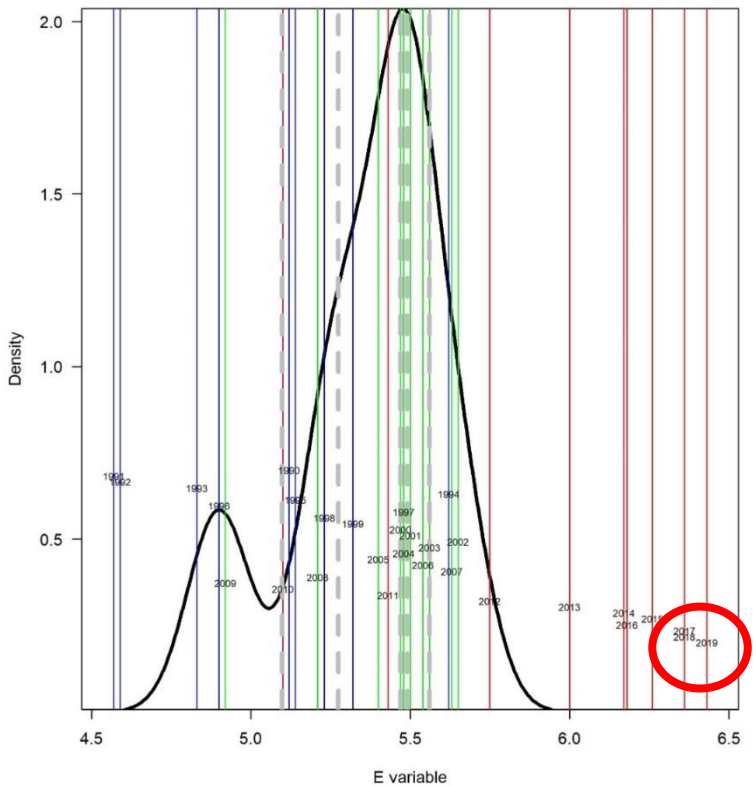
EXPOSURE= Magnitude of E forcing on stock productivity

E-baseline = period used to define the USR

$$Tdeep_{2018\text{-}2019}/Tdeep_{1996\text{-}2002}$$

$$CF_{ij} = S_i * E/E_{base} *$$

EXPOSURE
Magnitude of current E
deviation from Ebase



E-conditioning of advice: data-limited scoring method

k relates to the anticipated outcome (consequence) of E forcing (*k* depends on the hypothesis and managed quantity)

The definition of *k should take into account*:

1. The expected magnitude of change in stock productivity and response to F under E forcing

SIMULATION

$CF_{ij} = S_i * E/E_{base} *$

2. The level of risk considered acceptable under changing E conditions

RISK TOLERANCE

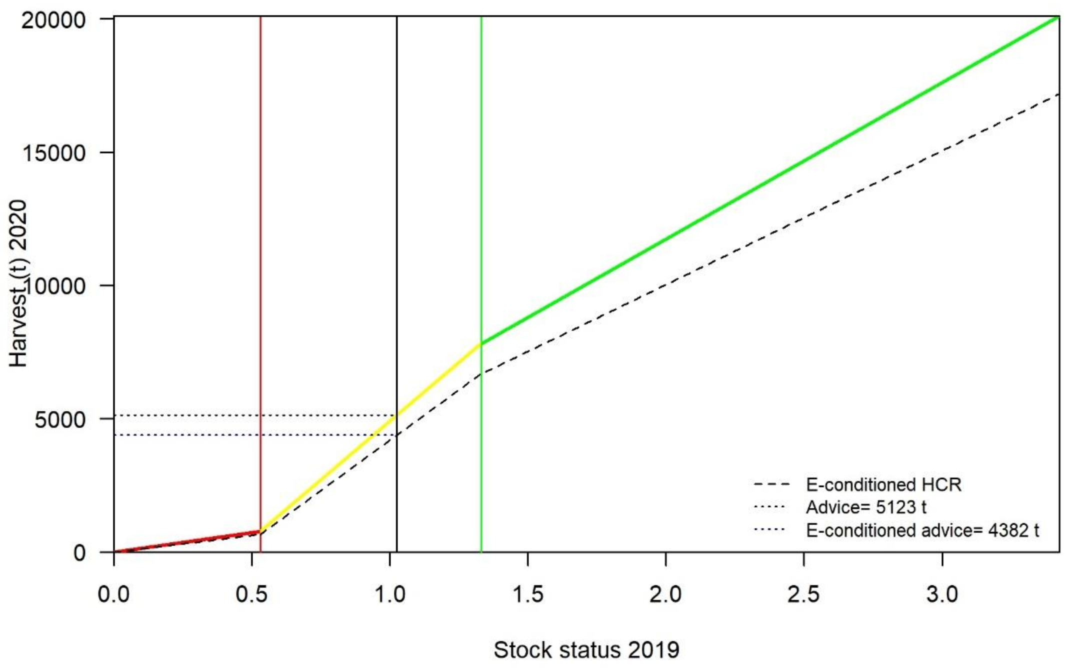
$$k_j = U(k_{min}, k_{max})$$

($kmin$=0.1 and $kmax$=0.3)

Scaling factor (consequence *j*)

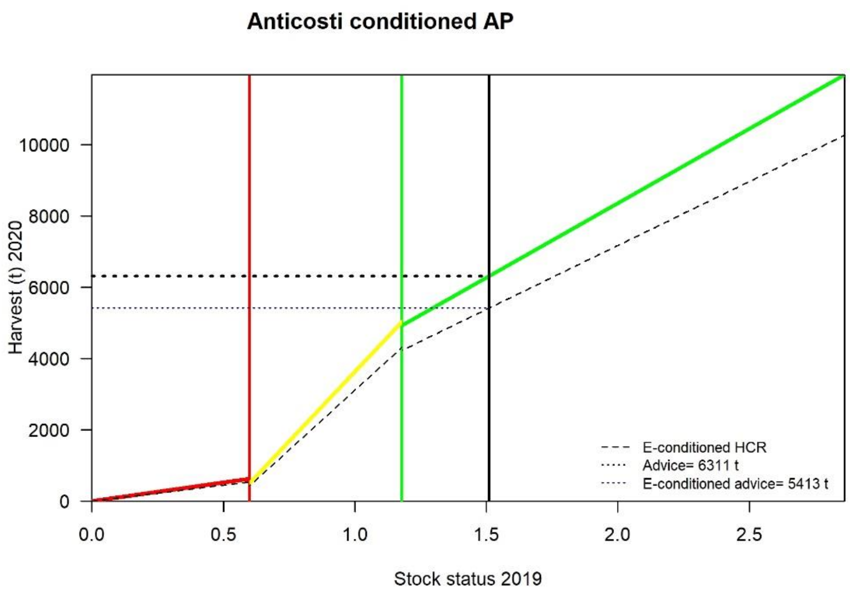
E-conditioning of advice: data-limited scoring method

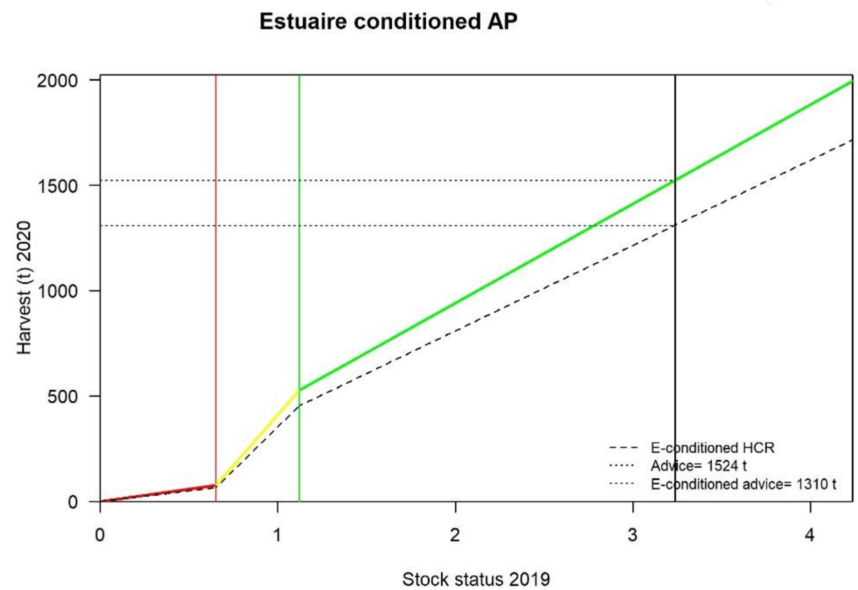
$$CF_{ij} = U(S_{min},S_{max})^{*} E/E_{base}{}^{*} U(k_{min},k_{max})$$

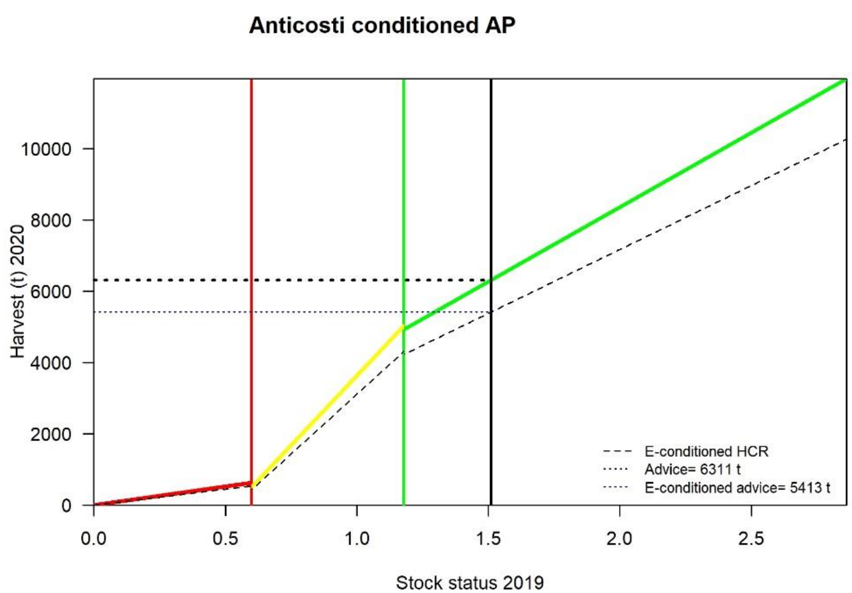


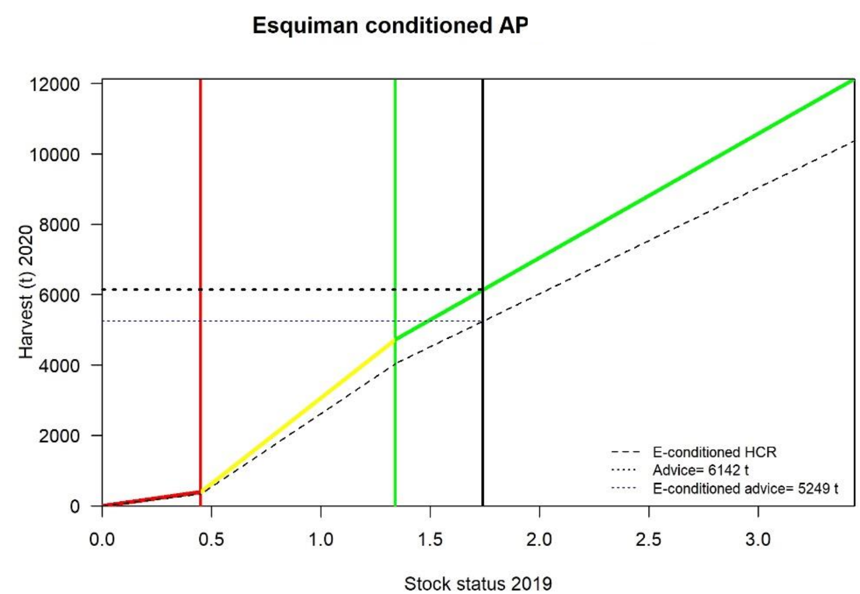
- *1-CF_{ij}* applied symmetrically to HCR parameters to derive E-conditioned advice
- *CF_{ij}* could also be used to condition the inflexion points (derive OCPs)
- Asymmetry required to maintain precaution under favourable E (1+*CF_{ij}*)

E-conditioning of advice: data-limited scoring method









E-conditioning of advice: data-limited scoring method

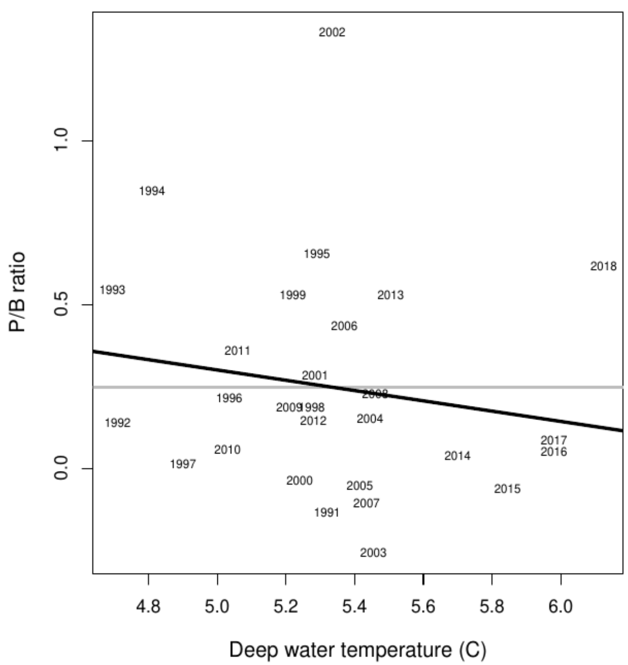
- E-conditioned advice is presented alongside status quo advice to ensure consistency in practice and effective communication
- Risk-based scoring method is straightforward and applicable to most data-limited stocks using existing data and information (e.g., sensitivity scores from climate vulnerability assessments (CVAs) and/or results from experimental/lab studies)
- Process-based understanding of productivity dependence on E is not required but all components of risk are included
- The approximated CFs determine the reduction in fishing pressure required to maintain the same probability of achieving PA objectives, given uncertainty contributed by E variation and change (which is evidenced but not yet quantified)

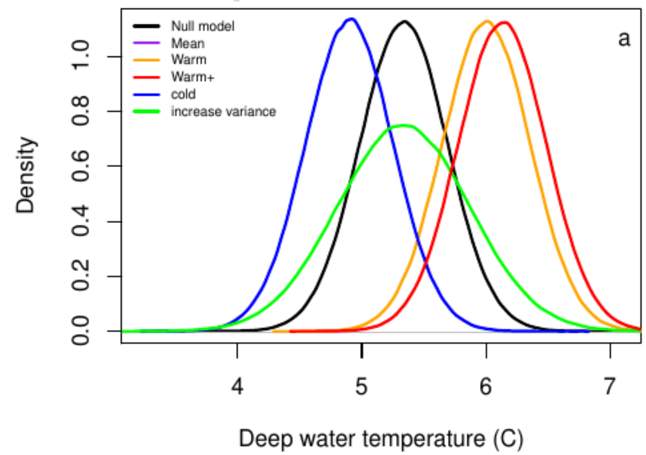
E-conditioning of advice using empirical modeling

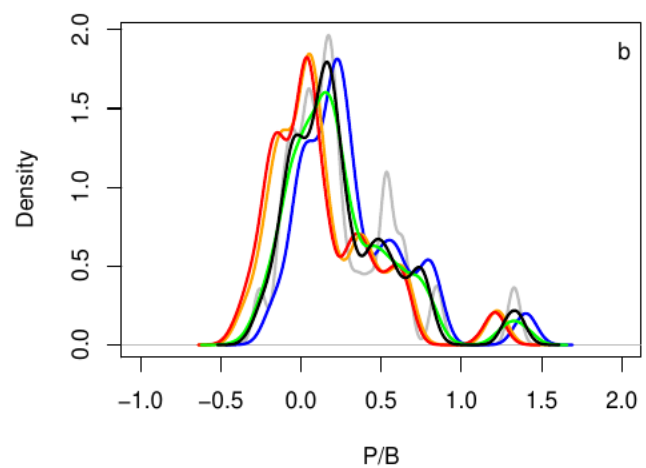
+ **Data and knowledge availability** **-**

CF estimation (empirical model)

Productivity-dependence on bottom water temperature (1990-2018)







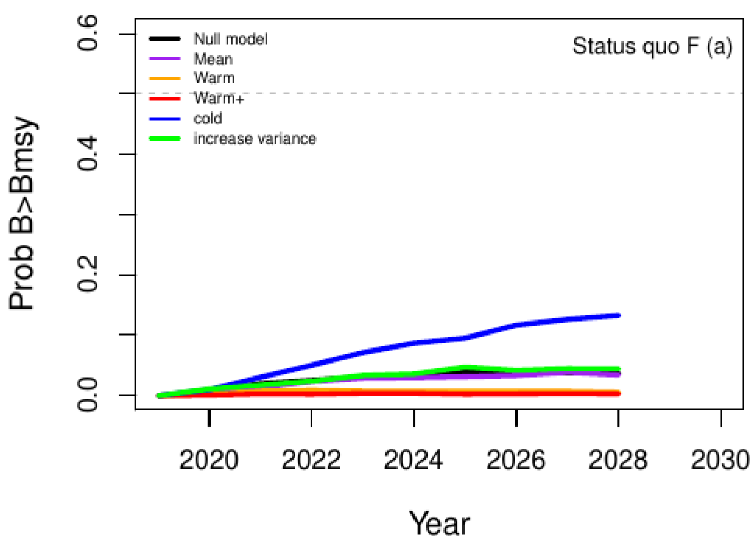
E-conditioning of advice using empirical modeling

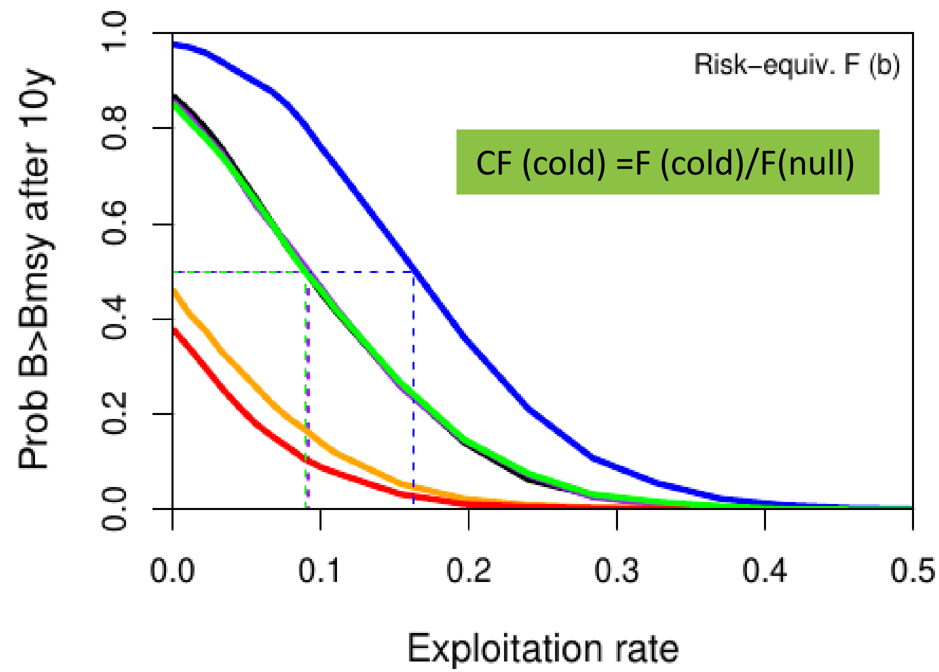
+ Data and knowledge availability -

CF estimation (empirical model)

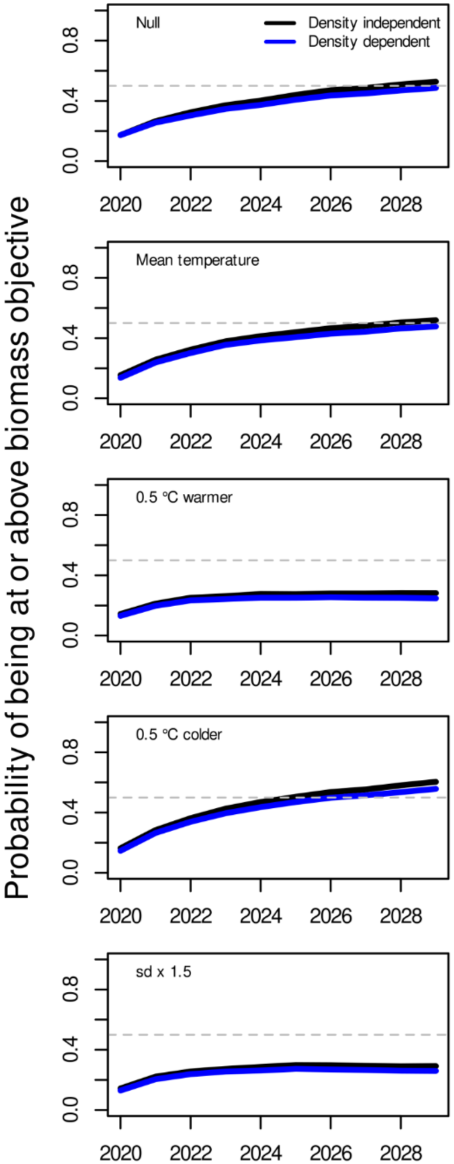
R package Climate Change Conditioned Advice (ccca)
www.github.com/duplisea/ccca

Risk equivalent advice conditioned for temperature effects on production





E-conditioning of advice using empirical modeling



CC scenario	Risk (2027)		Incremental Risk* ($Risk_{scenario}$-$Risk_{null}$)		Risk equivalent exploitation rate (@ 0.50 risk threshold)	
	No density-dependence	Density-dependence	No density-dependence	Density-dependence	No density-dependence	Density-dependence
Null model (production independent from temperature)	0.338	0.382	NA	NA	0.110	0.093
Mean temperature	0.346	0.386	0.008	0.004	0.122	0.102
0.5oC warmer	0.670	0.707	0.331	0.325	NP	NP
0.5oC colder	0.458	0.491	0.119	0.109	0.085	0.066
Increased variance (SD x 1.5)	0.765	0.790	0.427	0.408	NP	NP

R package Climate Change Conditioned Advice (ccca)
www.github.com/duplisea/ccca

E-conditioning of advice using empirical modeling

- E-conditioned advice is presented alongside status quo advice to ensure consistency in practice and effective communication using concepts of incremental risk

- Empirical-modelling approach can be undertaken for stocks that do not have an assessment model and used to project the stock forward based on current observations and plausible (risk-based) hypotheses for future E states

- Productivity dependence on E is estimated outside the assessment model, meaning that E-contributed uncertainty is only partially quantified. This can also be approximated by sampling from certain quantiles ranges of the E series.

- For a given risk level, the ratio of exploitation rates under plausible E-scenarios vs the mean model (average E conditions) is the estimated CF

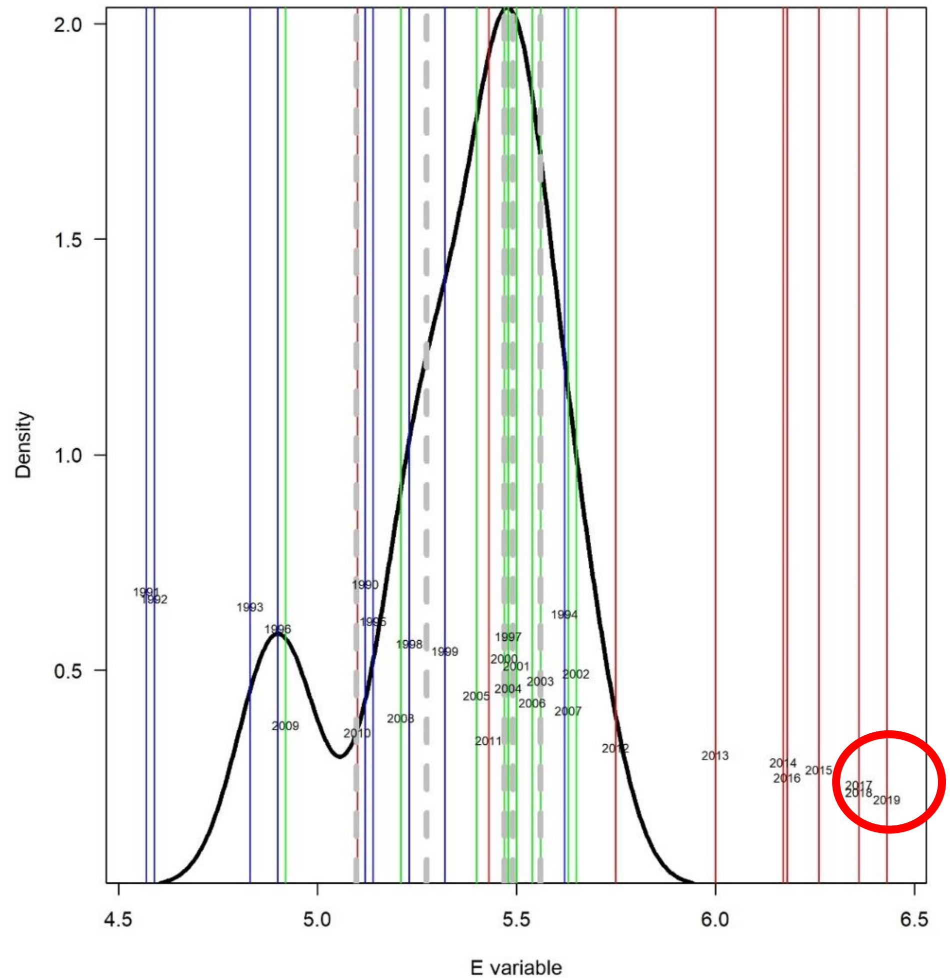
- Projection results may be used to identify when management objectives are no longer achievable at the risk level considered acceptable (i.e., when our risk assessment framework is no longer enough to manage exposure (F) because E-conditions have shifted beyond some safe operating space where consequences no longer carry the same meaning)

Three steps to developing risk-equivalent advice
accounting for ecosystem/environmental conditions:

1. Definition of risk-based ecosystem (E) hypotheses and identification of E variable(s) and baseline E conditions (Ebase)
2. Advice conditioning based on magnitude of change in E
3. Advice conditioning based on frequency and recurrence of E deviation from Ebase (tactical vs strategic considerations)


GSL bottom water temperature

- 2019 was the 7th consecutive year in which Tdeep>Tdeep[baseline]
- **Recurrence** of E deviation from Ebase is important: enhanced/reduced risk of productivity impairment, enhanced potential for cumulative effects, threshold effects and tipping points, etc.



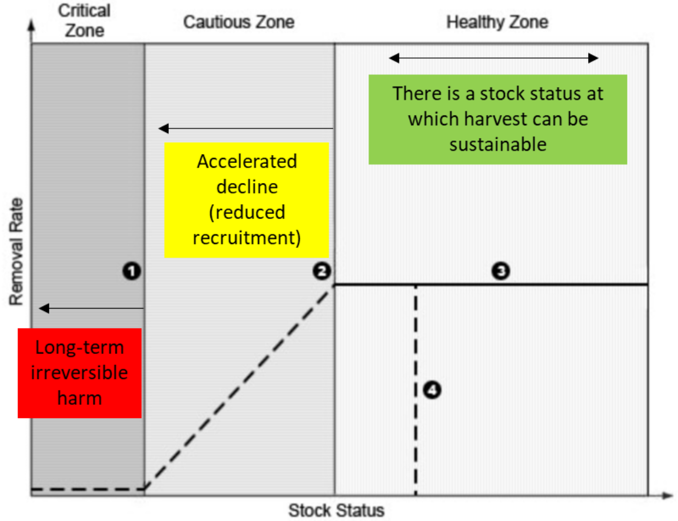
Options for risk-based conditioning of advice where there is evidence of directional, persistent change:

1. If data remain limited, implement scoring-based conditioning however <u>adjusting the k value</u> (consequence and risk tolerance)

$$CF_{ij} = S_i * E/E_{base} * k_j$$

2. Investigate productivity dependence on E to quantify E-contributed uncertainty and monitor its amplitude

3. Revisit and re-evaluate the entire risk framework to ensure it is consequence-equivalent in the face of persistent, directional E-changes and shifting productivity



Three steps to developing risk-equivalent advice
accounting for ecosystem/environmental conditions:

1. Definition of risk-based ecosystem (E) hypotheses and identification of E variable(s) and baseline E conditions (Ebase)

2. Advice conditioning based on <u>magnitude of change</u> in E

3. Advice conditioning based on <u>frequency and recurrence</u> of E deviation from Ebase (tactical vs strategic considerations)

Three steps to developing risk-equivalent advice
accounting for ecosystem/environmental conditions:

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Nationale EAFM initiative: guidance and methods development for scoping, identifying and monitoring stock-specific relevant E variables

Three steps to developing risk-equivalent advice accounting for ecosystem/environmental conditions:

1. Definition of risk-based ecosystem (E) hypotheses and identification of E variable(s) and baseline E conditions (Ebase)

2. Advice conditioning based on magnitude of change in E

3. Advice conditioning based on frequency and recurrence of E deviation from Ebase (tactical vs strategic considerations)

Nationale EAFM initiative: Additional case study applications (favourable E cases): further testing and refining of the risk-based framework

Scientific advice for fisheries is risk-based advice

E variables contribute risk in stock assessment

E is always included, though not explicitly

Risk equivalency is about consistently and explicitly accounting for E-contributed uncertainty in scientific advice for fisheries

A risk-based approach is consistent with existing practice and can be readily implemented

A risk-based framework provides a structured and standardised means of explicitly stating and efficiently communicating E considerations in science advice

How can the risk equivalency framework contribute to the National EAFM Initiative?

Risk conditioning of science advice is required to ensure functionally equivalent outcomes from fishing strategies considering potential, anticipated and/or observed E effects on stock productivity

How would the risk equivalency framework modify science advice?

Acknowledgments

- Co-authors
- DRS QC region and QC regional EA group
- Climate Change in Fisheries Assessments CSAS process and review group May 2018
- ACCASP funding

Discussion questions:

- How can the risk equivalency framework contribute to the National EAFM Initiative?
- How can the National EAFM Initiative contribute to the advancement of the risk equivalency framework?
- How would the risk equivalency framework modify science advice?
- Which EAFM case studies could the risk equivalency framework be applied to?
  - What work would be required to make that happen?
  - Which case studies or situations would be more challenging for the application of the risk equivalency framework? What is the nature of those challenges?
- How might the risk equivalency framework inform the eventual development of the EAFM toolbox of methods and the national EAFM framework?
  - Could the subgroup working on the toolbox/decision tree provide guidance in terms of how to integrate risk equivalency?

Accounting for environmental effects in fisheries assessments relies on the development of complex mechanistic understanding of the relationships between stock productivity and environmental parameters. This is often lengthy to achieve and seldom robust over time. An alternative is to account for environmental effects and related uncertainty in terms of risk enhancement or reduction factors. Scientific advice for fisheries is risk-based advice aimed at achieving sustainable use of fishery resources whilst minimising the risks of irreparable harm to fish stocks and fisheries ecosystems. Such risks are evaluated in relation to a set of management objectives (i.e., the reference levels) across which biological consequences and management actions are defined based on our understanding of the system and average environmental conditions. Risk equivalency is a way to maintain the risk of achieving the management objectives at a level considered acceptable and comparable among assessment types (e.g., data-limited versus data-rich assessments). It is commonly achieved via the development and application of precautionary buffers to the catch advice. We propose that risk equivalence can also be applied to ensure that the risk of achieving objectives remains comparable when environmental conditions shift outside the long-term mean used to define the reference levels. This will lead to fishing opportunities being reduced when environmental conditions are unfavourable (higher risk) and progressively augmented when environmental conditions are favourable (lower risk). Risk-equivalent advice conditioned for environmental variation can be developed and applied across the data-richness continuum and serve to identify when management objectives are no longer achievable at the risk level considered acceptable. We demonstrate this in case studies of northern shrimp Pandalus borealis and Greenland halibut Reinhardtius hippoglossoides in the Estuary and northern Gulf of St-Lawrence using both a data-moderate method (empirical modelling of productivity-dependence on environmental variables) and a data-limited method (scoring-based sensitivity assessment to environmental conditions). A risk equivalent approach is applicable whenever risk-based advice is formulated for fisheries and can facilitate the implementation of an ecosystem approach.