SAC-08-07c
Resolving potential redundancy of productivity attributes to improve ecological risk assessments

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CIAT
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Ecological Risk Assessment (ERA)

Approach used to assess relative ecological sustainability of diverse, data-limited bycatch assemblages impacted by fisheries

Productivity and Susceptibility Analysis (PSA)

- Semi-quantitative, attribute-based approach
- Measures relative sustainability of species based on an attribute ranking system related to their susceptibility to being captured and the capacity of the population to recover from depletion
- Tool for prioritizing species-specific research or mitigation measures to reduce risks from fishing

Improving the PSA method used for the purse-seine fishery

Focus – method development

- Determine which PSA productivity attributes are correlated
- Evaluate whether the vulnerability status changes when 1 or more correlated productivity attributes are removed

Overarching goals

- Apply results from this study to produce PSAs for fisheries other than large purse seine
- Potentially use PSA as an ongoing assessment tool for bycatch analyses

Desired outcome – a more parsimonious PSA model with fewer inputs

Review of PSA definitions

- **Vulnerability**: potential for the productivity of a stock to be diminished by direct and indirect fishing pressure. PSA: vulnerability is a combination of a stock's productivity and its susceptibility to the fishery.

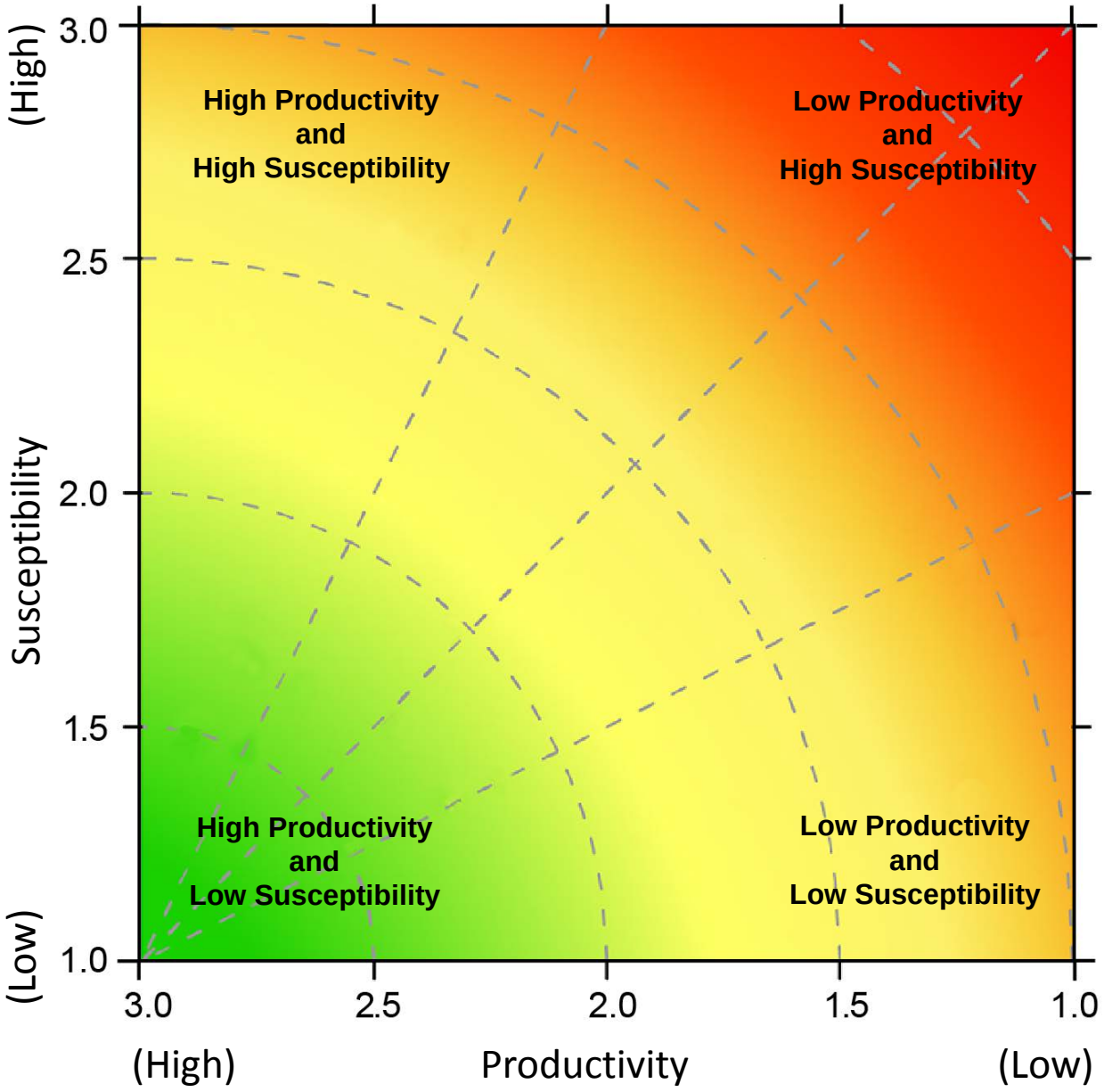
- **Productivity** – capacity to recover if stock is depleted (function of life history characteristics)

- **Susceptibility** – degree to which a fishery can negatively impact a stock (propensity of species to be captured by and incur mortality from a fishery). Can differ by fishery.

- Productivity and susceptibility attributes are assigned a rank of 1 to 3, reflecting the contribution of each attribute to overall sustainability of the species

Patrick, W.S., P. Spencer, J. Link, J. Cope, J. Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Cortés, O. Ormseth, K. Bigelow, and W. Overholtz. 2010. Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. Fish. Bull. U.S. 108: 305-322.

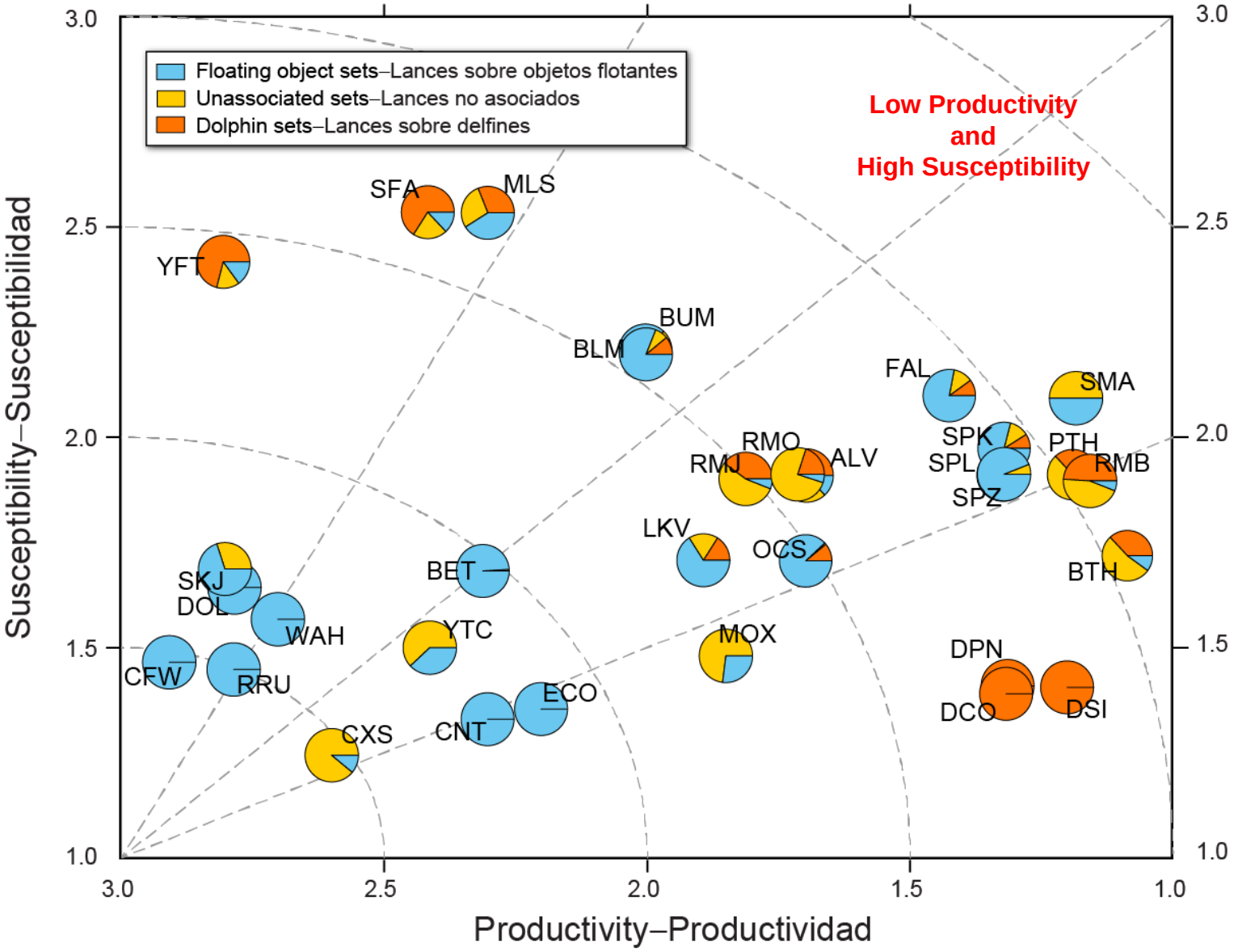
Illustrative PSA plot



Vulnerability (v) is measured as Euclidean distance from plot origin

$$v = \sqrt{(p-3)^2 + (s-1)^2}$$

Review EPO purse-seine PSA



Existing PSA productivity attributes

Productivity attributes and scoring thresholds used in the IATTC PSA of the large, purse-seine fishery

	Ranking – Clasificación		
Productivity attribute Atributo de productividad	**Low – Bajo (1)**	**Moderate – Moderado (2)**	**High – Alto (3)**
Intrinsic rate of population growth (*r*) Tasa intrínseca de crecimiento de la población (*r*)	≤ 0.1	> 0.1, ≤ 1.3	>1.3
Maximum age (years) Edad máxima (años)	≥ 20	> 11, < 20	≤ 11
Maximum size (cm) Talla máxima (cm)	> 350	> 200, ≤ 350	≤ 200
von Bertalanffy growth coefficient (*k*) Coeficiente de crecimiento de von Bertalanffy (*k*)	< 0.095	0.095 – 0.21	> 0.21
Natural mortality (*M*) Mortalidad natural (*M*)	< 0.25	0.25 – 0.48	> 0.48
Fecundity (measured) Fecundidad (medida)	< 10	10 – 200,000	> 200,000
Breeding strategy Estrategia de reproducción	≥ 4	1 to-a 3	0
Age at maturity (years) Edad de madurez (años)	≥ 7.0	≥ 2.7, < 7.0	< 2.7
Mean trophic level Nivel trófico medio	> 5.1	4.5 – 5.1	< 4.5

PSA productivity attributes and suspected correlations

Productivity attribute	Suspected correlation
Intrinsic rate of population growth *r* (maximum population growth that would be expected to occur under natural conditions i.e., in the absence of fishing; combines many other attributes)	Maximum size von Bertalannfy growth coefficient *k* Natural mortality Mean trophic level
Maximum age (direct indication of the natural mortality rate)	Natural mortality Maximum size Age at maturity
von Bertalannfy growth coefficient *k* (describes the rate at which a population approaches average length of an individual if fish lived indefinitely; long-lived, low-productivity stocks generally have low k)	Intrinsic rate of population growth *r* Natural mortality
Natural mortality (directly reflects population productivity, stocks with high rates of natural mortality require high levels of production to maintain population levels)	Intrinsic rate of population growth *r* Maximum age Age at maturity Mean trophic level
Fecundity (total # of viable offspring (or oocytes) that a fish produces annually)	Breeding strategy
Breeding strategy (relative investment by a species in the wellbeing of early stages of it's offsprings life; index of parental investment)	Age at maturity

Weighting of attributes

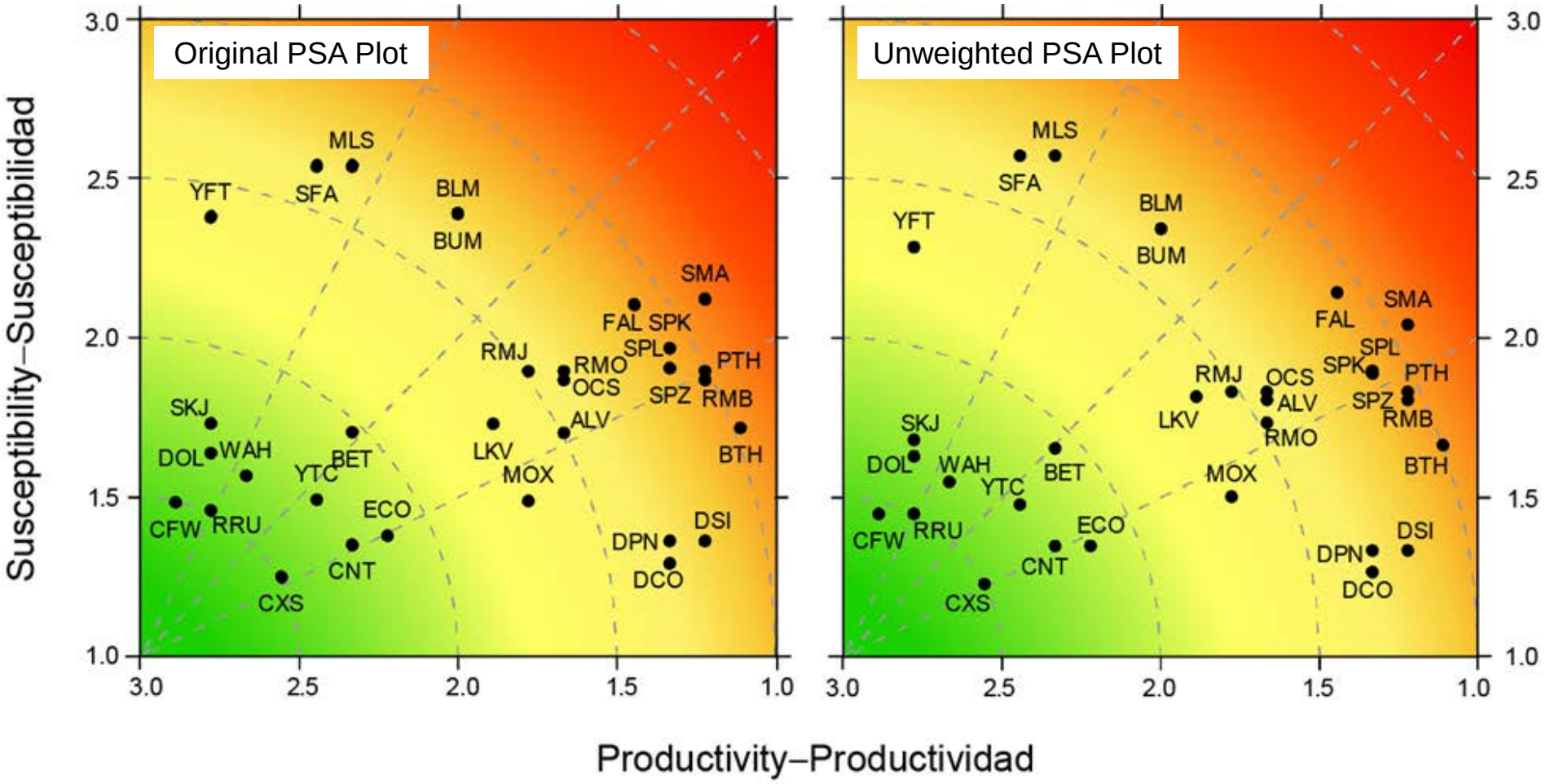
Goal – refine PSA methodology by assessing attribute weighting systems and correlation of attributes

1. Weighting system
   - Some PSAs incorporate a weighting system
   - A number is assigned to the attribute (e.g. 0 – 4)

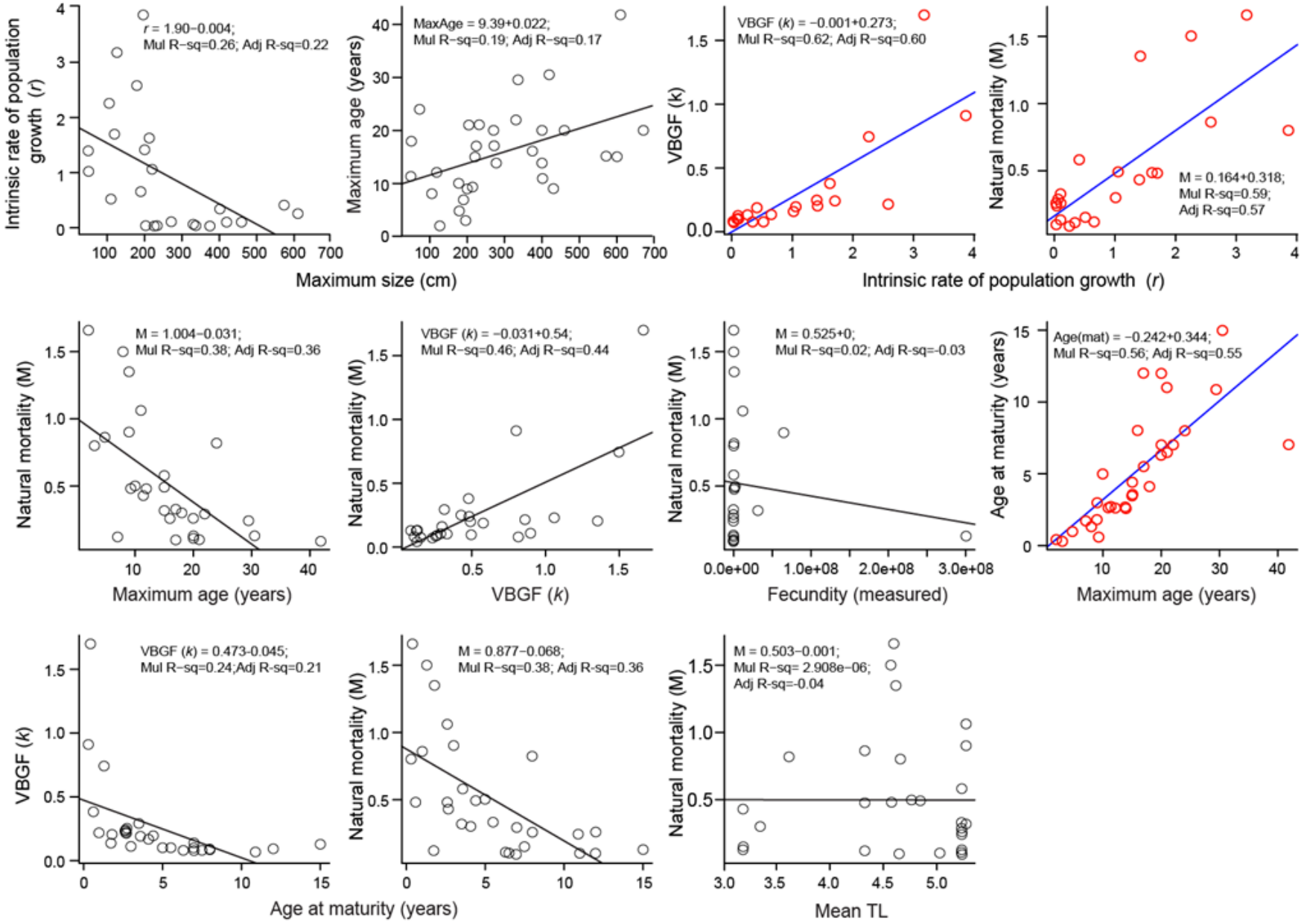
   (0 removes an attribute, 4 indicates an attribute is highly important)
   - Assigning a weight gives no indication of magnitude
   - Appears to be arbitrarily derived to emphasize perceived importance of an attribute

2. Correlation of attributes
   - Implicit weighting of correlated attributes creates positive bias
   - Over-estimation of a species' productivity
   - Under-estimation of the degree to which the impact of a fishery may have on sustainability

Assessing the weighting system



Assessing correlations



Attribute reduction approach

Removed between 1 and 4 attributes in a backwards stepwise approach

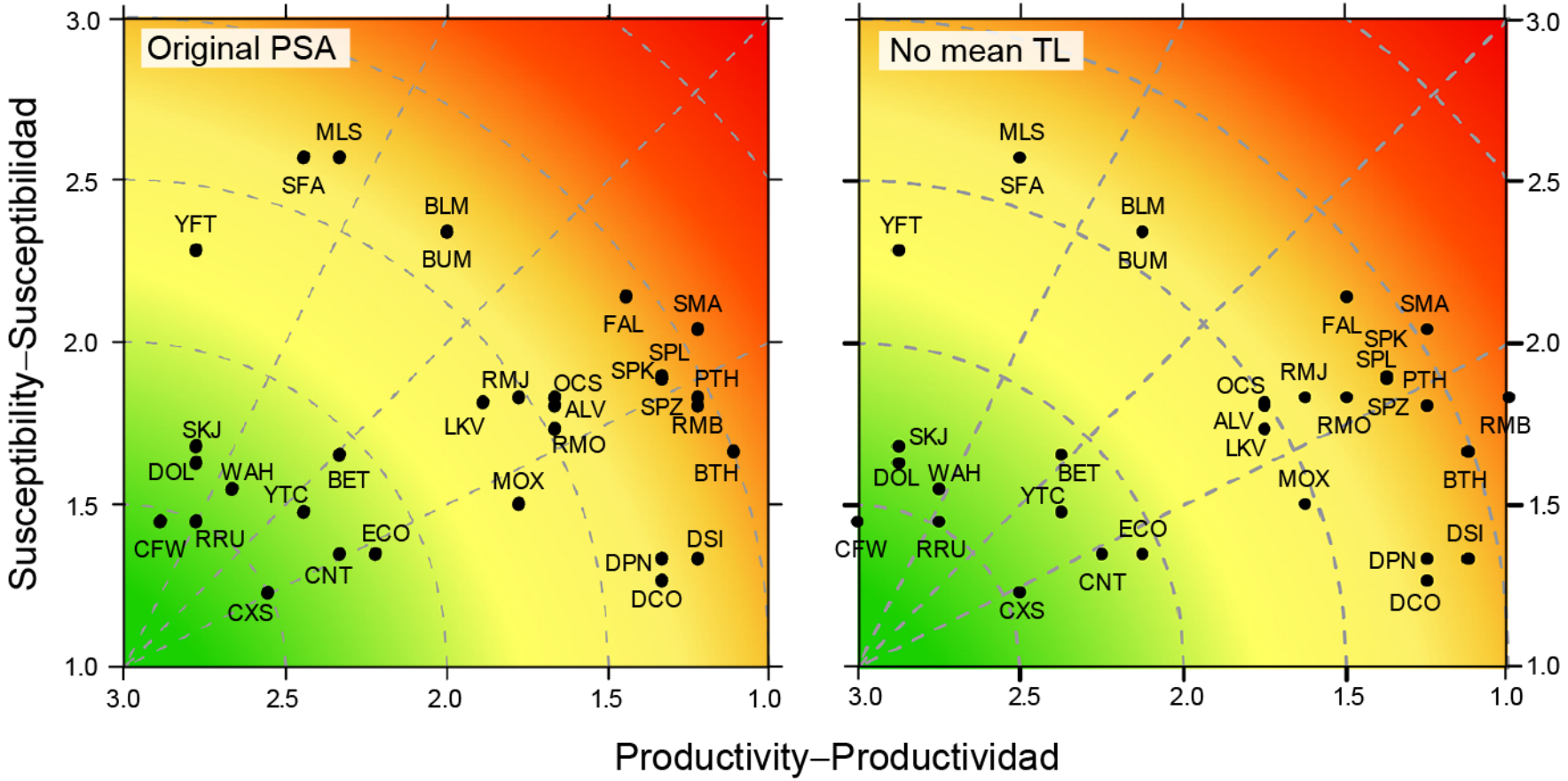
Graphically displayed species in a PSA plot

Compared new PSA plot against the original PSA plot

Evaluated movement patterns

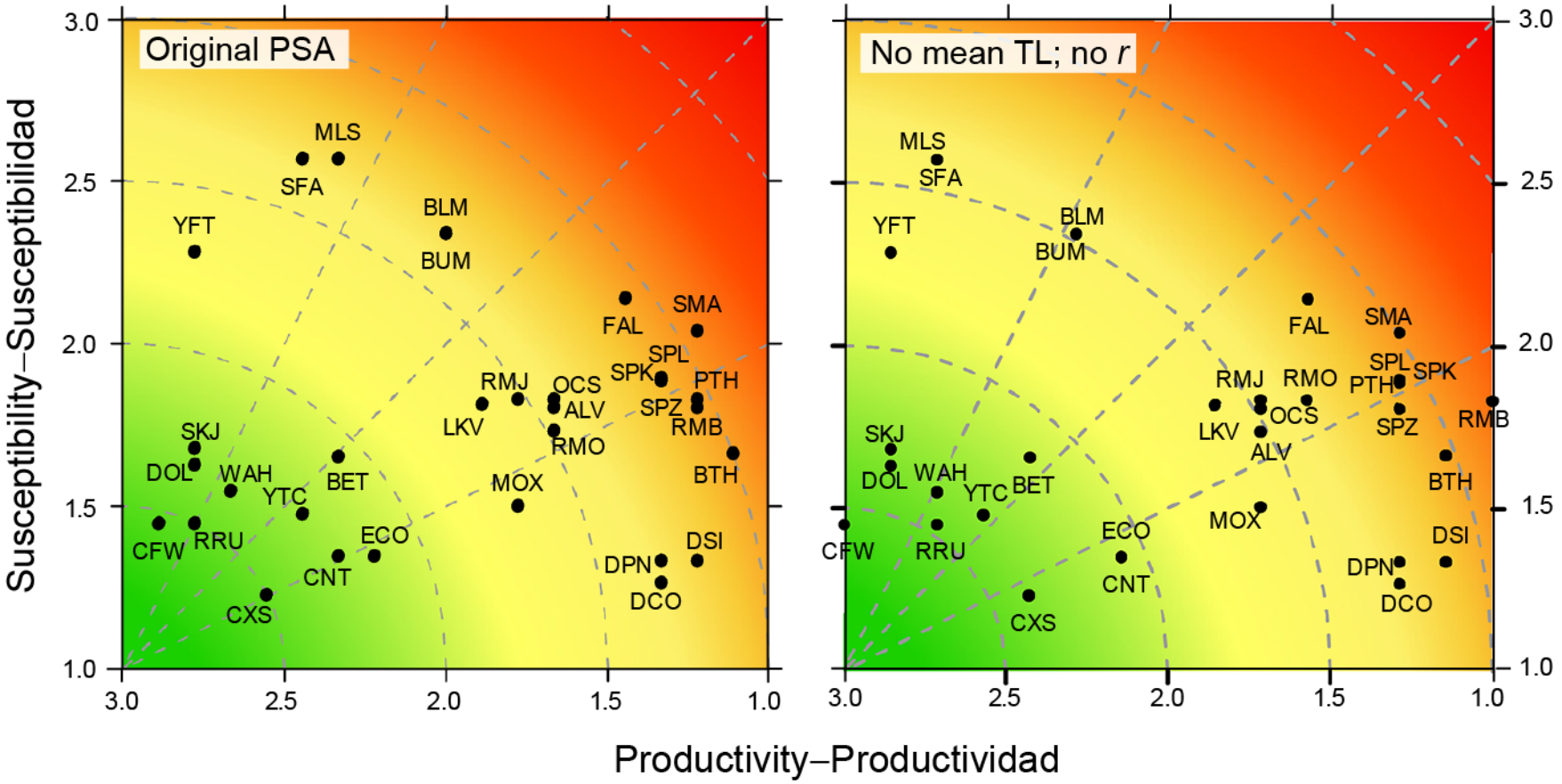
Attribute reduction approach

Scenario 1: minus 1 attribute
mean trophic level (TL) – not an independent measure of biological productivity



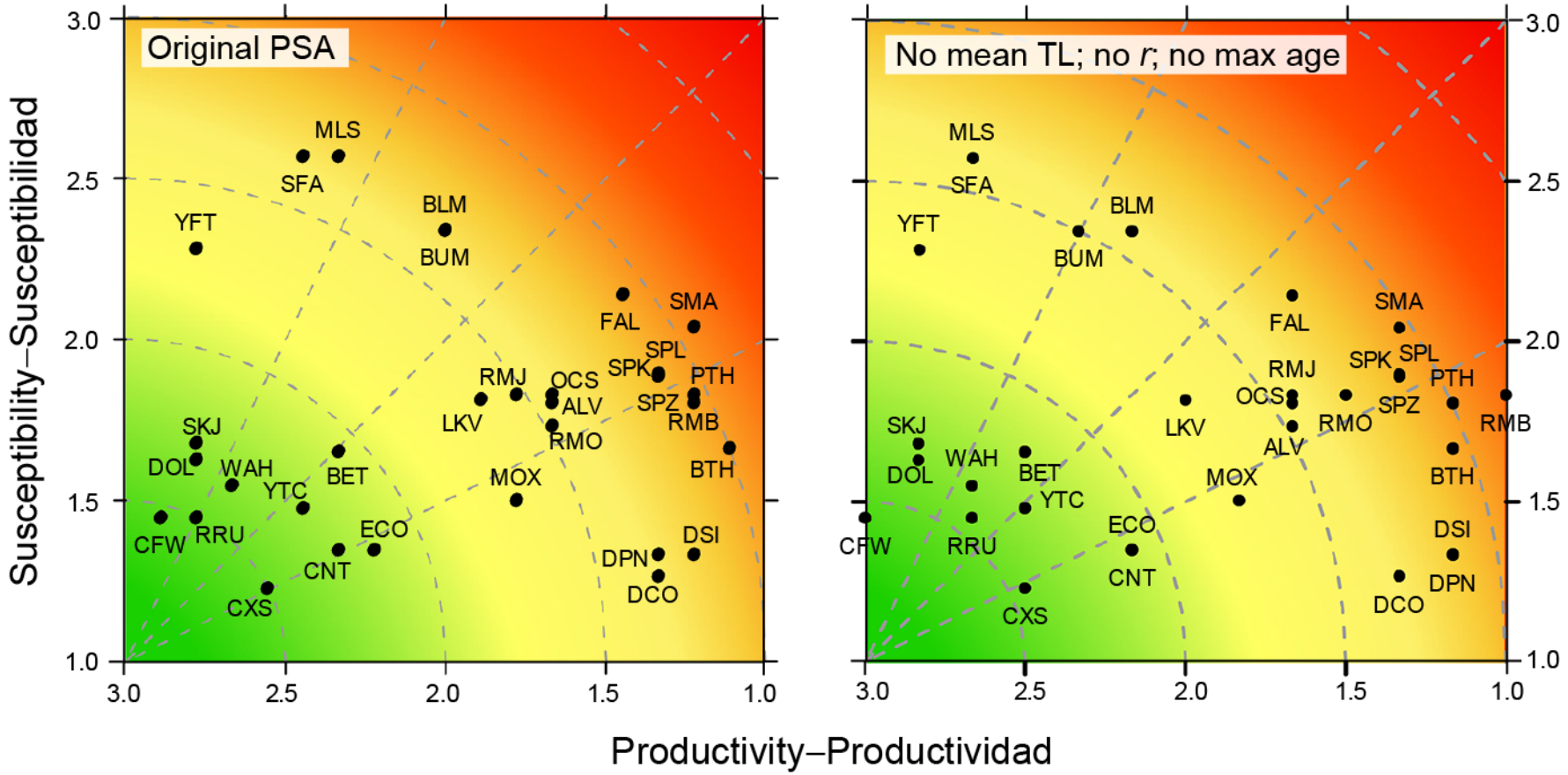
Attribute reduction approach

Scenario 2: minus 2 attributes
mean trophic level (TL) and intrinsic rate of population growth (*r*)



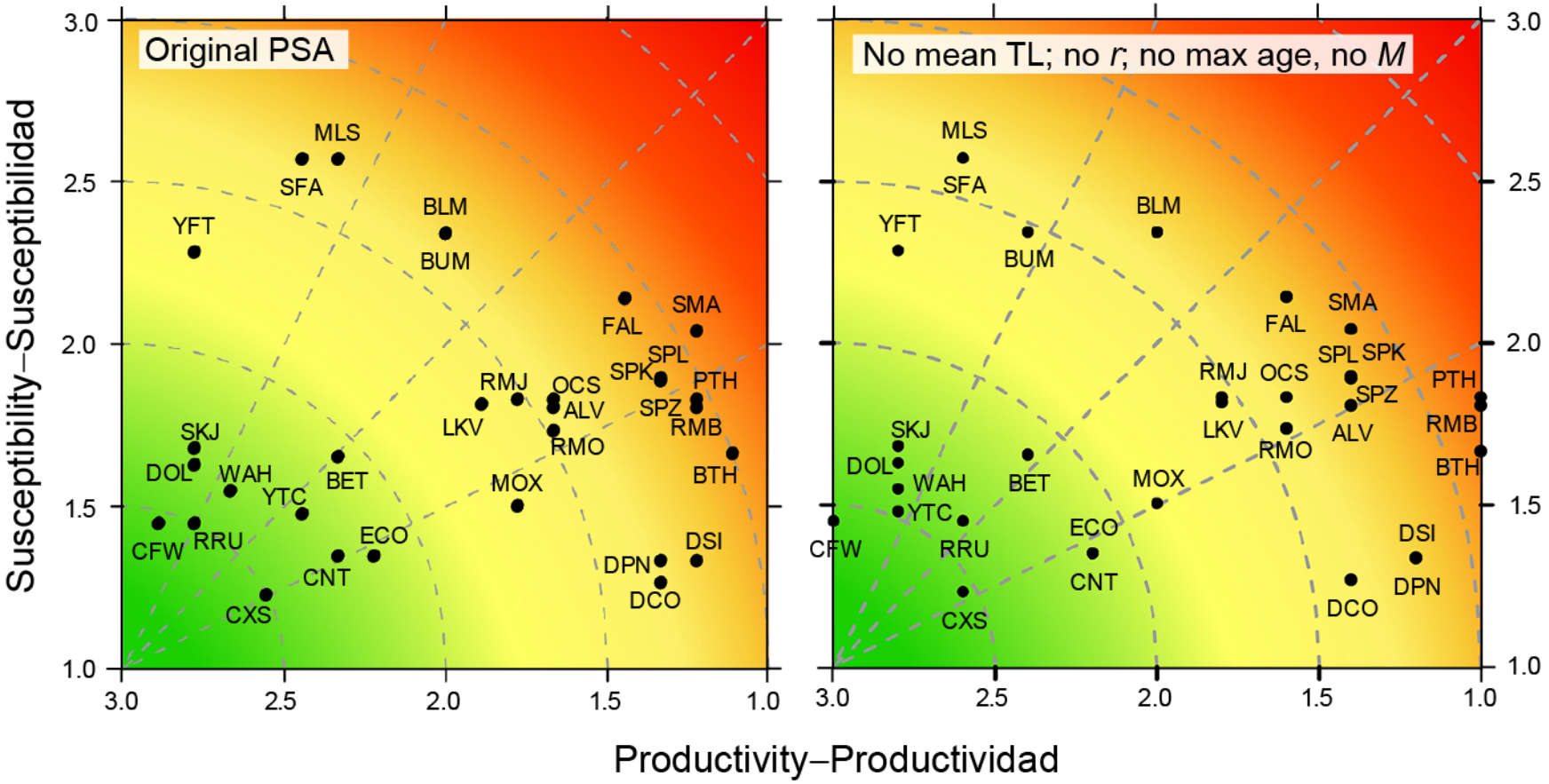
Attribute reduction approach

Scenario 3: minus 3 attributes
mean trophic level (TL), intrinsic rate of population growth (*r*), and maximum age



Attribute reduction approach

Scenario 4: minus 4 attributes
mean trophic level (TL), intrinsic rate of population growth (*r*), maximum age, and natural mortality (*M*)



Summary: Attribute reduction approach

After removing 4 productivity attributes, these species moved between risk categories:

Pelagic thresher sharks: borderline high risk into high risk

($v_{original} = 1.95$; $v_4 = 2.16$);

(p=1 for all productivity attributes except maximum age and natural mortality (p=2))

Giant manta rays: borderline high risk into high risk

($v_{original} = 1.96$; $v_4 = 2.17$);

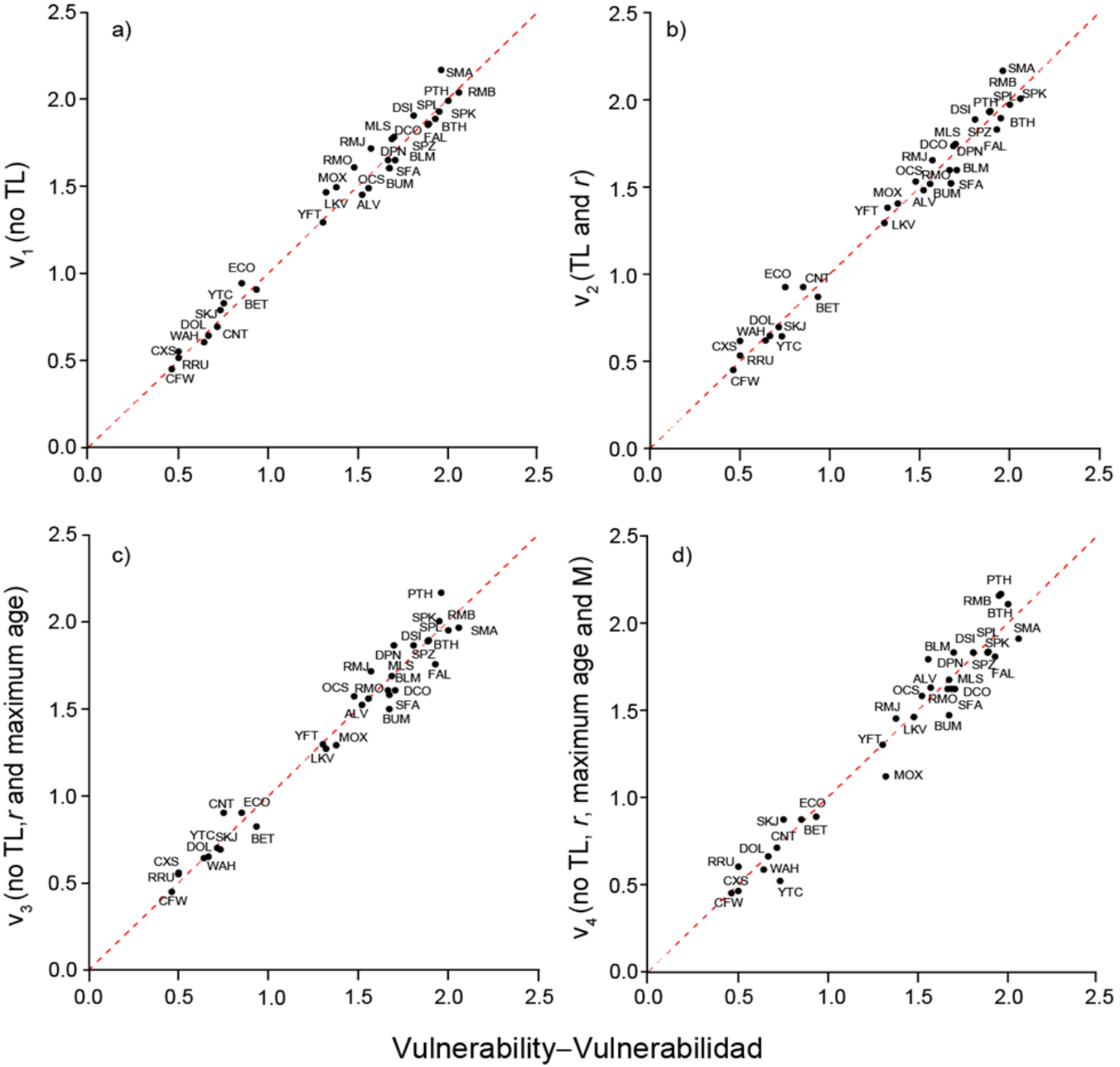
(p=1 for all productivity attributes except mean trophic level (p=3))

Shortfin mako sharks: high risk into moderate risk

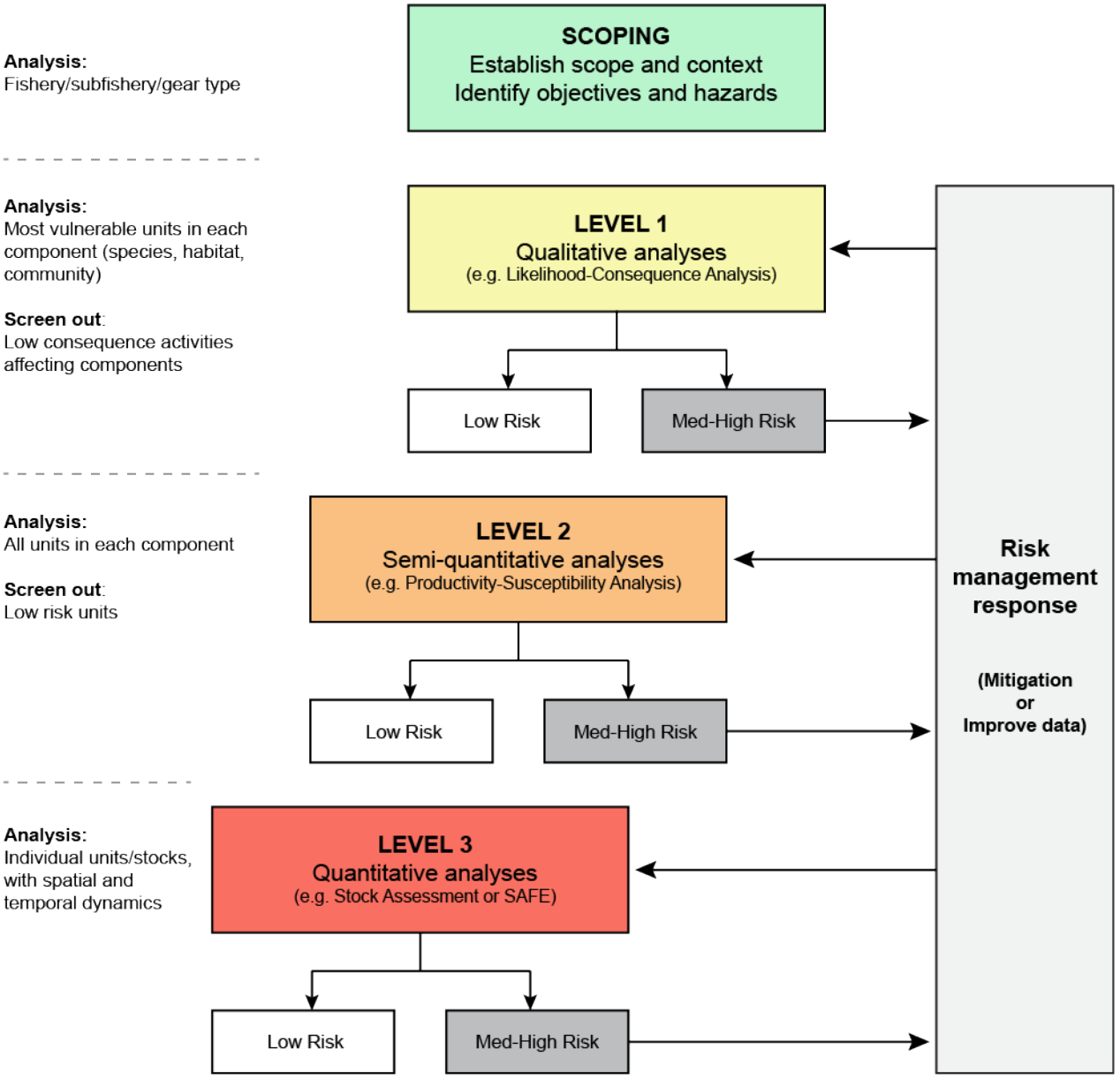
($v_{original} = 2.06$; $v_4 = 1.91$);

(p=1 for all productivity attributes except maximum size and fecundity (p=2))

Comparison of vulnerability scores



PSA: 1 approach (level 2) that can rapidly prioritize vulnerable species; PSA allows managers to (1) mitigate risks or (2) subject species to further research



Conclusion

Streamlining the PSA approach:

Redundancy in attributes – correlation between 3 pairs of attributes

Large departures in risk status were not observed

Methodological improvements:

Recommend using a reduced number of attributes

Result = less data required; approach becomes more rapid

Recommendations: teleosts and sharks

Five principal components of productivity scores

1. The rate of population growth (*e.g.* von Bertalanffy growth coefficient *k*, or intrinsic rate of population increase, *r*),

2. Maximum extent of growth in terms of length (L_∞ or L_{max}) or age (*e.g.* longevity in years),

3. Timing of reproductive maturity in terms of length ($L_{50\%}$) or age ($A_{50\%}$) at which half the population is mature, relative to length or age at capture in a particular fishery,

4. Reproductive output (*e.g.* fecundity, number of pups), and

5. Frequency of reproductive output (*e.g.* seasonally, annually).

Questions