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Evaluation of IUCN spatial distribution metrics for a migratory species, Fraser River Sockeye salmon

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ABSTRACT

The International Union for Conservation of Nature (IUCN) has developed criteria to assess extinction risk; the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an independent agency that assesses the vulnerability of Canadian species using IUCN criteria. Criterion B uses extent of occurrence, area of occupancy, and number of locations to evaluate risks associated with restricted spatial distribution in conjunction with several subcriteria. Concerns have been expressed about the use of these distribution metrics for migratory aquatic species as they often have naturally restricted distributions that change at different life stages. The conservation status of Sockeye salmon (*Oncorhynchus nerka*) of the Fraser River, British Columbia, Canada is currently being assessed and distribution metrics have been estimated. We compared metrics for Sockeye salmon to similar values for 57 assessments of vertebrate, invertebrate and plant species conducted by COSEWIC. Relationships among the metrics were generally similar between Fraser River Sockeye salmon and COSEWIC assessments, suggesting that despite concerns about the applicability of occurrence and abundance metrics and corresponding methodologies to highly migratory and aquatic taxa, Fraser River Sockeye salmon do not demonstrate large departures compared to other species assessed in Canada. The majority of Fraser River Sockeye salmon distribution metrics fell below thresholds for *endangered* or *threatened* statuses. However, we also observed that reported values for species assessed by COSEWIC had little relationship to the status that was ultimately assigned. Thus, based on results of this study, the ultimate role of the distribution metrics in COSEWIC status assessment is uncertain.

1. Introduction

The International Union for Conservation of Nature (IUCN) has created criteria for assessing the likelihood of a species' extinction given conditions at the time of assessment (Mace and Lande, 1991; Mace et al., 2008). The IUCN has developed a set of criteria for evaluating at risk species and thresholds have been set for the various risk categories. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an agency established to assess the vulnerability of populations in Canada to extinction (Shank, 1999; Hutchings and Festa-Bianchet, 2009) and COSEWIC has adopted much of the IUCN's criteria and recommended methodologies (COSEWIC, 2010; Powles, 2011). Both the IUCN and COSEWIC use five criteria for assessing the status of a species that are based on trends in abundance and distribution, small or very small abundances, and future population projections (COSEWIC, 2010; IUCN, 2013). Criterion B (one of the five criteria) makes use of information on the range of the species or the area of habitat occupied, along with supplemental information on number of locations, fragmentation, trends, and variation in abundance to assess status (Table 1). Use of this criterion requires the calculation of the Extent of Occurrence (EO), Area of Occupancy (AO), and the number of locations the species is known to exist at.

The concept of EO was first articulated by Gaston (1991) and is defined by the IUCN as 'the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon' (IUCN, 2013). It is intended to provide an estimate of the geographic spread of a species relative to spatially defined threats (Gaston and Fuller, 2009). Both COSEWIC and the IUCN recommend that EO be measured using minimum convex polygons (MCP) – 'the smallest polygon in which no internal angle exceeds 180 degrees and which contains all sites of occurrence' (COSEWIC,

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Table 1
IUCN and COSEWIC Criterion B for the evaluation of risk based on distribution or range (COSEWIC, 2010; IUCN, 2013). The IUCN risk category *critically endangered* has been omitted as COSEWIC does not use it.

Small distribution range and decline or fluctuation	Endangered	Threatened
B1. Extent of occurrence estimated to be	<5000 km^2	<20,000 km^2
or		
B2. Index of Area of Occupancy estimated to be and at least 2 of the following (a, b and/or c)	<500 km^2	<2000 km^2
a. Severely fragmented or known to exist at	⩽5 locations	⩽10 locations
b. Continuing decline, observed, inferred or projected, in any of:		
(i) Extent of occurrence		
(ii) Index Area of Occupancy		
(iii) Area, extent and/or quality of habitat		
(iv) Number of locations or populations		
(v) Number of mature individuals		
c. Extreme fluctuations in any of:		
(i) Extent of occurrence		
(ii) Index of Area of Occupancy		
(iii) Number of locations or populations		
(iv) Number of mature individuals		

2011) – following techniques similar to those described in Burgman and Fox (2003) and IUCN (2013). The EO can encompass large areas of unsuitable habitat, is partly dependent on the shape of a population's distribution, and has been criticized as being an overestimation of range size in many instances (Burgman and Fox, 2003; Gaston and Fuller, 2009).

AO, also first presented in Gaston (1991), is more closely linked with area actually used (Gaston and Fuller, 2009), and is a measure of the extent of habitat restriction. AO is defined as 'the area within [the] extent of occurrence which is occupied by a taxon' (IUCN, 2013). Thus, AO cannot exceed EO for a given population. COSEWIC requires that AO be assessed using a grid method as the sum of the areas of 2×2 km grid cells that contain an occurrence of the assessed population. Because the choice of scale, or grid size, will affect the estimated AO, the IUCN recommends that for most taxa, the 4 km^2 cell size be used (IUCN, 2013). AO has been criticized for being dependent on resolution of observations (Gaston, 1991; Keith et al., 2000), for overestimating occupied habitat, particularly for highly restricted distributions (Jetz et al., 2008), and potentially underestimating trends in habitat use (Thomas and Abery, 1995; Hartley and Kunin, 2003). To partially address some of these concerns, COSEWIC allows a second type of AO measure to be reported in assessments, the Biological AO (BAO), which is intended to more accurately reflect the actual area occupied by a taxon. However, there are no recommended techniques to estimate BAO, nor is it explicitly included in any COSEWIC or IUCN assessment criteria (COSEWIC, 2010; IUCN, 2013).

The IUCN defines the term 'location' as a 'geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present' (IUCN, 2013). Thus identification of the spatial extent of significant threats will inform the scale and number of locations. Because the number of locations depends on the assessment of the type and scale of relevant threats, the method of determining number of locations may vary among taxa. Number of locations is generally positively correlated with abundance, and negatively correlated with extinction risk (Hanski, 1982).

Concerns have been expressed about the use of EO and AO as distributional metrics for taxa that have naturally restricted distributions and for those that are highly migratory (Mace et al., 2008; Martin, 2009). EO and AO thresholds were developed for terrestrial species (Mace et al., 2008) and these distribution metrics may overestimate extinction risk for species with naturally restricted ranges. For example, species that reside exclusively on islands may naturally have distributions smaller than metric status thresholds (Robbirt et al., 2006; Abeli et al., 2009; Martin, 2009). As well, aquatic species that use shore lines or narrow water bodies may have more restricted distributions relative to terrestrial species (Simaika and Samways, 2010). Simaika and Samways (2010) suggest that for aquatic species, catchment area is a better metric for EO than MCP polygons. The IUCN recognizes the issue of 'linear' habitats for some aquatic species, but still recommends using MCP and grid methods to estimate EO and AO, respectively (IUCN, 2013).

Migration poses a challenge to status assessment as migration routes can cross international boundaries, and habitats used by different life stages may be very far apart. COSEWIC states that distributional metrics for migratory taxa should be based on "the smallest area essential at any stage to survival" (COSEWIC, 2011), while the IUCN advises that distributional metrics "should be based on the minimum of the breeding or non-breeding areas, but not both" (IUCN, 2013). Thus the choice of life stage at which to assess species may be a critical methodological choice that could greatly influence estimated distribution metrics.

Sockeye salmon (*Oncorhynchus nerka*) of the Fraser River, British Columbia are scheduled to be assessed by COSEWIC. In preparation of this assessment, work on population structure (Holtby and Ciruna, 2007), abundance and trends in abundance (Grant et al., 2011), and distribution metrics (de Mestral Bezanson et al., 2012) has been conducted. Sockeye salmon are a highly migratory and aquatic species with spawning distributions restricted to habitat along lake shores or within streams and rivers (Burgner, 1991). Thus there is concern about the relevance of IUCN and COSEWIC distributional metrics to a status assessment for Fraser River Sockeye salmon. We attempt to assess these concerns by evaluating three aspects of the distributional metrics estimated by de Mestral Bezanson et al. (2012): (1) methodological choices required for estimation; (2) relationships between the various distributional metrics and whether these relationships are similar to those observed in other taxa assessed by COSEWIC; (3) the relationship between distribution metric values and extinction risk status assigned by COSEWIC.

There are a variety of methodological choices involved in the estimation of EO, AO, BAO and number of locations. We evaluated the effect of the choice of EO estimation method and the life stage chosen on metric values. Relations between EO and AO have been observed for a variety of taxa (Mace et al., 2008). We evaluated whether relations among EO, AO, BAO and number of locations for Fraser River Sockeye salmon were similar to those found for other taxa assessed by COSEWIC. Our goal was to determine if the choices made by de Mestral Bezanson et al. (2012) yielded results consistent with other taxa that have been assessed by COSEWIC. Finally, we compared distribution metric values and the extinction risk status assigned by COSEWIC to evaluate the