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1. Introduction

The Southern Resident killer whales (SRKW; *Orcinus orca*) represent the southern population of the fish-eating ecotype inhabiting the northeast Pacific Ocean [1]. From late May through October, the three SRKW pods, termed J, K and L, frequent the inshore waters of Washington State and British Columbia, commonly known as the Salish Sea. Following a near 20% decline in their population during the late '90's, the population was listed as endangered under the Canadian Species at Risk Act in 2001 [2] and the U.S. Endangered Species Act in 2005 [1]. Only 78 individuals (J pod = 24 individuals; K pod = 19 individuals; L pod = 35 individuals) remain in the current population as of December, 2016 [3]. Reduced availability of their preferred prey, threatened and endangered Chinook salmon, appears to be at the core of the SRKW decline [4–7], although exposure to toxicants [8], and pressure from vessel disturbance may also contribute to these cumulative effects [9].

Reduced fecundity appears to be a particularly important contributor to the SRKWs failure to recover [4]. The rate of successful pregnancy in the wild population is unknown since, to date, pregnancy is only confirmed by observation of a newborn calf. SRKW typically give birth every 5.3 years [10]. However, holding age structure and survivorship constant, fecundity rates of SRKW (0.21) are significantly lower than those of Northern Resident (0.26;) [11] or Southeast Alaskan Resident killer whales (0.27) [12], neither of which are listed as at risk. Assuming a median peak fecundity rate of 0.21, the 31 potentially reproductive females in the SRKW population should have had 48 births between 2008–2015. Yet, only 28 births were recorded during that period. The 7 adult females in K pod have not had a birth since 2011, and just two births since 2007. The 24 females in the remaining two pods (J and L) have averaged < 1 birth per pod since 2011, with no births in 2013, but had 7 births in 2015. One of the two offspring born in 2014 died [3]. This study addresses causes of the low reproductive rate in SRKWs in an effort to recommend management decisions that can enhance population growth and long-term sustainability of this endangered population.

We examine determinants of pregnancy success and failure in the SRKWs from 2008 through 2014 based on hormone measures of pregnancy occurrence and health as well as physiological stress from genotyped feces. SRKW fecal samples are located with high efficiency by specially trained detection dogs, with detection rates over five times that by trained human observers [5,13,14]. Progesterone and testosterone collectively provide reliable indices of pregnancy occurrence, timing and health in killer whales. Concentrations of both P4 and T increase several-fold during gestation, although the increase is more gradual for T. Both hormones sharply decline to pre-conception levels around parturition [15,16]. We develop and validate a noninvasive endocrine measure of pregnancy occurrence and loss in the killer whales using metabolites of progesterone (P4) and testosterone (T) excreted in their feces.

Fecal glucocorticoid (GC) and thyroid (T3) hormone metabolite measures are used to monitor nutritional and disturbance stress within and between years. These two endocrine systems work closely together to regulate energy availability and utilization to meet nutritional, growth and thermoregulatory demands [17]. GCs rapidly rise in response to poor nutrition, cold temperature and disturbance stressors, mobilizing glucose to provide energy to deal with the immediate emergency [18,19]. GC concentrations over time are particularly informative for distinguishing nutritional from boat stress since abundances of both Chinook and whale-watching boats have very similar temporal patterns. Chinook and boat abundance are both relatively low in spring, peak in mid- to late August and then decline. Yet, the GC signal from nutritional stress should be lowest when fish abundance is at its peak while highest when boat density is at its peak [5].

Thyroid hormone (triiodothyronine, T3), on the other hand, produces a more conservative response to nutritional and thermal stress, functioning by adjusting metabolism. It is also