as High T UPg samples because both P4 and T concentrations in the High T samples were all well above those expected for luteal phase samples (Table 3, Fig 2). Moreover, Robeck et al [15,16] clearly distinguished luteal phase samples from pregnant samples by 4 weeks of gestation. This is consistent with our findings from Fig 2, indicating pregnancy detection among females by 100 days of gestation. Given the above, we consider only a small portion of the 8 singleton, low T UPg samples with P4 above the 2000 ng/g pregnancy threshold to be possibly misclassified as early abortions. However, the consistency of these patterns on multiple endocrine and temporal measures, across years, strengthens the assertion that pregnancy failure is a major constraint on killer whale population growth, triggered by insufficient prey.

The rise in fecal P4 concentrations that we observed among successful pregnancies was somewhat delayed compared to that observed in serum from captive killer whales [15]. This could suggest that our estimated birth dates, and hence our projected conception dates, actually occurred earlier than expected, increasing the likelihood that some perinatal mortalities were misclassified as late spontaneous abortions. However, the delayed P4 peak in feces of pregnant SRKWs compared to Robeck et al [15] most likely resulted from differences in the P4 metabolites measured in feces versus serum. The predominant P4 metabolite measured by our antibody is 5α-DHP [35]. Using an EIA version of the P4 antibody we used in our study, Robeck et al [15] found that 5α -DHP did not become the predominant progesterone metabolite in captive killer whale serum until 161–360 days of gestation, and remained secondarily so from 361 days gestation to term. Fecal progesterone metabolites spiked around mid-pregnancy in our study, consistent with the time when 5α -DHP predominated in serum [15]. It is also noteworthy that our testosterone antibody [37,40] followed a similar temporal pattern in SRKW to that described for captive whales by [16]. That also supports the reliability of our projected conception dates and occurrences of spontaneous abortion.

Exposure to persistent organic pollutants (POPs)—lipophilic compounds with established adverse health effects—in response to food stress add yet another cumulative risk of fetal demise and/or perinatal and neonatal mortality. Lundin et al. [8,50] showed that POPs, namely PCBs, DDTs, and PBDEs, increase in circulation in SRKWs when Fraser River Chinook abundance is lowest, presumably due to increased fat metabolism in response to nutritional stress. Mobilization of contaminants into circulation also occurs during the energetic demands of lactation, with an estimated 70–90% lactation transfer of maternal toxicant burden in primiparous females [51]. High POP burden has specifically been associated with disruption of reproduction success and reduced calf survival in marine mammals [52–55]. Most notably, Lundin et al. [8] found increased Persistent PCBs, the group of PCBs considered more persistent and more toxic [56], in the female whales classified with UPg's (73%; 95% CI, 61–85) compared to all other female reproductive groups (range 43–56%). Further evidence in support of the occurrence of UPg in this population is the unexpected inverse in bioaccumulation of POPs with age in "nulliparous" mature females (3 of 4 nulliparous whales had an unsuccessful pregnancy defined by fecal hormone measures). This occurrence is likely explained by toxicant offloading from an undocumented pregnancy or neonate loss.

Both poor nutrition and increased POP loads have each been demonstrated to suppress T3, which negatively impacts fetal brain growth [22,57,58]; immunosuppression may also occur, increasing risk of infection [53,59–61]. Salmon are the Southern Resident killer whales predominant prey and main source of toxic exposures [62,63]. This relation of reduced food supply and increased exposure to lipophilic POPs could be similarly impacting coastal Native American communities that depend on this same seasonal salmon resource and also appear to be experiencing high rates of reproductive loss [64,65].

Results of the SRKW study strongly suggest that recovering Fraser River (FRC) and Columbia River Chinook (CRC) runs should be among the highest priorities for managers aiming to