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Thiamine deficiency: A viable hypothesis for paralytic syndrome in Baltic birds. Commentary on Sonne et al., 2012. A review of the factors causing paralysis in wild birds: Implications for the paralytic syndrome observed in the Baltic Sea. *Science of the Total Environment* 416:32–39.

In a recent assessment of hypotheses presented by Balk et al. (2009) regarding the etiology of a paralytic disease inflicting bird populations in Northern Europe, Sonne et al. (2012) "call for a major coordinated effort on research…" to "… integrate clinical, physiological, ecological and demographic investigations at all levels to better dissect the causes, the effects on ecosystems and potential impact on affected populations." Further, they offer, "This should be undertaken before thiamine deficiency can be considered to constitute a serious problem to e.g. the Baltic ecosystems." While we agree that holistic approaches to environmental research and management are essential, our experience suggests that waiting for definitive results from long-term research and monitoring programs prior to "consideration" of thiamine deficiency as a major factor in the paralytic disease observed in wild bird populations would hinder the ability of natural resource managers to understand and mitigate declining trends in avian population abundance.

Managers entrusted to protect environmental quality must use the evidence at hand to make decisions to sustain and restore healthy ecosystems. Sonne et al. (2012) criticize Balk et al. (2009) for stating "that a major endemic/epidemic is taking place…", yet Balk et al. (2009) neither used the word "epidemic" nor made any claim that an epidemic was occurring. Instead, Balk et al. (2009) "propose thiamine deficiency as a possible cause for observed bird population declines", then provided evidence in support of that hypothesis.

Sonne et al. (2012) recommend a holistic approach to understand the problem of paralysis in wild birds, which is sound advice in addressing the complex environmental diseases found in fish and wildlife. However, their review focuses on criticizing aspects of Balk et al. (2009) by "providing a detailed review" of this study without describing any supporting evidence, suggesting that their "holistic review" was solely designed to cast doubt on the Balk et al. publication. Sonne et al. (2012) dismissal of evidence and supporting arguments provided by Balk et al. (2009) defies the scientific method (Gauch, 2002). Their persistent refutation of the possibility that thiamine deficiency may be an important factor in population declines of different types of birds in Northern Europe undercuts any hope that their review can lead the way to pursuing a holistic understanding of the problem.

By contrast, Balk et al. (2009) provided testable scientific hypotheses for the observed disease symptoms in three European bird species; these hypotheses were based upon empirical data supported by a logical framework for evaluating these data. Balk et al. (2009) did not identify a cause for the thiamine deficiency. Instead, they asserted that the paralytic symptoms observed in the studied populations were part of a multifaceted response to thiamine deficiency in these birds. They did not speculate how the thiamine deficiency occurs, thus they did not venture into causality. The eco-epidemiological approach promoted by Fox (1991) for evaluating cause–effect relationships between a disease and potential causal agents offers a useful framework derived from epidemiological criteria used to determine causality (Hill, 1965). Recent advances in statistical computation have provided an expanded framework for evaluating evidence in support of multiple hypotheses, thereby improving our ability to simultaneously evaluate a broad range of causal factors (Burnham and Anderson, 2002; Gauch, 2002). A rigorous evaluation of the paralytic disease described by Balk et al. (2009) using traditional cause–effect and multiple inference criteria would provide an important step in maintaining a holistic approach toward understanding causality of European bird declines. We have used these former criteria to understand causal factors for thiamine deficiency observed in Great Lakes salmonids (Brown et al., 2005). Ultimately, we established a strong linkage for a causal relationship between thiaminase-rich forage fish and thiamine deficiency in lake trout by following Koch's postulates in a controlled laboratory study (Honeyfield et al., 2005). Until this work was completed many fishery managers dismissed the importance of thiamine deficiency in a large-scale recruitment failure observed for decades in Laurentian Great Lakes lake trout populations. Prior to these studies, numerous causes were suggested for the lack of natural reproduction in Lake Michigan lake trout (Eshenroder et al., 1999), reminiscent of the multiple-cause perspective advocated by Sonne et al. (2012). Of these multiple potential causal factors, thiamine deficiency was belatedly placed on the list when it was demonstrated that thiamine treatment of affected lake trout fry substantially reversed incidence of early mortality syndrome (Fitzsimons, 1995). However, the community of fishery managers continued to voice an overwhelming preference for any or all of the other potential causes for the reproductive failure. It wasn't until these subsequent studies finally confirmed the unique and overarching importance of thiamine deficiency that the fishery managers in the Great Lakes embraced this idea (Bronte et al., 2008).

Based on our experience with apex salmonid predators in the Great Lakes we urge strong consideration of thiamine deficiency in Baltic avian populations as a plausible explanation for substantial avian mortality and ongoing population declines. Thiamine deficiency is not the only explanation for the array of avian issues that exist, but Balk et al. (2009) provided data and supporting evidence that does not warrant casual dismissal.

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