Many genes that affect replicative lifespan (RLS) in the budding yeast *Saccharomyces cerevisiae* also affect aging in other organisms such as *C. elegans* and *M. musculus*. We performed a systematic analysis of yeast RLS in a set of 4,698 viable single-gene deletion strains. Multiple functional gene clusters were identified, and full genome-to-genome comparison demonstrated a significant conservation in longevity pathways between yeast and *C. elegans.* Among the mechanisms of aging identified, deletion of tRNA exporter *LOS1* robustly extended lifespan. Dietary restriction (DR) and inhibition of mechanistic Target of Rapamycin (mTOR) exclude Los1 from the nucleus in a Rad53-dependent manner. Moreover, lifespan extension from deletion of *LOS1* is non-additive with DR or mTOR inhibition, and results in Gcn4 transcription factor activation. Thus, the DNA damage response and mTOR converge on Los1-mediated nuclear tRNA export to regulate Gcn4 activity and aging.