METHODS AND SOFTWARE PAPER

TurtleStatus

A life-history-calibrated replacement-ratio framework for early assessment of turtle populations

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DRAFT STATUS. This manuscript documents the current prototype, its mathematical basis and simulation behaviour. The species catalogue and screening-support score require independent audit and external validation before the tool is used for regulatory decisions.

Software: https://turtle-status.emydura.chatgpt.site

Version documented: prototype v0.1 | August 2026

Abstract

Freshwater turtles are difficult to assess before declines become entrenched because high adult survival can maintain conspicuous adult populations for years after recruitment has failed, while juveniles are often poorly detected. We developed TurtleStatus, a browser-based screening framework that compares an observed replacement-stage-to-adult ratio with a species-specific expectation derived from adult survival, replacement-stage survival and the duration for which near-mature animals remain identifiable. At demographic stationarity, the expected ratio is $E(R/A)=(1-S_A)(1-S_R^d)/[(1-S_R)S_R^d]$. The benchmark is calculated independently of uploaded observations; monitoring data determine the observed annual ratios, their precision and the strength of comparison. The framework accepts capture, standardised basking-camera and nesting-female records, explicitly flags incompatible stage definitions, incorporates effort and method uncertainty, identifies unusually large annual changes using log-ratio contrasts, and supplies a standardised three-stage stochastic projection. Sensitivity analysis showed that expected ratios decline sharply as adult survival increases and increase with the duration of the observable replacement window. With $S_R=0.86$ and a four-year window, expected ratios were 0.592, 0.296, 0.177, 0.118 and 0.059 for adult survival of 0.90, 0.95, 0.97, 0.98 and 0.99, respectively. Monte Carlo evaluation indicated a 2.9–4.1% false-alert rate under no change; approximately 200 independent classified turtles per year gave >0.90 probability of flagging a 60% annual ratio decline, whereas moderate declines required much larger samples. TurtleStatus therefore provides a transparent early-warning and data-triage tool rather than an abundance estimator or substitute for capture–mark–recapture. Its principal contribution is a general equation with species-specific baselines, coupled to explicit observation-quality gates and a validation pathway for networked monitoring.

Keywords: demographic monitoring; freshwater turtle; life history; population viability analysis; recruitment; replacement ratio; subadult; citizen science.

Plain-language significance

A turtle population can contain many adults yet still be running out of future adults. TurtleStatus asks whether the observable "replacement pipeline"—subadults or newly recruiting breeders—is large enough to replace the adult deaths normally expected for that species. It converts life-history knowledge into a testable monitoring benchmark while showing when the available observations are too biased or inconsistent for a strong conclusion.

1. Introduction

Turtles combine delayed maturity, high adult survival and long reproductive lifespans. These traits buffer adult abundance against short-term recruitment failure, but they also create a management delay: a population may appear numerically substantial until missing cohorts reach the age at which they should enter the adult population (Congdon et al. 1993, 1994; Heppell 1998). Population models repeatedly show high elasticity of population growth to adult survival in long-lived turtles, while recovery from adult losses is constrained by slow maturation (Crouse et al. 1987; Heppell et al. 2000).

Conventional monitoring does not fully solve this problem. Capture–mark–recapture (CMR) can estimate abundance, survival and detection when individual histories and a defensible sampling frame exist, but it is expensive, method-sensitive and often dominated by adults. Hoop-net dimensions, bait, trap type and basking behaviour can alter both capture success and observed size distributions (Tesche and Hodges 2015; Gulette et al. 2019). Visual and basking surveys are less invasive and scalable, yet detection varies with season, time, weather and species behaviour (Armstrong 2016). The absence of small turtles is therefore ambiguous: it can reflect recruitment failure, low juvenile detectability, small samples or the arbitrary definition of "juvenile."

McKnight et al. (2025) sharpened this problem using 41,021 freshwater turtles from 38 species and 428 populations. Their work showed the value of comparative body-size distributions while demonstrating strong effects of sample size and capture method. The present framework takes a deliberately narrower demographic target. It does not ask whether every juvenile age class is visible. Instead, it focuses on the replacement stage: turtles close enough to maturity that they are behaviourally and detectably more adult-like, but remain distinguishable from established adults for a species-specific interval. This stage is expected to respond to recruitment failure earlier than adult abundance while being more observable than hatchlings or small juveniles.

We present TurtleStatus, a technical framework and working browser tool that: (1) derives a replacement-stage benchmark from life history; (2) keeps that benchmark independent of the uploaded observations; (3) adjusts inference for years, sample size, effort, method and stage-definition quality; (4) detects unusual annual changes; (5) accommodates capture, basking and nesting-female pathways; and (6) connects the screening result to a transparent stochastic projection. We describe the current algorithms exactly, evaluate sensitivity and alert performance, and identify the validation needed before formal decision use.

2. Conceptual framework

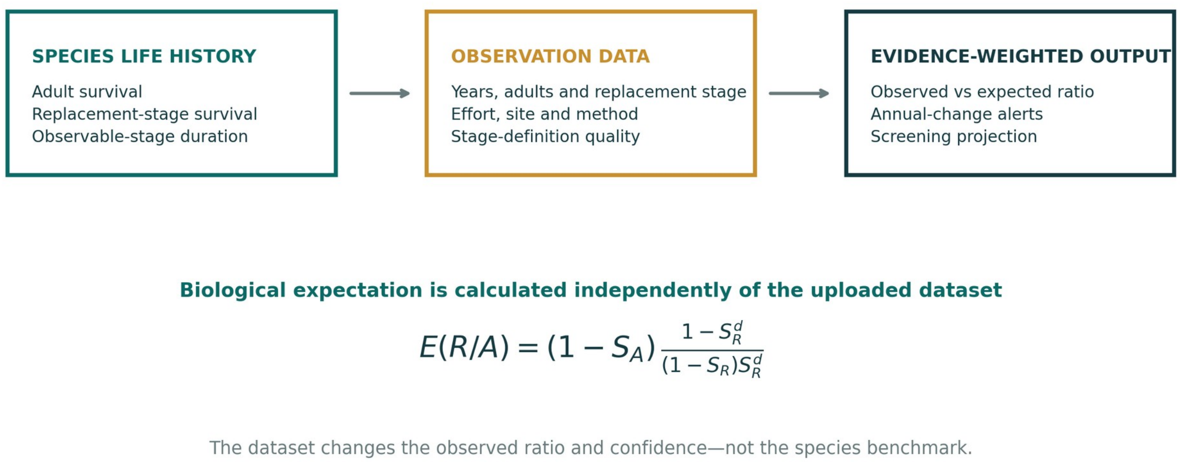

Figure 1. Separation of the biological, observation and decision layers in TurtleStatus. The species benchmark is derived without reference to the uploaded dataset.

The framework separates biological expectation from observation. This distinction is essential. Adult survival, replacement-stage survival and stage duration define how many near-mature animals should be present per established adult in a stationary population. Sampling determines how well that standing ratio is observed. Threat indicators—such as nest predation or adult female road mortality—help diagnose mechanism but do not redefine the expected ratio unless they provide evidence that a vital rate differs from the species prior.

> **ONE FRAMEWORK, SPECIES-SPECIFIC BASELINES.** There is no single universal numerical ratio for turtles. There is a universal replacement equation whose value changes predictably with each species' life history and the operational definition of the observable stage.

3. Methods

3.1 Software architecture and privacy

TurtleStatus is implemented as a client-side web application. Excel and comma-separated files are parsed within the user's browser; the prototype does not transmit uploaded records to a server. The interface follows four steps: species and monitoring pathway; upload and column mapping; evidence-quality review; and assessment. The current catalogue contains 348 turtle taxa and searchable aliases. Each trait is labelled by evidence grade, and user-adjusted values are carried into all downstream calculations. The catalogue is a prototype data product: taxonomic reconciliation, source-level provenance and independent trait audit are prerequisites for archival release.

Layer	Inputs	Primary output
Biological	Adult survival, replacement-stage survival, stage duration, age at maturity, fecundity, juvenile survival	Species-specific stable replacement expectation
Observation	Years, stage counts, effort, site, method, repeats, movement and classification uncertainty	Observed annual ratios, intervals and evidence quality
Trend	Consecutive annual counts and method uncertainty	Unusual annual-change alerts and descriptive direction
Projection	Stage structure, species traits, egg-to-year-one survival, projection horizon	Median trajectory, interval, decline and quasi-extinction screening metrics

Table 1. Logical layers of the TurtleStatus prototype.

3.2 Definition of the replacement stage

The replacement stage is an operational, species-specific monitoring class. It comprises turtles that are not yet established adults but are expected to enter the adult class during an observable window of d years. For capture data it should be defined using validated size, age, sex and maturity information. For camera platforms it may be defined from calibrated carapace length and, where visible, sex-specific tail morphology. For nesting datasets it is the class of new or young breeding females that can be distinguished from established nesters. Hatchlings and small juveniles are excluded unless the selected pathway and benchmark explicitly model them.

3.3 Derivation of the stable replacement ratio

Let A be the established-adult population immediately after census, S_A adult annual survival, S_R annual survival in the observable replacement stage, d the number of annual intervals in that stage, and I the number entering the replacement stage each year. Expected annual adult losses are $A(1−S\_A)$. Under a stationary stage distribution, entrants must satisfy:

$$I\ S\_R^d = A(1 - S\_A) \quad (1)$$

The standing replacement-stage population is the sum of d surviving entry cohorts:

$$R = I\ (1 + S\_R + \dots + S\_R^{d-1}) = I(1 - S\_R^d)/(1 - S\_R) \quad (2)$$

Substituting Equation 1 into Equation 2 gives the benchmark implemented in TurtleStatus:

$$E(R/A) = (1 - S\_A)(1 - S\_R^d) / [(1 - S\_R)S\_R^d] \quad (3)$$

This expression is a stationary replacement condition, not an estimate of abundance. It assumes constant vital rates, a closed stage accounting interval, no persistent transient cohort effects and consistent census timing. When d=1 in the nesting-female pathway, the prototype uses $(1−S\_A)/S\_A$, corresponding to new breeders expressed relative to established adults surviving to the post-breeding census. Users must document an alternative census convention if their data differ.

Symbol	Definition	Prototype role
A	Established adults	Ratio denominator and standardised projection baseline
R	Observable replacement-stage animals	Ratio numerator
S_A	Annual adult survival	Determines expected annual adult losses

Symbol	Definition	Prototype role
S_R	Annual replacement-stage survival	Determines standing cohorts and maturation
d	Observable-stage duration in years	Number of near-mature cohorts visible
I	Annual entry to replacement stage	Implicit flow required for adult replacement

Table 2. Notation used in the replacement benchmark.

3.4 Input processing and repeat captures

The prototype accepts annual summaries or individual-level workbooks. For a recognised individual-turtle workbook, records are filtered to the selected species. Rows explicitly labelled as repeat captures are removed, and remaining data are reduced to one turtle-year per identifier before aggregation by year, site and method. Adult labels are mapped to the established-adult class. Only explicit subadult or equivalent validated replacement labels are mapped to R. Juvenile, hatchling, unknown and inconsistent immature labels are not automatically forced into R. If incompatible terminology is detected, the biological expectation remains available but the observed-versus-expected conclusion is gated as uncertain.

This deduplication is intentionally conservative but incomplete. It does not estimate detection, temporary emigration or individual availability. A turtle observed at multiple sites in one year may require project-specific reconciliation. Zero-detection surveys and effort must be retained in future schema versions; the current annual count ratio cannot distinguish a biological zero from a missing survey unless users supply that information.

3.5 Annual ratios and approximate sampling intervals

For year t, the raw annual ratio is $q_t=R_t/A_t$. The pooled descriptive ratio is $\Sigma R_t/\Sigma A_t$. For graphical uncertainty, TurtleStatus applies a Haldane correction and the large-sample log-ratio approximation:

$$\tilde{q}_t = (R_t + 0.5)/(A_t + 0.5) \quad (4)$$

$$SE[\log(\tilde{q}_t)] = \sqrt{1/(R_t+0.5) + 1/(A_t+0.5)} \quad (5)$$

$$CI_{95} = \exp\{\log(\tilde{q}_t) \pm 1.96\ SE[\log(\tilde{q}_t)]\} \quad (6)$$

These intervals treat classified adult and replacement counts as independent count contributions. They do not account for repeated individuals across years, clustering within visits, variable effort or imperfect stage-specific detection. They are therefore sampling guides, not full confidence intervals for a population ratio.

3.6 Evidence-quality score and adequacy support

The current prototype uses a transparent heuristic score Q to widen or narrow the comparison. Let Y be the number of represented years, N the total number of classified adult and replacement records, E, L and M be indicators that effort, site and method fields are present, U be a user-selected method/selectivity uncertainty penalty, and O indicate an open population. The implemented score is:

$$Q = \text{clamp}[0.32(Y/5) + 0.28\sqrt{N/20} + 0.16E + 0.12L + 0.12M - U - 0.10O, 0.08, 0.96] \quad (7)$$

A comparison scale is then formed using pooled observed ratio q, expected ratio e, continuity constant 0.015, and:

$$\sigma^* = \sqrt{1/\max(\Sigma R,1) + 1/\max(\Sigma A,1) + (1-Q)^2 + 2U} \quad (8)$$

$$H = \text{logistic}_{1.702}\{ \log[(q+0.015)/(e+0.015)] / \sigma^* \} \quad (9)$$

The interface currently describes H as a “probability replacement is adequate.” That label is stronger than justified. Q and H have not been calibrated against populations of known demographic status and are not posterior probabilities. In this manuscript we call H a screening adequacy-support index. Thresholds are $H \le 0.20$, strong evidence of replacement failure; $0.20 < H \le 0.40$, possible deficit; $0.40 < H < 0.80$, inconclusive; and $H \ge 0.80$, likely adequate. A priority revision is to relabel the interface and replace this heuristic with a hierarchical observation model after empirical calibration.

Component	Prototype weight	Interpretation
Years	$0.32 \times Y/5$	Rewards temporal replication; presently not separately capped
Sample size	$0.28 \times \sqrt{N/20}$	Rewards independent classified observations
Effort present	+0.16	Indicates ability to separate survey from demographic change
Site present	+0.12	Supports spatial audit
Method present	+0.12	Supports method audit
Selectivity penalty	−U	User-specified 0–0.30 uncertainty
Open population	−0.10	Allows movement to weaken inference
Final clamp	0.08–0.96	Prevents certainty at either extreme

Table 3. Components of the current evidence-quality score. These weights are design parameters requiring empirical calibration.

3.7 Descriptive temporal direction and annual-change alerts

The displayed annual direction is the average proportional endpoint change: $[(q_T-q_1)/q_1]/(T-1)$. It is descriptive, sensitive to endpoints and withheld when stage labels or methods are incompatible. For consecutive years, the log-ratio contrast is:

$$\Delta_t = \log[(R_t+0.5)/(A_t+0.5)] - \log[(R_{t-1}+0.5)/(A_{t-1}+0.5)] \quad (10)$$

$$SE(\Delta_t)=\sqrt{\Sigma_{j=t-1}^{t}[1/(R_j+0.5)+1/(A_j+0.5)] + U^2} \quad (11)$$

A point is flagged when $|\Delta_t/SE(\Delta_t)| \ge 1.96$ and both annual combined counts are at least 20. The alert is explicitly diagnostic: effort, sites, methods, repeat captures and classification must be checked before a biological interpretation.

3.8 Standardised stochastic projection

The tool includes a three-stage screening projection for juveniles J, observable replacement-stage turtles R and established adults A. Starting adults are standardised to $A_0=100$ because capture totals are not abundance. $R_0=100q$, or 100e when stage comparability is gated. Let m be age at maturity, d the replacement-stage duration and $j=\max(1,m-d)$ the juvenile-stage duration. $J_0=\max[10,R_0(j/d)]$. The annual transitions are:

$$J_{t+1}=J_t S_J(1-1/j)+A_t F_t \quad (12)$$

$$R_{t+1}=J_t S_J/j+R_t S_R(1-1/d) \quad (13)$$

$$A_{t+1}=A_t S_A+R_t S_R/d \quad (14)$$

Female recruitment is $F_t=0.5\times$eggs per female per year$\times$egg-to-year-one survival$\times$lognormal annual variation. The prototype runs 600 deterministic-seed Monte Carlo trajectories. A shared standard-normal environmental shock perturbs annual adult, replacement and juvenile survival on log scales of 0.035, 0.055 and 0.09, respectively; rates are bounded to biologically permissive intervals. The fecundity coefficient of variation increases with method uncertainty and observed temporal instability. Outputs are the median trajectory, 10th–90th percentiles, median $\lambda=(\text{median } A_T/100)^{(1/T)}$, the fraction ending below 100 adults, and the fraction ever falling below 20 adults.

> **SCOPE OF THE PROJECTION.** The uploaded ratio sets starting stage structure but does not yet estimate an ongoing recruitment multiplier. Consequently, future vital rates can dominate the projection even when the observed ratio is low. This PVA is an auditable sensitivity display, not a fitted population model.

3.9 Simulation evaluation

We evaluated two properties of the prototype. First, we calculated Equation 3 across adult survival 0.90–0.995, replacement-stage survival 0.55–0.98 and stage durations of two, four and six years. Second, we evaluated the annual-change alert using 30,000 Monte Carlo pairs per condition. Annual combined classified samples were fixed at 25, 50, 100, 200 or 400. Counts were allocated between adults and replacement stages using binomial sampling with a baseline ratio of 0.35, followed by no change or 20%, 40% or 60% ratio declines. Method uncertainty was $U=0.08$. The proportion of pairs exceeding $|z|=1.96$ was recorded as false-alert rate under no change and detection probability under decline.

3.10 Fictional worked example

The downloadable training workbook contains eight years (2018–2025), two sites, two methods, repeat records and consistently classified Chelodina longicollis. Annual adult counts were 80, 83, 79, 84, 87, 82, 86 and 88; replacement counts were 34, 31, 29, 30, 27, 25, 23 and 21. The example is fictional and designed to demonstrate a declining ratio, column mapping, repeat handling and output interpretation. For the illustrative benchmark we used $S_A=0.98$, $S_R=0.86$ and $d=4$ years.

4. Results

4.1 Life-history sensitivity

The stable replacement expectation was most strongly reduced by high adult survival and increased with a longer observable stage (Figure 2). At $S_R=0.86$, expected ratios for $d=4$ were 0.592, 0.296, 0.177, 0.118 and 0.059 as S_A increased from 0.90 to 0.95, 0.97, 0.98 and 0.99. At $S_A=0.98$, increasing d from two to four to six years increased the expectation from 0.050 to 0.118 to 0.210. Thus, a raw ratio cannot be interpreted without both life history and an operational stage-duration definition.

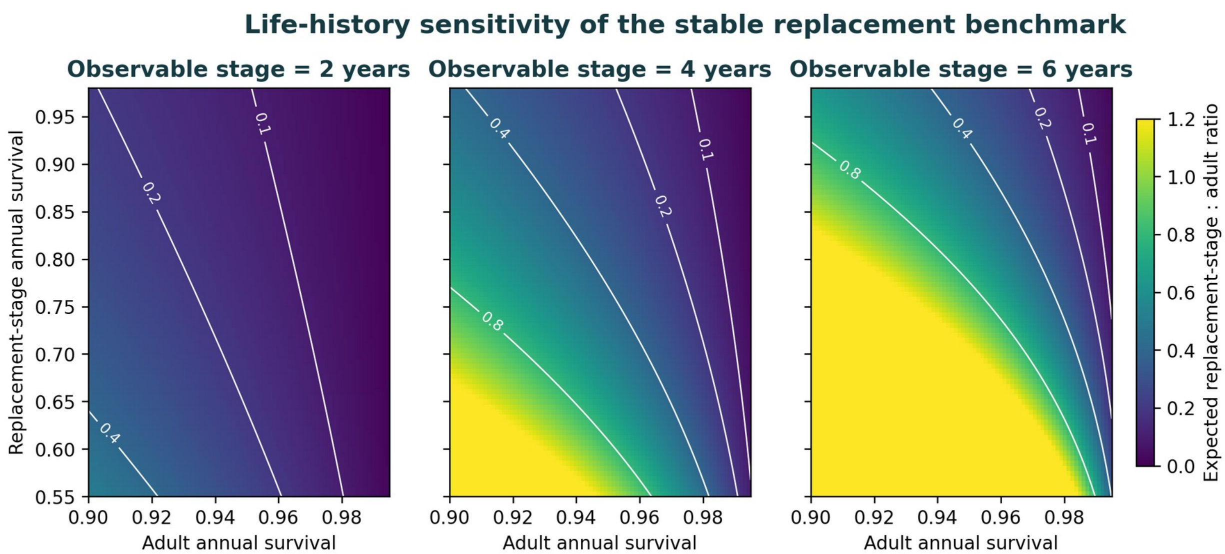

Figure 2. Sensitivity of the stable replacement-stage-to-adult ratio to adult survival, replacement-stage survival and observable-stage duration.

Adult survival	d=2	d=4	d=6
0.90	0.251	0.592	1.051
0.95	0.126	0.296	0.526
0.97	0.075	0.177	0.315
0.98	0.050	0.118	0.210
0.99	0.025	0.059	0.105

Table 4. Expected replacement-stage-to-adult ratios for S_R=0.86.

4.2 Annual-change alert performance

The alert was conservative under the simulated null conditions, with false-alert rates of 0.029–0.041 across sample sizes. A 20% decline was rarely detected (0.042–0.202). A 40% decline increased detection from 0.075 at n=25 to 0.781 at n=400. A 60% decline was detected with probabilities 0.146, 0.359, 0.661, 0.927 and 0.998 for n=25, 50, 100, 200 and 400, respectively. These results emphasise that “many photographs” are not equivalent to many independent classified turtles; moderate annual changes require large, standardised samples.

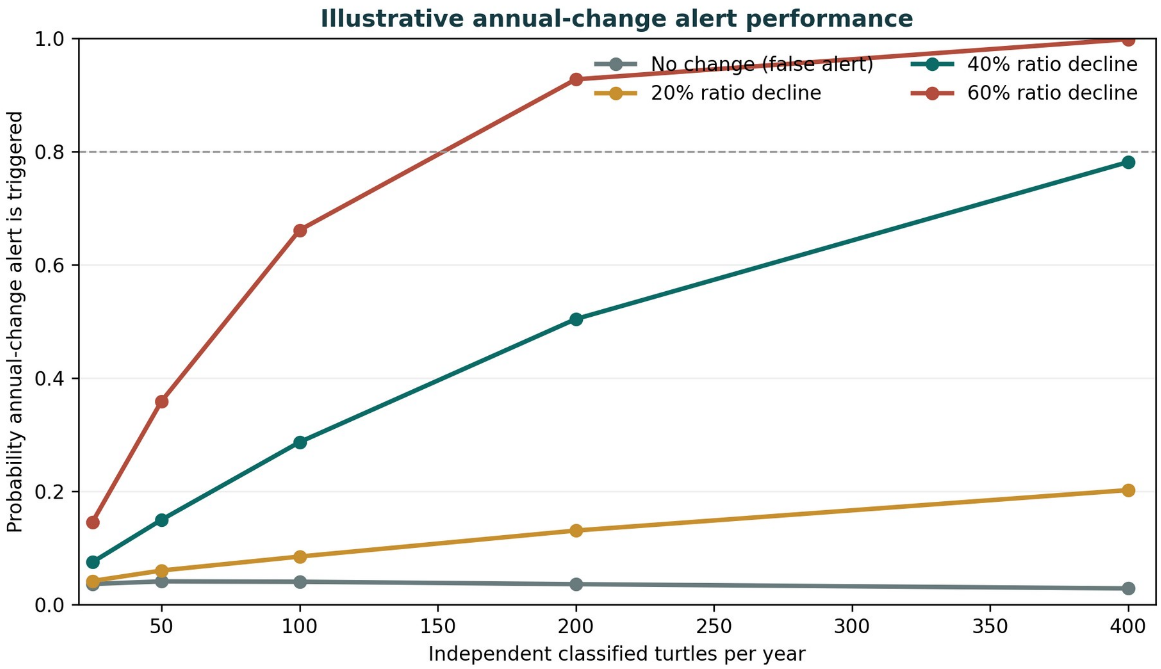

Figure 3. Monte Carlo performance of the annual-change alert under a baseline replacement-to-adult ratio of 0.35 and method uncertainty U=0.08.

Ratio change	n=25	n=50	n=100	n=200	n=400
No change	0.036	0.041	0.040	0.036	0.029
20% decline	0.042	0.060	0.085	0.131	0.202
40% decline	0.075	0.150	0.287	0.504	0.781
60% decline	0.146	0.359	0.661	0.927	0.998

Table 5. Probability of triggering the prototype annual-change alert in 30,000 simulated year pairs per condition.

4.3 Worked example

The fictional pooled ratio was 0.329, above the illustrative species expectation of 0.118, but it declined from 0.425 in 2018 to 0.239 in 2025—an average endpoint decline of 6.26% per year. This combination is intentionally instructive: the population does not cross the replacement benchmark during the example, yet the declining pipeline warrants continued standardised monitoring. A single healthy/declining label would discard that early-warning information.

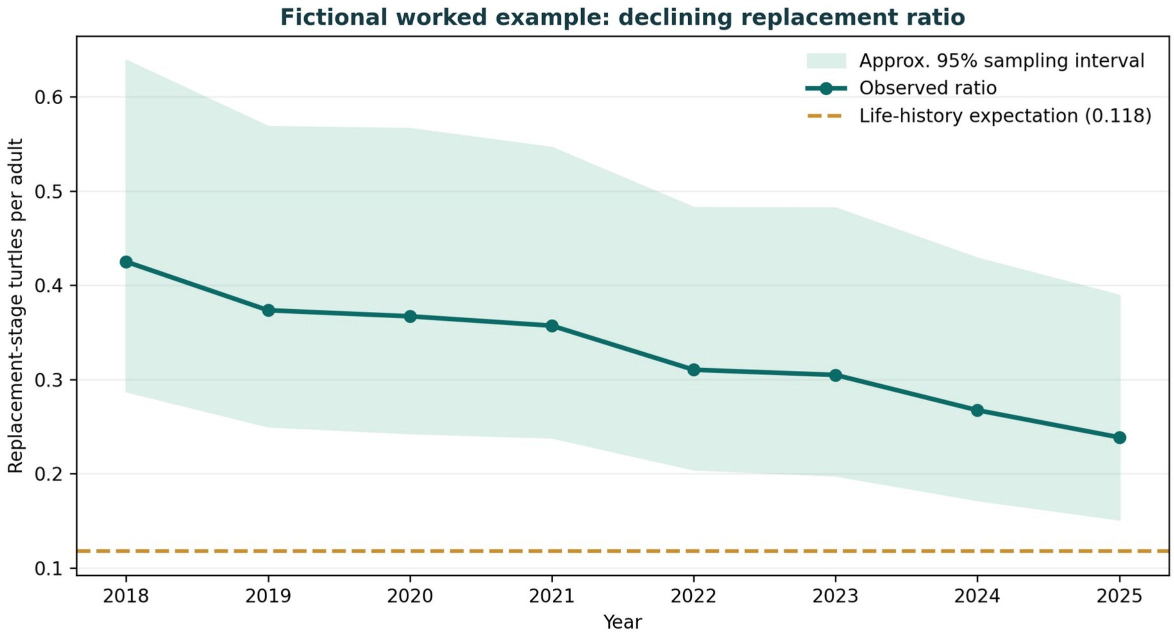

Figure 4. Fictional worked example. Approximate intervals reflect annual adult and replacement counts but not repeated-individual, effort or detectability uncertainty.

5. Discussion

5.1 From universal ratio to universal equation

The central contribution is not a universal numerical threshold. Turtle life histories differ too strongly for that claim. Instead, Equation 3 supplies a universal accounting relationship with species-specific parameters. This resolves an apparent tension in demographic monitoring: managers need interpretable baselines, but comparative work shows that raw body-size structures vary with species, environment, sample size and method (McKnight et al. 2025). TurtleStatus makes the baseline conditional and editable rather than pretending those sources of variation do not exist.

The model also clarifies why the observable replacement stage is more defensible than a pooled "juvenile" class. Small juveniles may be cryptic, use different habitats, escape or avoid traps, and survive at strongly size-dependent rates (Iverson 1991). Near-mature turtles can behave more like adults and remain distinguishable by size for several years. The value of this stage is therefore its position in the pipeline: it integrates earlier survival and is close enough to adult entry to provide a leading indicator.

5.2 Standardised platforms and network inference

Fixed-length basking platforms with overhead cameras can make the operational stage more repeatable. Platform lines provide a size reference, while overhead video can support species classification, carapace measurement, sex classification where tails are visible, and duplicate filtering. A network of nodes enables two complementary tests: whether each local population departs from its species benchmark and whether similar departures occur coherently across sites. Hierarchical site-year models should ultimately replace pooled ratios, estimating method- and environment-specific detection while partially pooling information across nodes.

Public participation expands temporal coverage but changes the sampling unit. Random snapshots during basking hours are useful only when time, location, weather, platform identity and duplicate groups are retained. Automated cameras can define independent time windows; opportunistic public images should be treated as observation events, not individual turtles, unless identity is resolved. Reference sites sampled repeatedly can help estimate temporal availability (Armstrong 2016).

5.3 Nesting populations and multiple monitoring pathways

Some populations are monitored primarily through nesting females. In constrained nesting habitat, new small adults may be highly detectable even when juveniles are not. The nesting pathway treats entry of young breeders as the replacement signal and requires consistent individual identity or validated size/age rules. This extends the framework to species and programmes for which the most observable demographic transition occurs at nesting rather than basking or trapping.

Pathways should not be combined naively. Capture, basking and nesting methods sample different availability processes. Parallel estimates can be more informative than a pooled ratio: agreement strengthens the demographic interpretation; disagreement points to method bias, sex structure, movement or habitat-specific change.

5.4 Diagnosing cause with external threat indicators

A replacement deficit indicates that the pipeline is changing, not why. Mechanistic data can shorten the diagnosis. The National Nest Predation Survey uses standardised artificial chicken-egg nests to index spatial and temporal variation in nest predation; such indices are informative when their biases and predator cues are acknowledged (Marchand et al. 2002; Spencer et al. 2017). TurtleSAT mortality reports can identify roadkill, sex-biased adult mortality and geographic hotspots. Adult female mortality is particularly consequential in long-lived turtles (Steen et al. 2006). Joint interpretation can distinguish a pipeline failure consistent with low nest survival from a population additionally destabilised by elevated adult mortality.

5.5 Relationship to CMR, CPUE and integrated population models

TurtleStatus does not replace CMR. When robust encounter histories exist, multistate CMR or integrated population models should estimate stage-specific survival, transition, detection and movement directly. Nor does it treat catch per unit effort as abundance without assumptions. Its niche is earlier and broader: screening heterogeneous datasets, exposing where the biological expectation and observation process disagree, and prioritising populations for intensive analysis. It may also supply informative priors and hypotheses for a later integrated model.

5.6 Limitations

- Equation 3 assumes stationarity and constant vital rates; transient cohorts, density dependence and episodic recruitment can produce legitimate deviations.

- Observed counts are not corrected for stage-specific detection. Method uncertainty widens a heuristic score but cannot remove bias.
- The evidence-quality weights and adequacy-support thresholds are design parameters, not empirically calibrated probabilities.
- The endpoint trend is descriptive and can be driven by the first or last year. A hierarchical trend model is preferable when sufficient years exist.
- The screening PVA uses the ratio mainly as starting stage structure; it does not yet infer an ongoing recruitment multiplier from the time series.
- Trait priors vary in quality and scale. Population-specific adult survival can differ from a species-wide estimate, especially under road mortality, harvest, disease or drought.
- Sex structure is simplified. Female-biased adult mortality and sex-specific maturity can invalidate a pooled ratio.
- Open populations may reflect movement rather than local birth and survival.

5.7 Validation and development roadmap

Priority	Required analysis	Decision criterion
1. Trait audit	Source every taxon-level trait; reconcile synonyms; publish evidence grades and imputation model	Reproducible species catalogue with versioned provenance
2. Empirical calibration	Apply to populations with reliable CMR/IPM estimates of λ and recruitment	Sensitivity, specificity and calibration curves for known status
3. Detection model	Paired platform, trapping and nesting surveys; repeated visits and environmental covariates	Stage- and method-specific detection estimates
4. Hierarchical trend	Site-year state-space model with effort offsets and partial pooling	Calibrated probability of sustained decline
5. PVA coupling	Infer recruitment multiplier from ratio time series and propagate parameter uncertainty	Projection responds coherently to observed pipeline deficits
6. Prospective test	Pre-register alerts in monitoring networks and evaluate later adult recruitment	Demonstrated lead time over adult abundance

Table 6. Minimum validation programme before regulatory or recovery-plan use.

6. Conclusions

TurtleStatus converts a fundamental life-history accounting relationship into a practical early-warning framework. Its novelty lies in combining a universal equation with species-specific baselines, an explicitly defined replacement stage, observation-quality gates and multiple monitoring pathways. The approach avoids two common errors: treating an adult-rich population as necessarily secure and treating every absence of small juveniles as evidence of collapse. Instead, it asks whether the visible replacement pipeline is adequate, how confidently it was observed, whether it is changing, and what evidence should be collected next.

The prototype is deliberately transparent, but transparency also reveals its present limits. The support score is heuristic, detection is not fitted, and the screening PVA is not a substitute for a formal demographic model. These are not reasons to abandon the approach; they define a clear validation programme. Networked, size-calibrated monitoring platforms, TurtleSAT mortality data and the National Nest Predation Survey provide a realistic path from screening tool to a globally comparable turtle early-warning system.

Data and code availability

The public prototype and fictional training workbook are available at https://turtle-status.emydura.chatgpt.site. The worked example contains no real population data. Before journal submission, the exact source-code release, archived version identifier, species catalogue and simulation scripts should be deposited in a permanent repository with a DOI.

Ethics statement

The software and simulations reported here used no live animals and no personal data. Applications to field datasets remain subject to the permits, animal ethics approvals, Indigenous data governance and sensitive-species protections governing those original data.

Author contributions

R.-J. Spencer: conceptualisation, methodology, conservation application and manuscript development. Additional software, statistical, data-curation and validation contributions are to be assigned before submission.

Competing interests

To be declared. TurtleStatus is a companion to TurtlePlanner and may support programmes associated with 1 Million Turtles and Intelligent EcoTransformations. Any institutional, commercial or funding interests should be stated explicitly at submission.

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Appendix A. Algorithm summary

This appendix records the current prototype in implementation order so later software versions can be compared against the manuscript.

A1. Biological benchmark

Select species prior; apply user-adjusted adult survival, replacement survival and observable-stage duration; compute Equation 3 independently of uploaded counts.

A2. Data aggregation

Filter species; remove explicit repeat captures; retain one turtle-year; group by year, site and method; count established adults and validated replacement-stage animals.

A3. Comparability gate

If juvenile, hatchling, unknown or inconsistent stage terms cannot be mapped to the benchmarked window, show the expectation but withhold a strong comparison.

A4. Observation summary

Calculate annual raw ratios, pooled ratio, Haldane-corrected approximate intervals and descriptive endpoint direction.

A5. Evidence score

Combine years, classified sample, field availability, movement and user uncertainty through Equation 7; label limited, moderate or strong evidence.

A6. Screening support

Calculate Equations 8–9 and apply descriptive thresholds; do not interpret as a calibrated probability.

A7. Annual alerts

Compare consecutive Haldane-corrected log ratios using Equations 10–11; flag $|z| \geq 1.96$ only when each year has at least 20 classified records.

A8. Projection

Standardise adults to 100; initialise replacement and juvenile stages; run 600 stochastic trajectories using Equations 12–14; report median and 10th–90th percentiles, λ, decline fraction and quasi-extinction fraction.