Supplementary Information for: Survival variability and population density in fish populations: 2007-04-04591C.

Contents

1 Supplementary methods

Analytical models for survival variability The full theoretical treatment of survival variability and population density proceeds as follows. Note that the salient features are presented in the Methods section of the manuscript but are repeated here for continuity.

Recruitment can be written[1] as

$$R_t = E_t \exp(-(C_{1,t} + C_{2,t} + C_{3,t})) \quad (1)$$

Where E_t is the number of eggs produced in year t and $C_{i,t}$ is the cumulative mortality in stage i; $i = 1$ for the egg stage, $i = 2$ for the late larval stage, and $i = 3$ for the juvenile phase. Population size in the egg, late-larval, and late juvenile phase (when they recruit to the older population) are given by E_t, N_t, and R_t, respectively. In order to analyze the effect of density dependence on the relationship between variability and reproductive adult abundance we will examine a model in which density dependence arises in the juvenile stage, a treatment which is motivated by the demonstration of the suitability of this choice for many fish populations[2,3]. Stochastic mortality, independent of density, is assumed to take place during both the larval and juvenile stages. The number of late-stage larval fish, is $N_t = E_t \exp(-(C_{1,t} + C_{2,t}))$. The number of fish surviving from the late-larval stage through to the end of the juvenile phase is given by

$$R_t = N_t \exp(-C_{3,t}) \quad (2)$$

It is useful to formulate the above equations in terms of deviations from their means. Letting $C_{3,t} = \overline{C_3} + \Delta C_{3,t}$ and $\ln N_t = \overline{\ln N} + \Delta \ln N_t$ gives

$$\ln R_t = \overline{\ln R} + \Delta \ln N_t - \Delta C_{3,t} \quad (3)$$

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where

$$\overline{\ln R} = \overline{\ln N} - \overline{C_3} = \ln(N_* \exp(-\overline{C_3})) \tag{4}$$

and N_* is the geometric mean abundance of the late-larval stage[1]. Rearranging (3)

$$\begin{aligned} \ln R_t - \overline{\ln R} &= \Delta \ln N_t - \Delta C_{3,t} && (5) \\ \exp(\ln R_t - \overline{\ln R}) &= \exp(\Delta \ln N_t - \Delta C_{3,t}) && (6) \\ \frac{R_t}{R_*} &= \exp(\Delta \ln N_t - \Delta C_{3,t}) && (7) \\ R_t &= R_* \exp(\Delta \ln N_t - \Delta C_{3,t}) && (8) \end{aligned}$$

where R_* is the geometric mean recruitment. The effect of density dependence can be incorporated by writing

$$\Delta C_{3,t} = f(\Delta \ln N_t) + \delta_t - \bar{f} \ , \tag{9}$$

where f is an as yet unspecified function representing density dependence, δ_t represents mortality in the juvenile stage unrelated to density and $\bar{f}$ is the time average of $f(\Delta \ln N_t)$. Letting $\varepsilon_t = \sum_{i=1}^{2} \Delta C_{i,t}$ be the sum of the demeaned mortalities in the egg and larval stages, it has been shown[4] that

$$\Delta \ln N_t = \Delta \ln E_t - \varepsilon_t \approx \Delta \ln S_t - \varepsilon_t = \ln S_t - \ln S_* - \varepsilon_t = \ln(S_t/S_*) - \varepsilon_t \tag{10}$$

where E_t is egg production, S_* is geometric mean adult abundance, and we have used $\Delta \ln S_t \approx \Delta \ln E_t$, valid when egg production is linearly related to adult abundance. Substituting (10) and

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(9) into (8), we can now write

$$R_t = R_* \exp(\ln(S_t/S_*) - (\varepsilon_t + f(\Delta \ln S_t - \varepsilon_t) + \delta_t - \bar{f})) \tag{11}$$

$$= \frac{R_* \exp(\ln(S_t/S_*))}{\exp(\varepsilon_t + f(\Delta \ln S_t - \varepsilon_t) + \delta_t - \bar{f})} \tag{12}$$

$$= R_* \frac{S_t}{S_*} \exp(-(\varepsilon_t + f(\Delta \ln S_t - \varepsilon_t) + \delta_t - \bar{f})) \tag{13}$$

At a given adult abundance, $S_t = S_0$, log survival is $\ln(R_t/S_0)$, therefore, from (13), we have

$$\ln(R_t/S_0) = \ln(R_*/S_*) - \varepsilon_t - f[\ln(S_0/S_*) - \varepsilon_t] - \delta_t + \bar{f} \tag{14}$$

One conclusion is immediately apparent from (14): the variability of survival, Var$[\ln(R_t/S_0)]$, will be independent of adult abundance only if $f[\ln(S_0/S_*) - \varepsilon_t]$ is linear. Specifically, write $f[\ln(S_0/S_*) - \varepsilon_t] = \lambda[\ln(S_0/S_*) - \varepsilon_t]$. Prescribing a density-dependent mortality which is linear in log-abundance is the core of key factor analysis[5,6] and is essential to the analytic tractability of key factor analysis. The variability of survival is derived as follows, substituting $\lambda[\ln(S_0/S_*) - \varepsilon_t]$ into (14)

$$\ln(R_t/S_0) = \ln(R_*/S_*) - \varepsilon_t - \lambda[\ln(S_0/S_*) - \varepsilon_t] - \delta_t + \bar{f} \tag{15}$$

$$= \ln(R_*/S_*) - \varepsilon_t(1-\lambda) - \lambda \ln(S_0/S_*) - \delta_t + \bar{f} \tag{16}$$

$$\text{Var}(\ln(R_t/S_0)) \approx (1-\lambda)^2\sigma_\varepsilon^2 + \sigma_\delta^2 \tag{17}$$

where σ_ε and σ_δ are the standard deviations of ε and δ, respectively. The survival variability is independent of S_0 and the effect of density dependent juvenile mortality (λ) is clearly to reduce survival variability. A similar expression was previously obtained for the Gompertz form of density dependence[7]. Note that for small ε_t an expression analogous to (17) may be derived, using the delta

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method[8], which is a Taylor series expansion, valid for any smooth f

$$\text{Var}[\ln(R_t/S_0)] \approx [1 - f'(\ln(S_0/S_*) - \varepsilon_t)]^2\sigma_\varepsilon^2 + \sigma_\delta^2 \tag{18}$$

Here, $f'(\ln(S_0/S_*) - \varepsilon_t)$ is the first derivative of f with respect to ε_t, evaluated at its mean. It is evident that the variance of survival will be a minimum for the adult abundance at which $f'(\ln(S_0/S_*)-\varepsilon_t)$ is maximum. However, this result is not valid for large σ_ε and thus it is necessary to consider a case where the variance of survival can be derived without demanding that σ_ε be small.

It is useful to consider common models and how the variability in recruitment and survival is a function of egg abundance. For the commonly applied Ricker spawner-recruit function, where survival is a linear function of adult abundance

$$f[\ln(S_0/S_*) - \varepsilon_t] = \exp[\ln(S_0/S_*) - \varepsilon_t + \gamma] = \beta S_0 \exp(-\varepsilon_t) \tag{19}$$

where $\beta = e^\gamma/S_*$. From (19) and (13), one has

$$R_t = \alpha S_0 \exp(-\beta S_0 e^{-\varepsilon_t} - \varepsilon_t - \delta_t) \tag{20}$$

where several constants have been combined into the parameter α. In the limit of zero noise one obtains from (20) the Ricker form, $R_t = \alpha S_0 \exp(-\beta S_0)$.

From (20), the variability of survival is

$$\text{Var}[\ln(R_t/S_0)] = \sigma_\varepsilon^2 + \beta^2 S_0^2 \text{Var}(\exp(-\varepsilon_t)) + 2\beta S_0 \text{Cov}(\varepsilon_t, \exp(-\varepsilon_t)) + \sigma_\delta^2 \tag{21}$$

The variance term on the right side of (21) may be obtained from the variance of a lognormal distribution, $\text{Var}(\exp(-\varepsilon_t)) = \exp(\sigma_\varepsilon)(\exp(\sigma_\varepsilon) - 1)$, and the covariance term may be computed as follows

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$$\mathrm{Cov}(\varepsilon_t, \exp(-\varepsilon_t)) = E[\varepsilon_t \exp(-\varepsilon_t)] - E[\varepsilon_t]E[\exp(-\varepsilon_t)] \tag{22}$$

$$E[\varepsilon_t] = 0 \tag{23}$$

$$\therefore \mathrm{Cov}(\varepsilon_t, \exp(-\varepsilon_t)) = E[\varepsilon_t \exp(-\varepsilon_t)] \tag{24}$$

$$\mathrm{Cov}(\varepsilon_t, \exp(-\varepsilon_t)) = \int_{-\infty}^{\infty} \varepsilon_t \exp(-\varepsilon_t) \frac{1}{\sqrt{2\pi}\sigma_\varepsilon} \exp(-\frac{\varepsilon_t^2}{2\sigma_\varepsilon^2})\, dx \tag{25}$$

$$= -\exp(\frac{\sigma_\varepsilon^2}{2})\sigma_\varepsilon^2 \tag{26}$$

where $E[\cdot]$ is the expectation operator and we have used $E[g(x)] = \int g(x)f(x)\,dx$, where $f(x)$ is the density function of x. Equation (21) may now be reduced to

$$\mathrm{Var}[\ln(R_t/S_0)] = \sigma_\varepsilon^2 + \beta^2 S_0^2 \exp(\sigma_\varepsilon^2)[\exp(\sigma_\varepsilon^2) - 1] - 2\beta S_0 \sigma_\varepsilon^2 \exp(\sigma_\varepsilon^2/2) + \sigma_\delta^2 \tag{27}$$

For small σ_ε

$$\mathrm{Var}[\ln(R_t/S_0)] \approx \sigma_\varepsilon^2(1 - \beta S_0)^2 + \sigma_\delta^2 \tag{28}$$

which can also be obtained from (18). In general, it is apparent from (28) that for large $\beta S_0 > 1$, the term containing $\beta^2 S_0^2$ will dominate and the variability of survival will increase with S_0. For $\beta S_0 \ll 1$, the term in $2\beta S_0$ will dominate that containing $\beta^2 S_0^2$ and thus the variability of survival will decrease as S_0 increases. Therefore, the variability of survival will have a bowl-shaped dependence on S_0. As σ_ε increases the bottom of the bowl will be pushed closer to the $S_0 = 0$ axis. These aspects of the function's behaviour and a comparison with the delta method approximation are illustrated in Fig. S1.

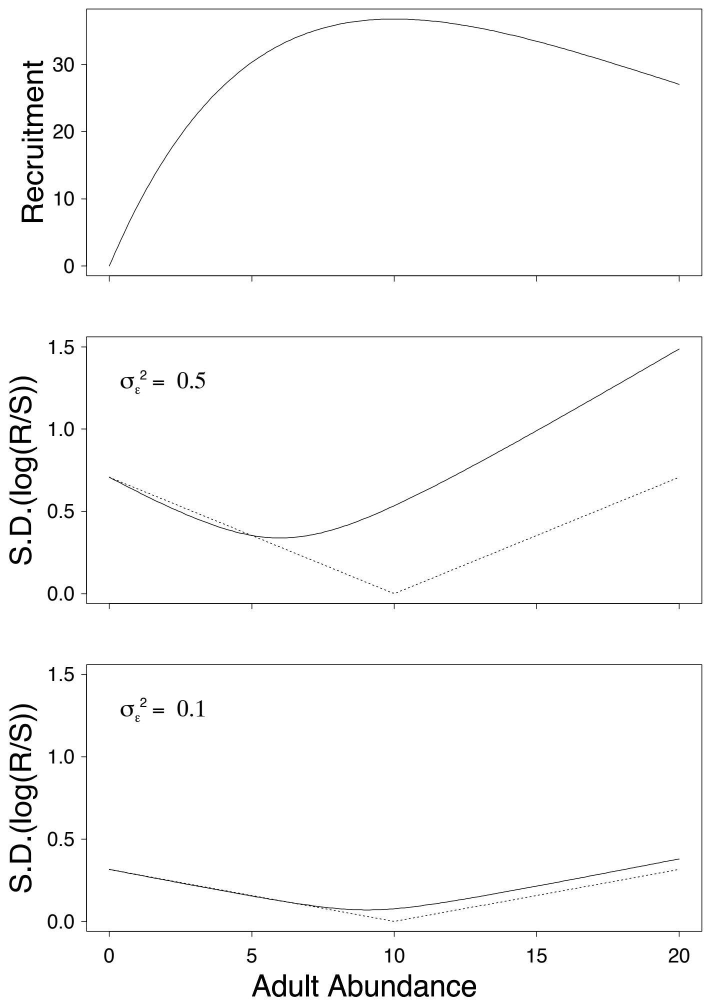

Figure 1: The relationship between recruitment (top panel) and the standard deviation of survival at median ($\sigma_\varepsilon^2 = 0.5$, middle panel) and low ($\sigma_\varepsilon^2 = 0.1$, lower panel) pre-density-dependent variable mortality levels. The solid line is the exact solution and the dotted line in the delta approximation. The recruitment is from the equation $R = 3Se^{-\frac{1}{10}S}$.

Delta method approximations to survival variability Direct analytic calculation of the variance terms for population growth models that do not exhibit linearity between survival and adult abundance are not available in closed form, here we use a delta method approximation to the variance of a function[8]. In order to generalize the results across commonly applied models, the three-parameter Deriso-Schnute[9,10] stock-recruitment model is used

$$R_t = \alpha S(1-\beta\gamma S_0)^{\frac{1}{\gamma}} \tag{29}$$

$$\ln(R_t/S_0) = \ln(\alpha) + \frac{1}{\gamma}\ln(1-\beta\gamma S_0) \tag{30}$$

The delta method approximation follows from equation (18) where

$$f[\ln(S_0/S_*) - \varepsilon_t] = \frac{1}{\gamma}\ln(1-\beta\gamma S_0\exp(-\varepsilon_t)) \tag{31}$$

$$f'[\ln(S_0/S_*) - \varepsilon_t] = \beta S_0/(1-\gamma\beta S_0) \tag{32}$$

$$\text{Var}(\ln(R_t/S_0)) \approx (1-\beta S_0/(1-\gamma\beta S_0))^2\sigma_\varepsilon^2 \tag{33}$$

Possible models of survival range over a degree of compensation continuum between constant productivity (no density dependence) when $\gamma << -1$ and high degrees of over-compensation when $\gamma \geq 0$ (e.g. Ricker and Schaefer model). We fix $\gamma \in \{-1000, -2, -1, 0, 1\}$ for cases of no density dependence, Cushing-like density dependence (non-asymptotic recruitment), Beverton-Holt compensation, and Ricker and Schaefer over-compensation models, respectively. $\sigma_\epsilon^2 = 0.5$ and $\beta = 0.02$ for all models except the Schaefer model for which $\beta = 0.0085$. The delta method at $\beta = 0.02$ gives well behaved approximate variances for all models except the Schaefer. The Schaefer model is problematic at this value due to the behaviour of the term $(1-\beta S_0)$ as it approaches 0. For this reason we chose to use a smaller value of β which avoids this situation but still retains the properties of this model. The depensatory Beverton-Holt survival model used was $\ln(R_t/S_0) = \ln(\alpha) + \frac{1}{\gamma}\ln(1-\beta\gamma S_0) + \ln(S_0) - \ln(S_0+d)$, where d is the strength of depensation at low S.

Sensitivity analysis The purpose of the sensitivity analysis is to determine what effect parameter values have on the model outcome of survival variability. We perform sensitivity analyses on the Beverton-Holt and Ricker model cases of the Deriso-Schnute model to illustrate the general concepts. We perform the sensitivity analysis over a reasonable set of parameter ranges as estimated from the individual fits. To estimate the effect of a given parameter, we hold the other parameters fixed at the median estimate for that parameter and estimate a target function. The two target functions were: for the Beverton-Holt, an estimate of the change in the variance in survival $\Delta\sigma^2_{ln\frac{R}{S}}$ from the lowest parameter value to the highest (estimate of the slope); for the Ricker: because of the quadratic nature of the function of survival variability over adult density, the difference between the first and last values tells us little, therefore we estimate the sum of the absolute value of the first order difference ($\sum_{i=1}^{n}|\sigma^2_{ln\frac{R_i}{S_i}} - \sigma^2_{ln\frac{R_{i-1}}{S_{i-1}}}|$) over all densities to provide a metric for how much change occurs in the variance in survival over the parameter space. The results of the sensitivity analysis are illustrated in Fig. S2.

The effect of increasing the variance in survival in the egg and larval stages is to increase the rate of change of survival variability. Consequently, a large value for σ^2_ϵ will ensure strong survival variability. Note that the positive values of $\Delta\sigma^2_{ln\frac{R}{S}}$, indicate that the variability will decrease over adult abundance where this form of density dependence arises in the juvenile phase. The density-

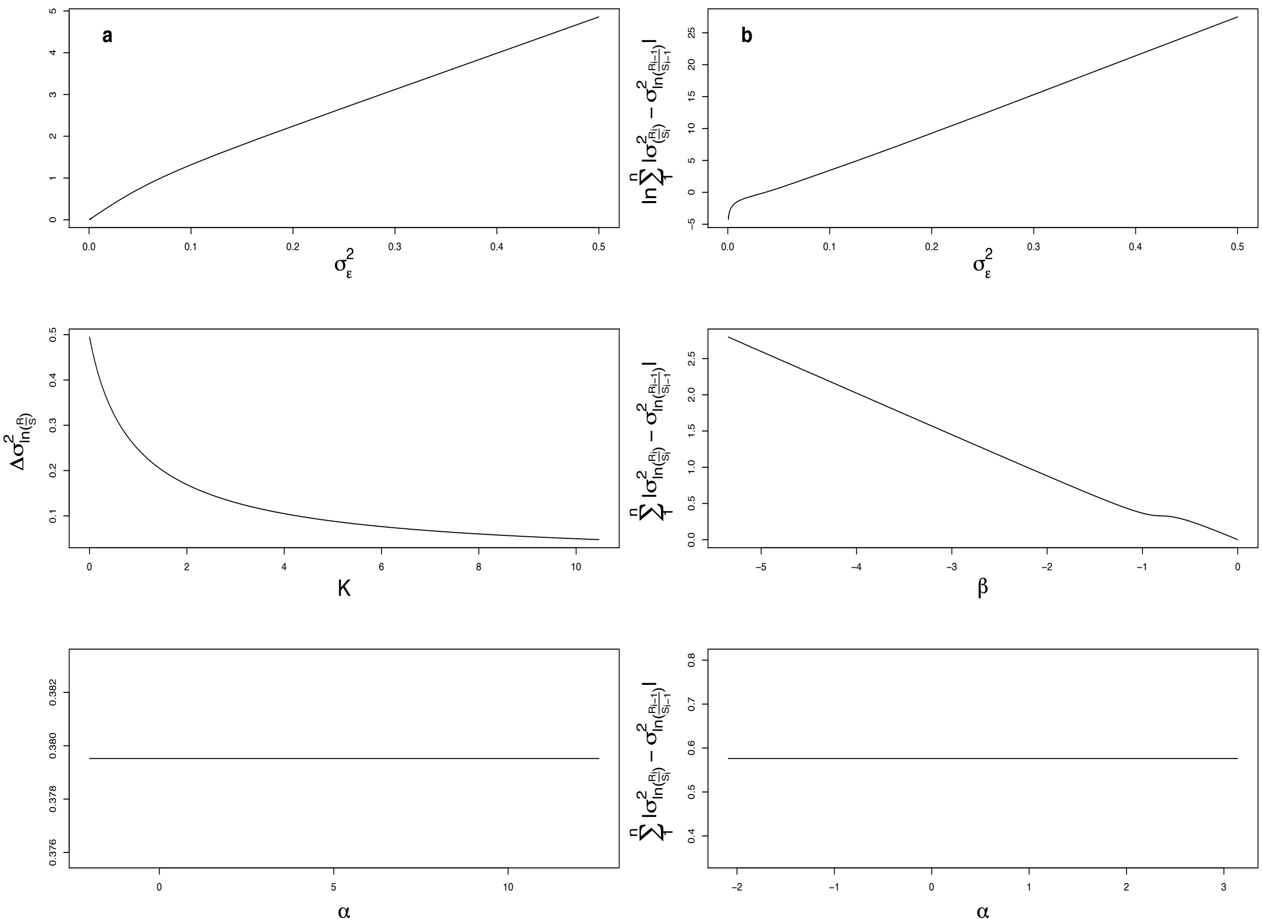

Figure 2: Sensitivity analysis results for the Beverton-Holt (**a**) and Ricker (**b**) survival models. The re-scaled adult abundance ranges between 0 and 1. The range of values chosen were Beverton-Holt: $\alpha \in [-2.0, 12.6]$, $K = 1/\beta \in [1e-09, 10.46]$) and (Ricker: $\alpha \in [-2.0, 3.1]$, $\beta \in [-5.34, -1e-09]$). For the variance of mortality in the egg and larval stages we chose $\sigma^2_\epsilon \in [0, 0.5]$. The target function for the Beverton-Holt was change in the variance in survival forom the lowest parameter value to the highest $\Delta\sigma^2_{ln\frac{R}{S}}$ and for the Ricker: the sum of the absolute value of the first order difference ($\sum_{i=1}^{n} |\sigma^2_{ln\frac{R_i}{S_i}} - \sigma^2_{ln\frac{R_{i-1}}{S_{i-1}}}|$).

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dependent parameters also behave in an intuitive manner. The stronger the regulation (low carrying capacity $K = 1/\beta$ in the Beverton-Holt), the greater the change of survival variability over adult density. If we consider a weakly regulated population to have a high K value, survival variability over adult density will be relatively flat, thus the value of $\Delta\sigma^2_{ln\frac{R}{S}}$ will be low. In contrast, strongly regulated populations (low K) will experience marked changes in survival variability (strongly negative slope approximated by $\Delta\sigma^2_{ln\frac{R}{S}}$) over adult density. For the Ricker β, stronger regulation results in more change in the variance in survival over adult density. Weakly regulated populations are characterised by small changes in survival variability over adult density. No change is observed in the survival variability over the ranges for α in both the Beverton-Holt and Ricker models. This is because α is independent of density.

Meta-analytical methods Data were analyzed taxonomically by population within a species. To investigate whether the results are robust to different survival model formulations, we fit survival models with fixed $\gamma \in \{1, 0, -1\}$ in

$$\ln(R_t/S_t) \quad = \quad \ln(\alpha) + \frac{1}{\gamma}\ln(1 - \beta\gamma S_t) \tag{34}$$

corresponding to the commonly applied Schaefer, Ricker ($\lim_{\gamma\to 0}\alpha S_t(1-\beta\gamma S_t)^{1/\gamma} = \alpha S e^{-\beta S_t}$), and Beverton-Holt models, respectively.

The fixed-effects estimates are estimated by species in two seperate ways.

1. For species with greater than 4 populations a mixed-effects meta-analysis combining all the

populations was used. The model fit to each species was

$$\ln(\frac{R_{t,i}}{S_{t,i}}) = \ln(\alpha + \mu_{i1}) + \frac{1}{\gamma}\ln(1 - (\beta + \mu_{i2})\gamma S_i) + e^{(\eta_0 + \mu_{i3}) + \eta_1 S_i} \tag{35}$$

Where $\alpha, \beta, \eta_0, \eta_1$ are the fixed-effects parameters for a given species and the μ_{ij} are the random effects parameters distributed $N(0, \sigma^2_{\mu_j})$. There are random effects on all parameters except the slope of the variance because we want maximum flexibility for the model form for each population within a species but want to obtain an overall estimate of the change in the variance over abundance.

2. For species with less than 5 populations, there aren't enough degrees of freedom to estimate all parameters (the degrees of freedom in a mixed-effects analysis in SAS PROC NLMIXED is the number of populations minus the number of random effects). Here, estimates of the slope of the variance were combined within a species using a weighted average of the individual population estimates, weighted by their respective sampling variances

$$\hat{\eta} = \frac{\sum_{i=1}^{k} W_i \eta_i}{\sum_{i=1}^{k} W_i} \tag{36}$$

where $W_i = 1/s_i^2$, s_i being the standard deviation associated with the estimated heteroscedastic coefficient η_i in population i.

Ideally all species-level estimates would come from the fixed-effects parameters from a mixed-effects fit, which makes the best use of all the data.

We are primarily interested in the general trend of the change in variance over adult abundance per species but provide an overall estimate of η_1 by combining the estimates of the fixed-effects estimated from 1 and 2 above using a random effects meta-analysis [11]. The fixed-effects results per species were combined to provide an overall heteroscedastic coefficient result according to

$$\hat{\eta_{me}} = \frac{\sum_{i=1}^{k} w_i(\hat{\tau})\eta_i}{\sum_{i=1}^{k} w_i(\hat{\tau})} \tag{37}$$

where $\hat{\tau}$ is the inter-population variation estimated by restricted maximum likelihood [11] and

$$w_i(\hat{\tau}) = \frac{1}{s_i^2 + \hat{\tau}^2} \tag{38}$$

2 Supplementary figures

Presented in Fig. S3-S8 are the individual population-level fits to the survival data from each available population under the Schaefer, Ricker, and Beverton-Holt survival model assumptions. Provided in the top-right of each plot is the population ID and estimate of the heteroscedastic coefficient.

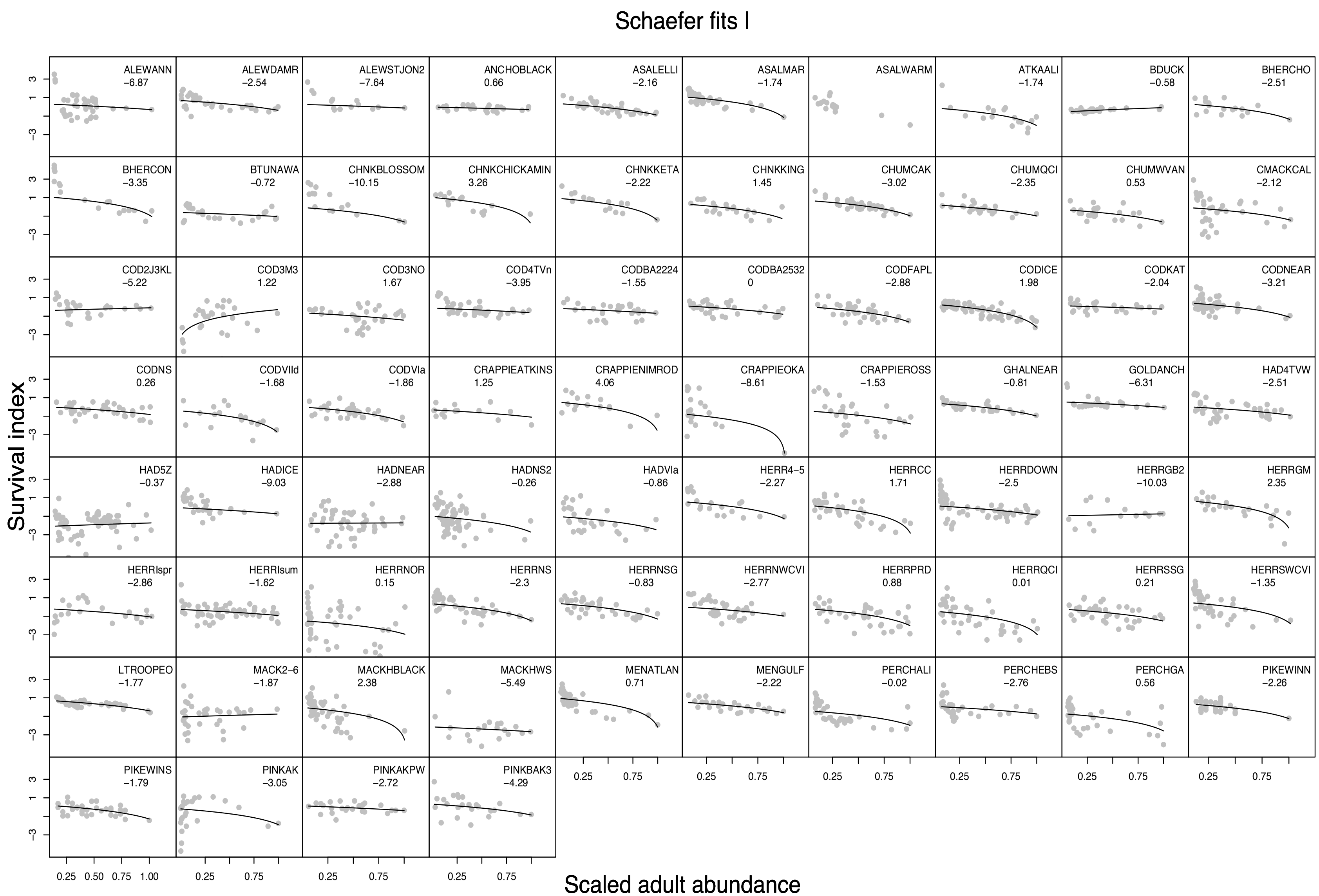

Figure 3: Individual population-level fits of the heteroscedastic Schaefer survival model. The legend in each plot represents the population ID and the estimate of the slope of the variance for that population.

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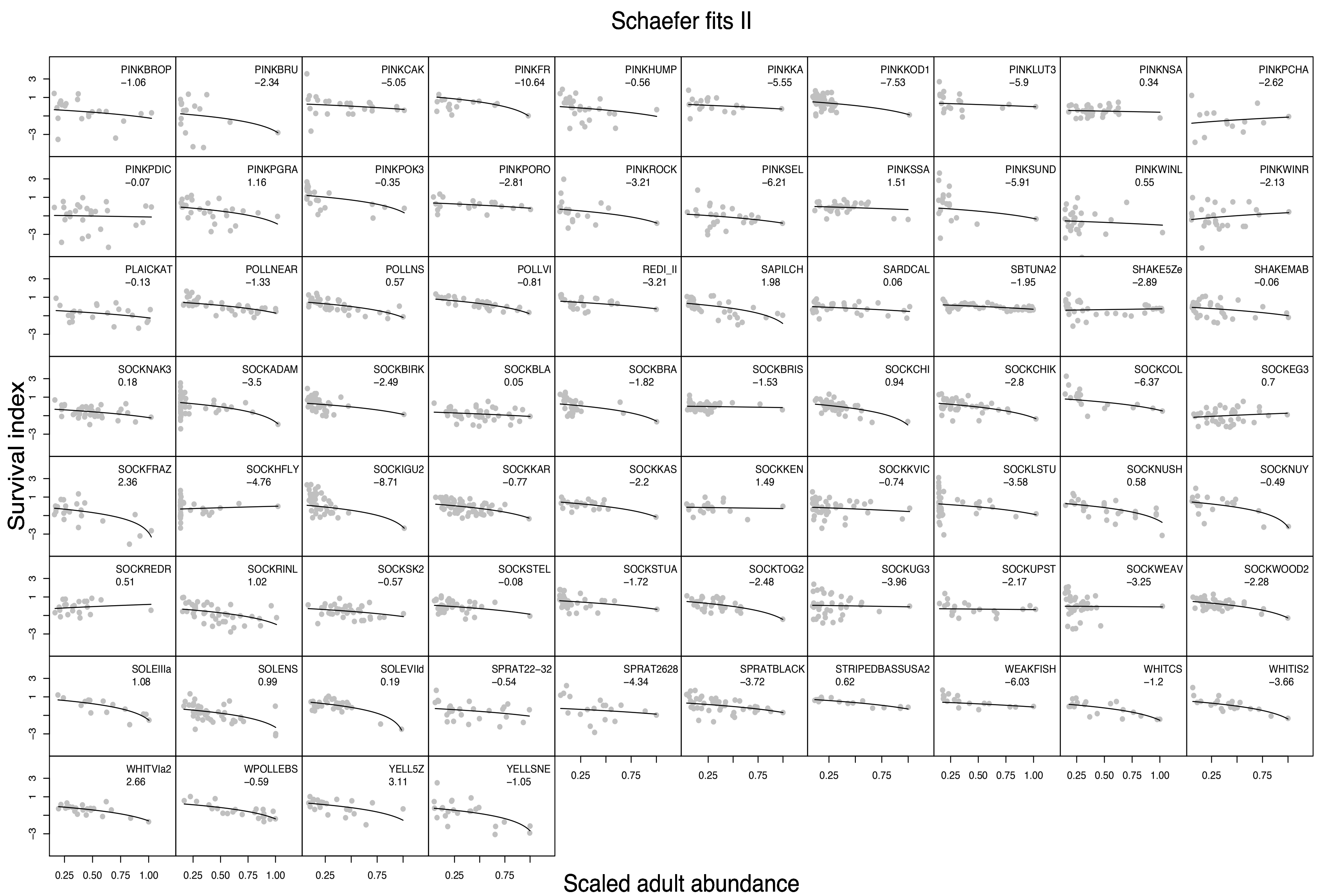

Figure 4: Individual population-level fits of the heteroscedastic Schaefer survival model continued. The legend in each plot represents the population ID and the estimate of the slope of the variance for that population.

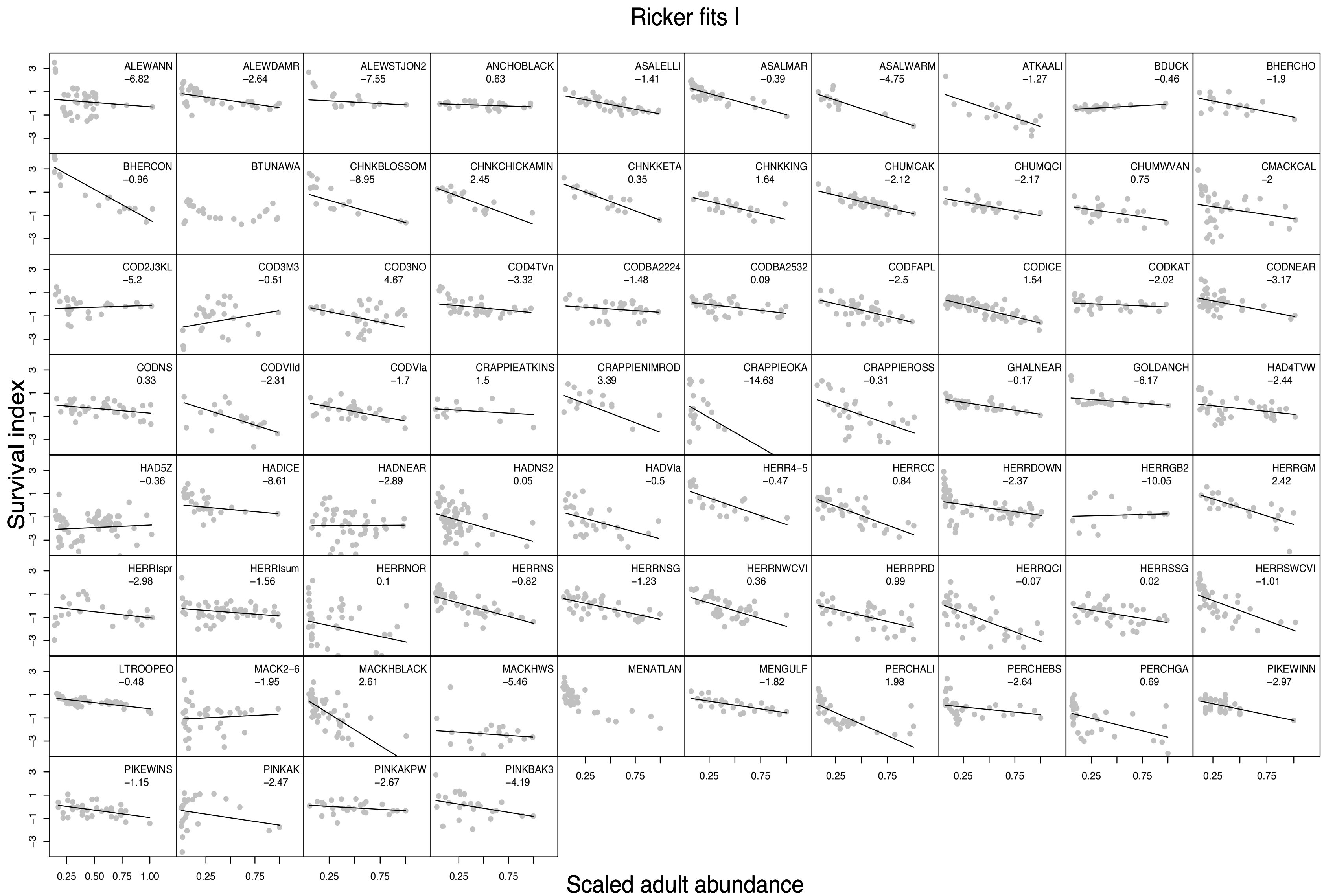

Figure 5: Individual population-level fits of the heteroscedastic Ricker survival model. The legend in each plot represents the population ID and the estimate of the slope of the variance for that population.

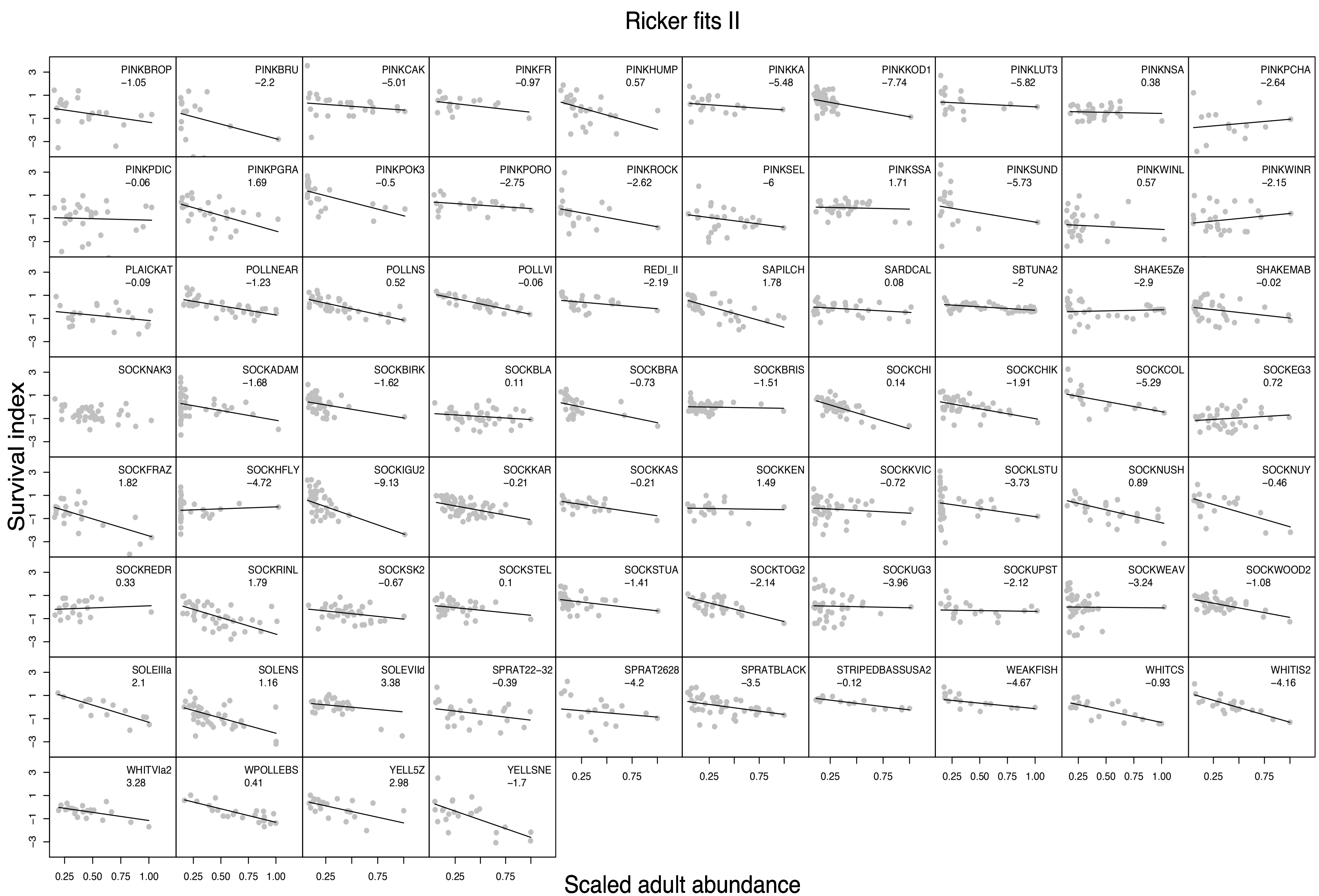

Figure 6: Individual population-level fits of the heteroscedastic Ricker survival model continued. The legend in each plot represents the population ID and the estimate of the slope of the variance for that population.

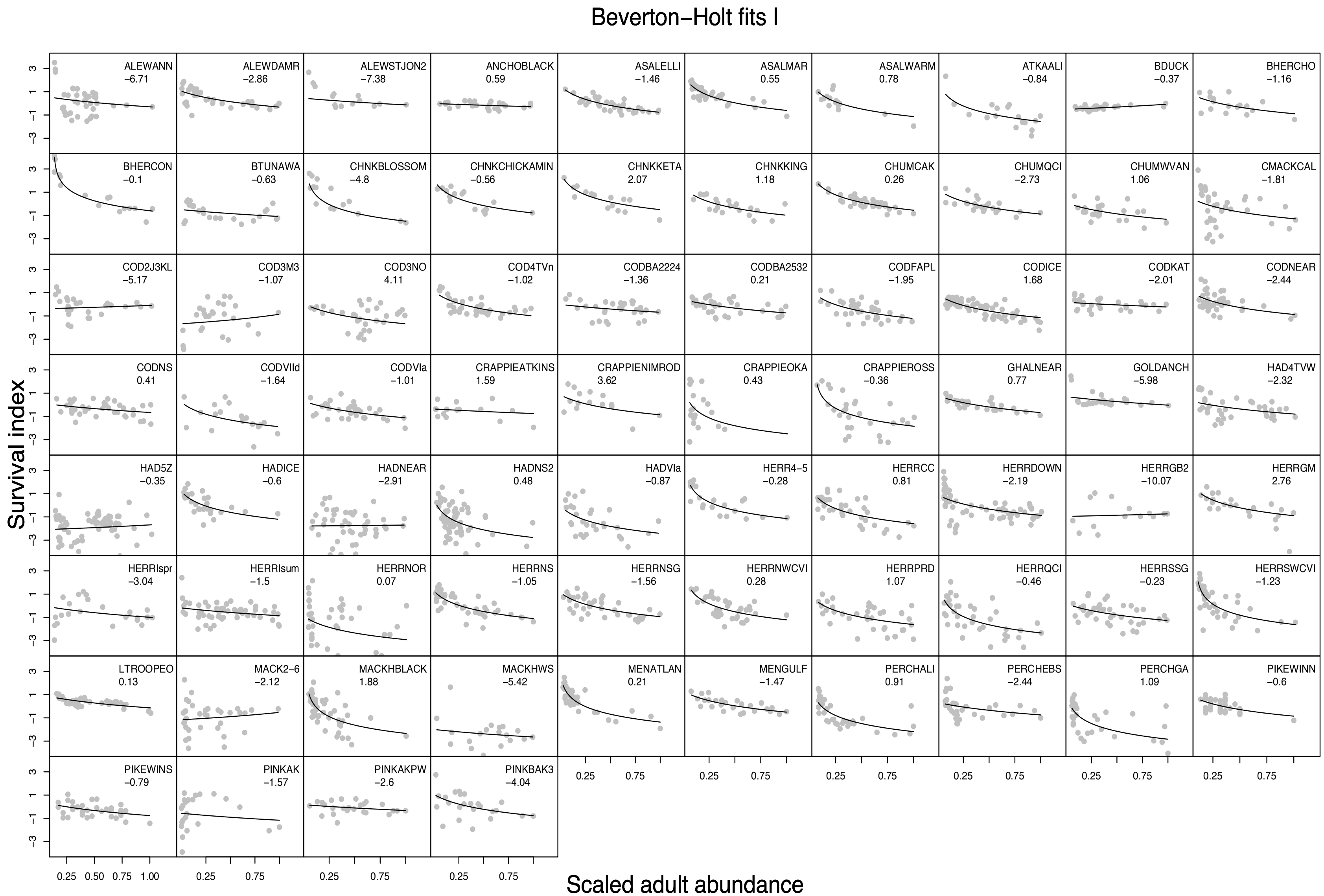

Figure 7: Individual population-level fits of the heteroscedastic Beverton-Holt survival model. The legend in each plot represents the population ID and the estimate of the slope of the variance for that population.

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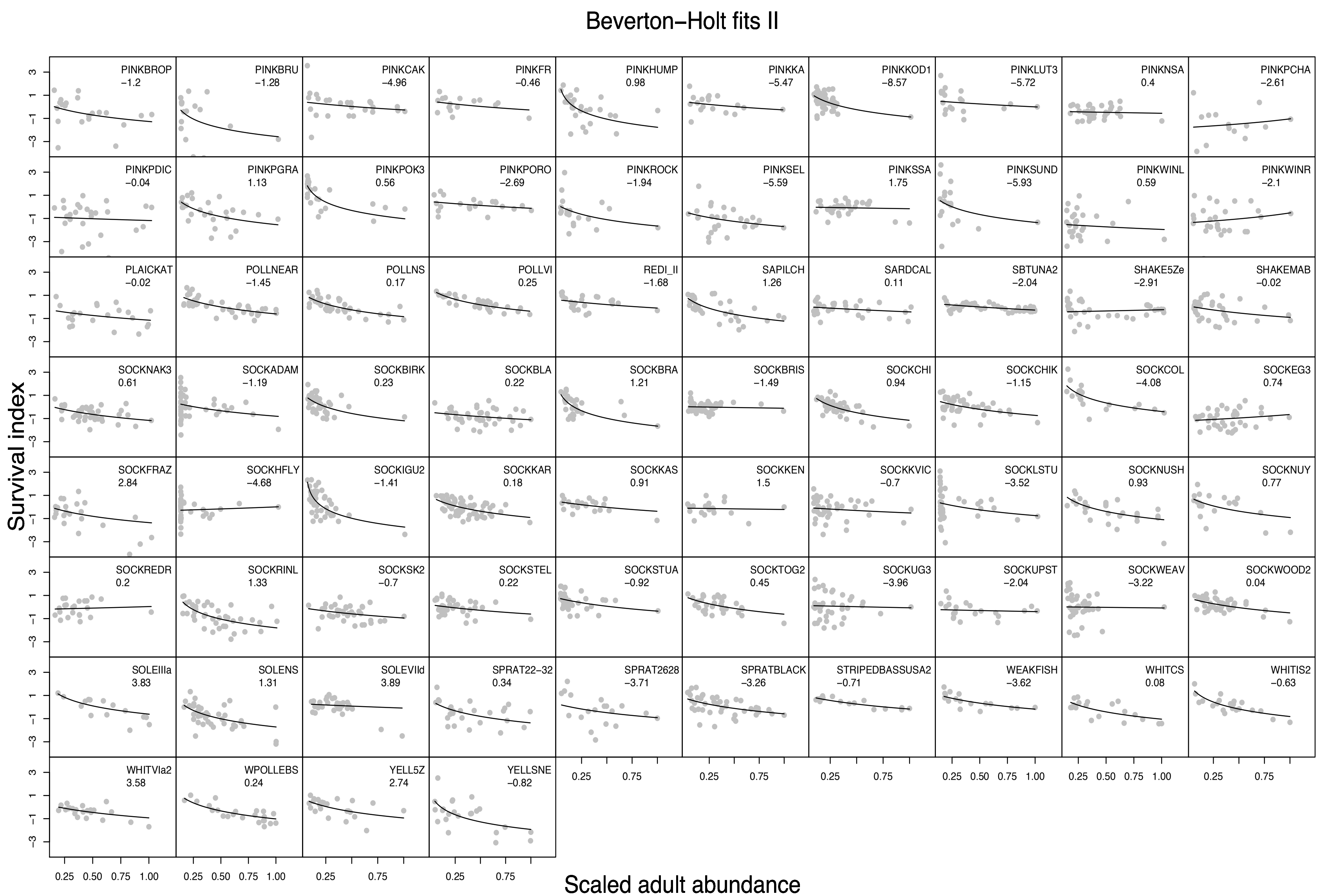

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Figure 8: Individual population-level fits of the heteroscedastic Beverton-Holt survival model continued. The legend in each plot represents the population ID and the estimate of the slope of the variance for that population.

3 Supplementary tables

The details of each population ID analysed are presented in Table S1.

Table 1: Stock details for each population analysed

ID	Order	Family	Latin name	Common name	Area
ALEWANN	Clupeiformes	Clupeidae	*Alosa pseudoharengus*	Anadromous alewife	Annaquatucket River, USA
ALEWDAMR	Clupeiformes	Clupeidae	*Alosa pseudoharengus*	Anadromous alewife	Damariscotta River
ALEWSTJON2	Clupeiformes	Clupeidae	*Alosa pseudoharengus*	Anadromous alewife	Saint John River
ANCHOBLACK	Clupeiformes	Engraulidae	*Engraulis encrasicolus*	Anchovy	Black Sea
ASALELLI	Salmoniformes	Salmonidae	*Salmo salar*	Atlantic salmon	Ellidaar River, Iceland
ASALMAR	Salmoniformes	Salmonidae	*Salmo salar*	Atlantic salmon	Margaree River, NS , Canada
ASALWARM	Salmoniformes	Salmonidae	*Salmo salar*	Atlantic salmon	Western Arm Brook, Canada
ATKAALI	Scorpaeniformes	Hexagrammidae	*Pleurogrammus monopterygius*	Atka mackerel	Eastern Bering Sea and Aleutian Islands
BDUCK	Aulopiformes	Synodontidae	*Harpodon nehereus*	Bombay duck	Northwest coast of India
BHERCHO	Clupeiformes	Clupeidae	*Alosa aestivalis*	Blueback herring	Chowan River, USA
BHERCON	Clupeiformes	Clupeidae	*Alosa aestivalis*	Blueback herring	Connecticut River, USA
BTUNAWA	Perciformes	Scombridae	*Thunnus thynnus*	Atlantic bluefin tuna	West Atlantic
CHNKBLOSSOM	Salmoniformes	Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon	Blossom River, Alaska-B.C
CHNKCHICKAMIN	Salmoniformes	Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon	Chickamin River, Alaska-B.C
CHNKKETA	Salmoniformes	Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon	Keta River, Alaska-B.C
CHNKKING	Salmoniformes	Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon	King Salmon River, Alaska
CHUMCAK	Salmoniformes	Salmonidae	*Oncorhynchus keta*	Chum salmon	Central Alaska
CHUMQCI	Salmoniformes	Salmonidae	*Oncorhynchus keta*	Chum salmon	Queen Charlotte Islands, B.C
CHUMWVAN	Salmoniformes	Salmonidae	*Oncorhynchus keta*	Chum salmon	West Coast Vancouver Island, B.C
CMACKCAL	Perciformes	Scombridae	*Scomber japonicus*	Chub mackerel	Southern California
COD2J3KL	Gadiformes	Gadidae	*Gadus morhua*	Cod	NAFO 2J3KL
COD3M3	Gadiformes	Gadidae	*Gadus morhua*	Cod	Flemish Cap (NAFO Div 3M)
COD3NO	Gadiformes	Gadidae	*Gadus morhua*	Cod	NAFO 3NO
COD4TVn	Gadiformes	Gadidae	*Gadus morhua*	Cod	NAFO 4TVn
CODBA2224	Gadiformes	Gadidae	*Gadus morhua*	Cod	Baltic Areas 22 and 24
CODBA2532	Gadiformes	Gadidae	*Gadus morhua*	Cod	Baltic Areas 25-32
CODFAPL	Gadiformes	Gadidae	*Gadus morhua*	Cod	Faroe Plateau
CODICE	Gadiformes	Gadidae	*Gadus morhua*	Cod	Iceland
CODKAT	Gadiformes	Gadidae	*Gadus morhua*	Cod	Kattegat
CODNEAR	Gadiformes	Gadidae	*Gadus morhua*	Cod	North East Arctic
CODNS	Gadiformes	Gadidae	*Gadus morhua*	Cod	North Sea
CODVIId	Gadiformes	Gadidae	*Gadus morhua*	Cod	ICES VIId
CODVIa	Gadiformes	Gadidae	*Gadus morhua*	Cod	ICES VIa
CRAPPIEATKINS	Perciformes	Centrarchidae	*Promoxis annularis* and *nigromaculatus*	Crappie	Atkins Reservoir, Arkansas

Table 1 – continued on next page

Table 1 – continued from previous page

ID	Order	Family	Latin name	Common name	Area
CRAPPIENIMROD	Perciformes	Centrarchidae	*Promoxis annularis* and *nigromaculatus*	Crappie	Nimrod Reservoir, Arkansas
CRAPPIEOKA	Perciformes	Centrarchidae	*Promoxis annularis* and *nigromaculatus*	Crappie	Okatibbee Reservoir, Mississippi
CRAPPIEROSS	Perciformes	Centrarchidae	*Promoxis annularis* and *nigromaculatus*	Crappie	Ross Barnett Reservoir, Mississippi
GHALNEAR	Pleuronectiformes	Pleuronectidae	*Reinhardtius hippoglossoides*	Greenland halibut	North East Arctic
GOLDANCH	Clupeiformes	Engraulidae	*Coilia dussumieri*	Gold-spotted grenadier anchovy	Northwest coast of India
HAD4TVW	Gadiformes	Gadidae	*Melanogrammus aeglefinus*	Haddock	NAFO 4TVW
HAD5Z	Gadiformes	Gadidae	*Melanogrammus aeglefinus*	Haddock	NAFO 5Z
HADICE	Gadiformes	Gadidae	*Melanogrammus aeglefinus*	Haddock	Iceland
HADNEAR	Gadiformes	Gadidae	*Melanogrammus aeglefinus*	Haddock	North East Arctic
HADNS2	Gadiformes	Gadidae	*Melanogrammus aeglefinus*	Haddock	North Sea
HADVIa	Gadiformes	Gadidae	*Melanogrammus aeglefinus*	Haddock	ICES VIa
HERR4-5	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	NAFO 4-5
HERRCC	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Central Coast B.C
HERRDOWN	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Downs stock
HERRGB2	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Georges Bank
HERRGM	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Gulf of Maine
HERRIspr	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Iceland (Spring spawners)
HERRIsum	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Iceland (Summer spawners)
HERRNOR	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Norway (Spring spawners)
HERRNS	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	North Sea
HERRNSG	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	North Strait of Georgia
HERRNWCVI	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	North West Coast Vancouver Island
HERRPRD	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Prince Rupert District
HERRQCI	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Queen Charlotte Islands
HERRSSG	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	Southern Strait of Georgia
HERRSWCVI	Clupeiformes	Clupeidae	*Clupea harengus*	Herring	South West Coast Vancouver Island
LTROOPEO	Salmoniformes	Salmonidae	*Salvelinus namaycush*	Lake trout	Lake Opeongo, Ontario
MACK2-6	Perciformes	Scombridae	*Scomber scombrus*	Mackerel	NAFO 2 to 6
MACKHBLACK	Perciformes	Carangidae	*Trachurus mediterraneus*	Mediterranean horse mackerel	Black Sea
MACKHWS	Perciformes	Carangidae	*Trachurus trachurus*	Horse mackerel	Western ICES
MENATLAN	Clupeiformes	Clupeidae	*Brevoortia tyrannus*	Atlantic Menhaden	U S Atlantic
MENGULF	Clupeiformes	Clupeidae	*Brevoortia patronus*	Gulf Menhaden	Gulf of Mexico
PERCHALI	Scorpaeniformes	Scorpaenidae	*Sebastes alutus*	Pacific ocean perch	Aleutian Is
PERCHEBS	Scorpaeniformes	Scorpaenidae	*Sebastes alutus*	Pacific ocean perch	Eastern Berring Sea
PERCHGA	Scorpaeniformes	Scorpaenidae	*Sebastes alutus*	Pacific ocean perch	Gulf of Alaska
PIKEWINN	Salmoniformes	Esocidae	*Esox lucius*	Pike	North Basin, Windermere Lake
PIKEWINS	Salmoniformes	Esocidae	*Esox lucius*	Pike	South Basin, Windermere Lake
PINKAKPW	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Prince William Sound, Alaska
PINKBAK3	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Bakhura River, Sakhalin Is
PINKBROP	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Brown's Peak Creek, Cook Inlet, Alaska
PINKBRU	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Bruin Bay, Cook Inlet, Alaska

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ID	Order	Family	Latin name	Common name	Area
PINKCAK	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Central Alaska
PINKFR	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Fraser River, B.C
PINKHUMP	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Humpy Creek, Cook Inlet, Alaska
PINKKA	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Kodiak Area, Alaska
PINKKOD1	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Kodiak Archipelago, Alaska
PINKLUT3	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Lutoga River, Sakhalin Is
PINKNSA	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Northern Panhandle, Alaska
PINKPCHA	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Port Chatham, Cook Inlet, Alaska
PINKPDIC	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Port Dick, Cook Inlet, Alaska
PINKPGRA	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Port Graham, Cook Inlet, Alaska
PINKPOK3	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Pokosnaya River, Sakhalin Is
PINKPORO	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Poronal River, Sakhalin Is
PINKROCK	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Rocky River, Cook Inlet, Alaska
PINKSEL	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Seldovia, Cook Inlet, Alaska
PINKSSA	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Southern Panhandle, Alaska
PINKSUND	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Sunday Creek, Cook Inlet, Alaska
PINKWINL	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Windy Left, Cook Inlet, Alaska
PINKWINR	Salmoniformes	Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Windy Right, Cook Inlet, Alaska
PLAICKAT	Pleuronectiformes	Pleuronectidae	*Pleuronectes platessa*	Plaice	Kattegat
POLLNEAR	Gadiformes	Gadidae	*Pollachius virens*	Pollock or saithe	North East Arctic
POLLNS	Gadiformes	Gadidae	*Pollachius virens*	Pollock or saithe	North Sea
POLLVI	Gadiformes	Gadidae	*Pollachius virens*	Pollock or saithe	ICES VI
REDI.II	Scorpaeniformes	Scorpaenidae	*Sebastes mentella*	Redfish	North East Arctic
SAPILCH	Clupeiformes	Clupeidae	*Sardinops sagax*	Sardine	South Africa
SARDCAL	Clupeiformes	Clupeidae	*Sardinops sagax*	Sardine	California
SBTUNA2	Perciformes	Scombridae	*Thunnus maccoyii*	Southern bluefin tuna	Southern Pacific
SHAKE5Ze	Gadiformes	Gadidae	*Merluccius bilinearis*	Silver hake	NAFO 5Ze
SHAKEMAB	Gadiformes	Gadidae	*Merluccius bilinearis*	Silver hake	Mid Atlantic Bight
SOCKADAM	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Adams Complex, B.C
SOCKBIRK	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Birkenhead River, B.C
SOCKBLA	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Black Lake, Alaska
SOCKBRA	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Branch River, Alaska
SOCKBRIS	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Bristol Bay, Alaska
SOCKCHI	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Chignik Lake, Alaska
SOCKCHIK	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Chilko River, B.C
SOCKCOL	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Columbia River
SOCKEG3	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Egegik River, Alaska
SOCKFRAZ	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Frazer Lake, Alaska
SOCKHFLY	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Horsefly River, B.C
SOCKIGU2	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Igushik River, Alaska
SOCKKAR	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Karluk River, Alaska

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ID	Order	Family	Latin name	Common name	Area
SOCKKAS	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Kasilof River, Alaska
SOCKKEN	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Kenai River, Alaska
SOCKKVIC	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Kvichak River, Alaska
SOCKLSTU	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Late Stuart Complex, B.C
SOCKNAK3	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Naknek, Alaska
SOCKNUSH	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Nushagak River, Alaska
SOCKNUY	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Nuyakuk River, Alaska
SOCKREDR	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Red River, Alaska
SOCKRINL	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Rivers Inlet, B.C
SOCKSK2	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Skeena River, B.C
SOCKSTEL	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Stellako River, B.C
SOCKSTUA	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Early Stuart Complex, B.C
SOCKTOG2	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Togiak River, Alaska
SOCKUG3	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Ugashik River, Alaska
SOCKUPST	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Ayakulik, Kodiak Island, Alaska
SOCKWEAV	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Weaver Creek, B.C
SOCKWOOD2	Salmoniformes	Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Wood River, Alaska
SOLEIIIa	Pleuronectiformes	Soleidae	*Solea vulgaris*	Sole	ICES IIIa
SOLENS	Pleuronectiformes	Soleidae	*Solea vulgaris*	Sole	North Sea
SOLEVIId	Pleuronectiformes	Soleidae	*Solea vulgaris*	Sole	ICES VIId
SPRAT22-32	Clupeiformes	Clupeidae	*Sprattus sprattus*	Sprat	Baltic Areas 22-32
SPRAT2628	Clupeiformes	Clupeidae	*Sprattus sprattus*	Sprat	Baltic Areas 26 and 28
SPRATBLACK	Clupeiformes	Clupeidae	*Sprattus sprattus*	Sprat	Black Sea
STRIPEDBASSUSA2	Perciformes	Moronidae	*Morone saxatilis*	Striped bass	East Coast, USA
WEAKFISH	Perciformes	Sciaenidae	*Cynoscion guatucupa*	Weakfish	East Coast, USA
WHITCS	Gadiformes	Gadidae	*Merlangius merlangus*	Whiting	Celtic Sea
WHITIS2	Gadiformes	Gadidae	*Merlangius merlangus*	Whiting	Irish Sea
WHITVIa2	Gadiformes	Gadidae	*Merlangius merlangus*	Whiting	ICES VIa
WPOLLEBS	Gadiformes	Gadidae	*Theragra chalcogramma*	Walleye pollock	E Bering Sea
YELL5Z	Pleuronectiformes	Pleuronectidae	*Pleuronectes ferrugineus*	Yellowtail flounder	NAFO 5Z
YELLSNE	Pleuronectiformes	Pleuronectidae	*Pleuronectes ferrugineus*	Yellowtail flounder	Southern New England

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