Appendix A: Selected Likelihood Profiles for the 2025 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

William T. Stockhausen

2025-09-01

Introduction

This appendix provides selected results from likelihood profiles on several key parameters of the preferred 2025 Tanner crab assessment model, 22.03d5 (2025) (Stockhausen 2025).The likelihood profiles were conducted by fixing a normally-estimated parameter at a value, optimizing the model to determine the values of other estimated parameters and model quantities at the MLE conditioned on the fixed value, and repeating this over a range of values for the selected parameter. Plotting the value of an objective function component against the fixed values may provide some insight into which data components most strongly influence convergence to the value of the parameter at the unconditioned MLE. Plotting the value of another parameter against the range of values of the selected parameter may provide insight into the nonlinear degree to which the two parameters are correlated. Plotting the value of a model quantity against the range of values of the selected parameter may provide insight into the degree to which the model quantity is determined by the value of the selected parameter. Here, likelihood profiles are presented for the parameters representing post-1974 mean ln-scale recruitment ("pLnR[2]"), the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab ("pDM1[1]"), and fully-selected catchability for males in the 1982+ NMFS EBS surveys ('pQ[3]').

Likelihood profile results for the total objective function

The total objective function value (O) is plotted against the profiled parameters in Figure 1. In each case, O is a smoothly-varying, concave upwards function of the profiled parameter value with its minimum at the parameter's value in the unconditional MLE.

Likelihood profile results for the profiled parameters

For each profiled parameter, the dependence of the other two parameters profiled here is illustrated in Figure 2. The results indicate that the recruitment ("pLnR[2]") and natural mortality on immature crab ("pDM1[1]") parameters are positively correlated across the ranges shown, while the

recruitment and survey catchability parameters ("pQ[3]") are less strongly negatively correlated. The mortality and catchability parameters are the least (positively) correlated.

Likelihood profile results for management quantities

The dependence of various management quantities on the profiled parameters is illustrated in Figures 3-5. Each of the management quantities exhibited a roughly quadratically-increasing dependence across the range of the recruitment parameter, without exhibiting a minimum (Figure 3). Average recruitment, F_{MSY} and F_{OFL} were strongly increasing functions of the natural mortality parameter while virgin biomass ("B100") and MSY were strongly decreasing functions. Current biomass, projected biomass, and the OFL were semi-quadratic functions of the natural mortality parameter, exhibiting distinct minima within the range profiled (Figure 4). In strong contrast to the trends with the recruitment parameter, each of the management quantities exhibited a roughly quadratically-decreasing dependence across the range of the survey catchability parameter, without exhibiting a minimum (Figure 5).

Likelihood profile results for data components of the objective function

The variation in the likelihood associated with different data components included in the total likelihood is illustrated in Figures 6-16. The dependence of these quantities on the profiled parameters are much more complicated than those for the total objective function.

References

Stockhausen, W.T. 2025. 2025 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands Regions 2025 Final Crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/Meeting/Details/3097.

Figures

List of Figures

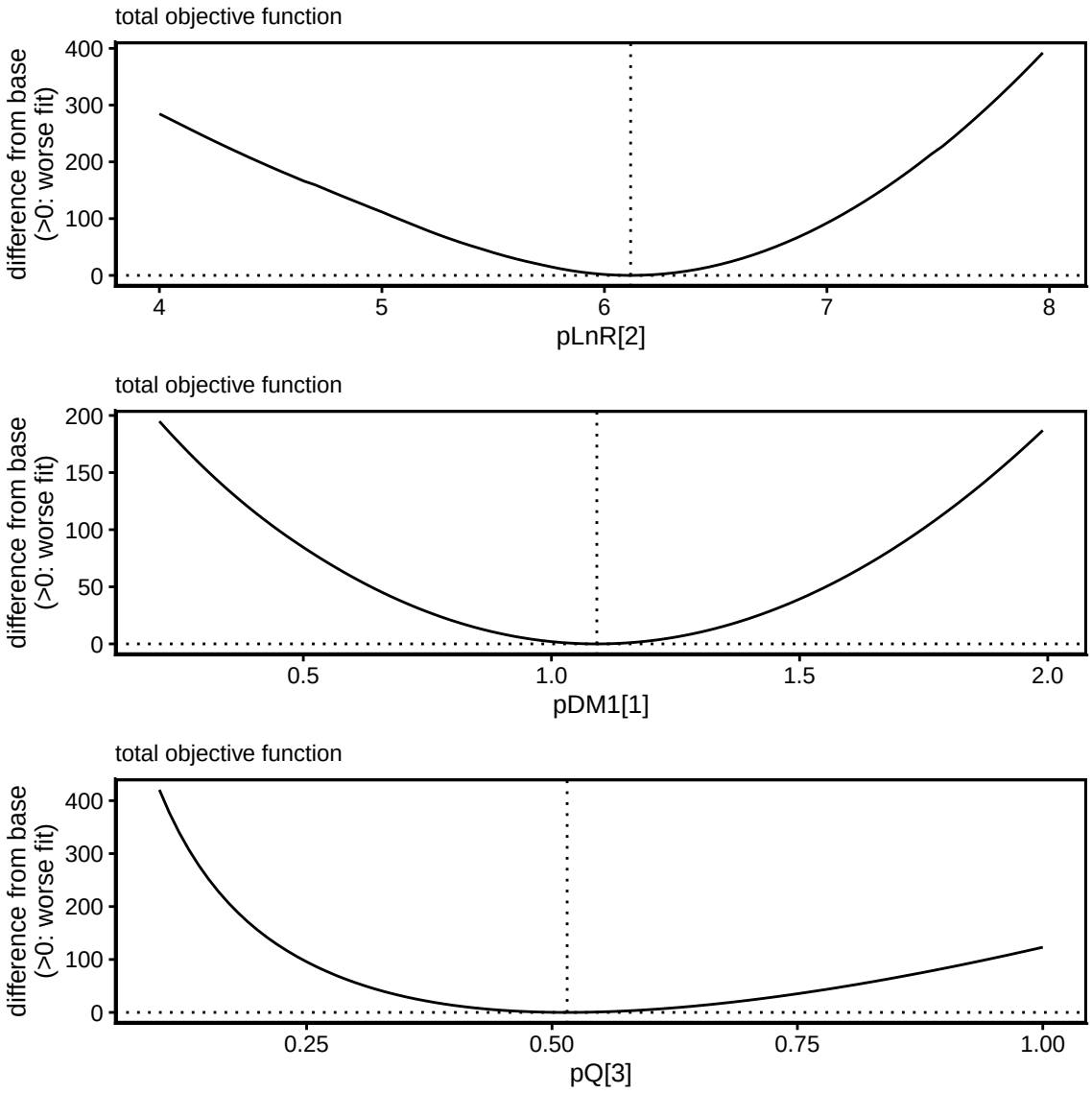

Figure 1. Total objective function, relative to the unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

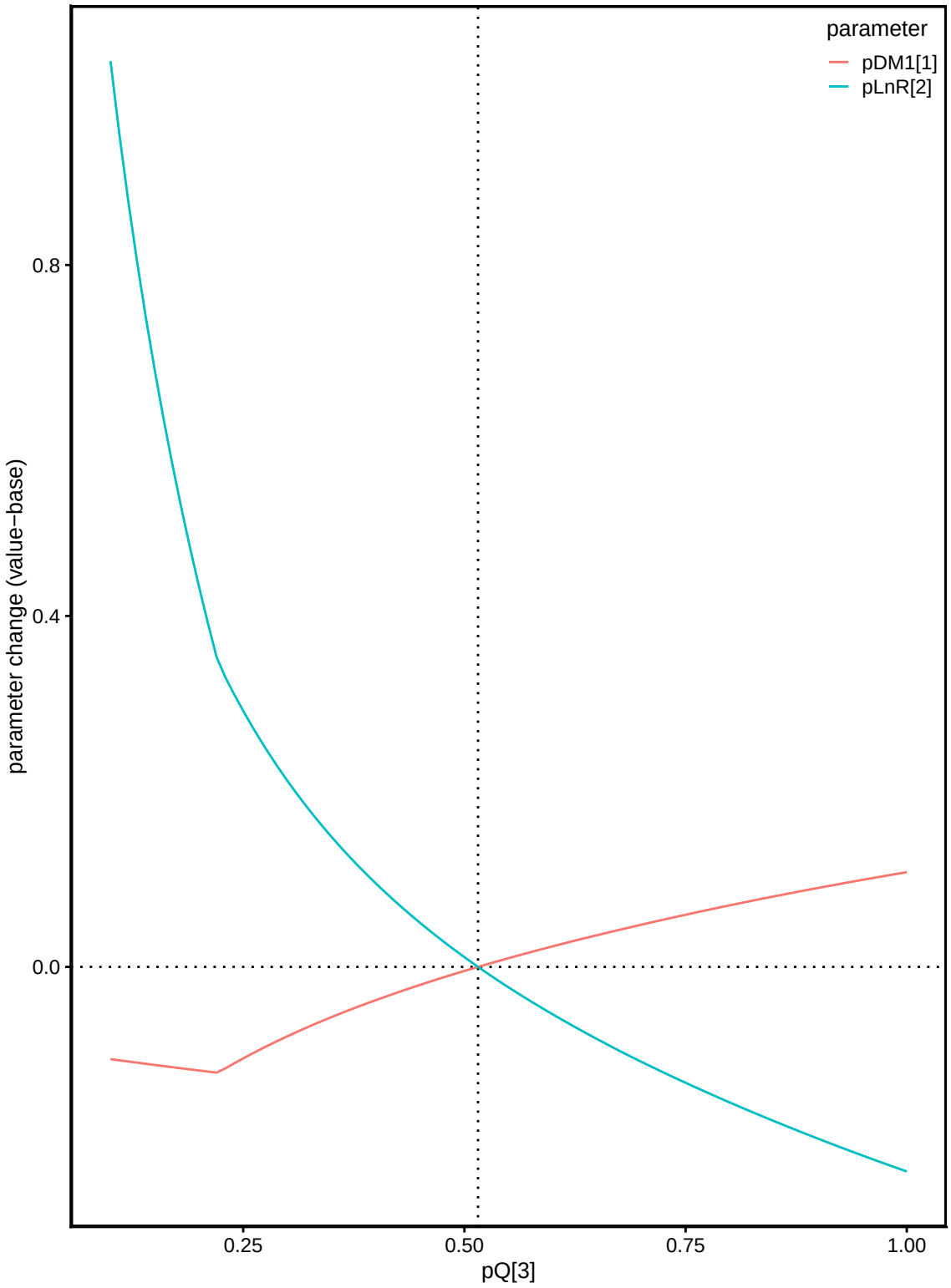

Figure 2. Absolute parameter differences in the "other" profiled parameters as functions of a profiled parameter. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

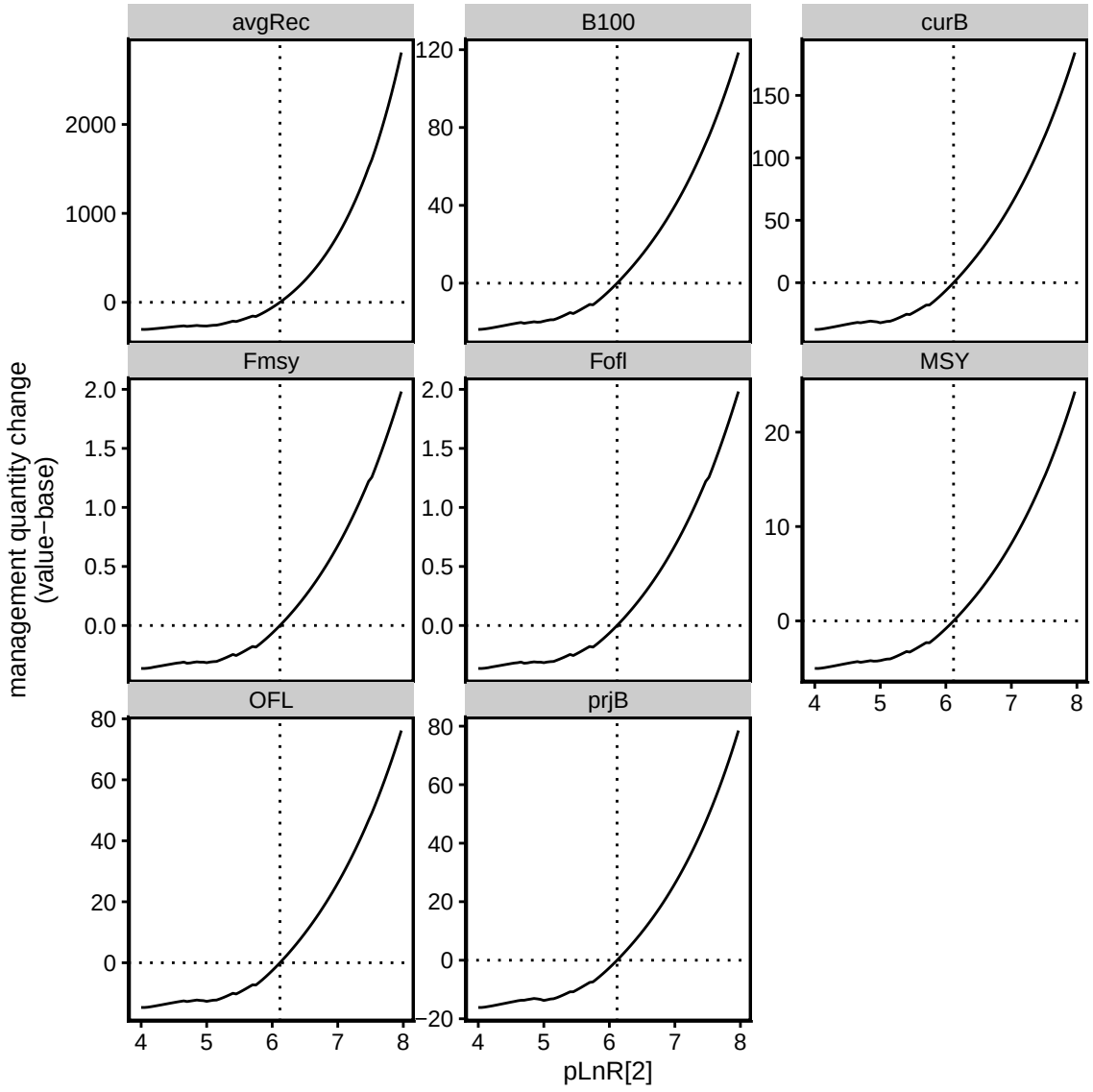

Figure 3. Differences in management quantity values relative to those for the unconditioned MLE. avgRec: average recruitment, B100: unfished biomass, curB: current biomass, Fmsy: directed fishing mortality that results in MSY, Fofl: directed fishing mortality that results in the OFL, MSY: maximum sustainable yield, OFL: overfishing limit, prjB: projected biomass. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

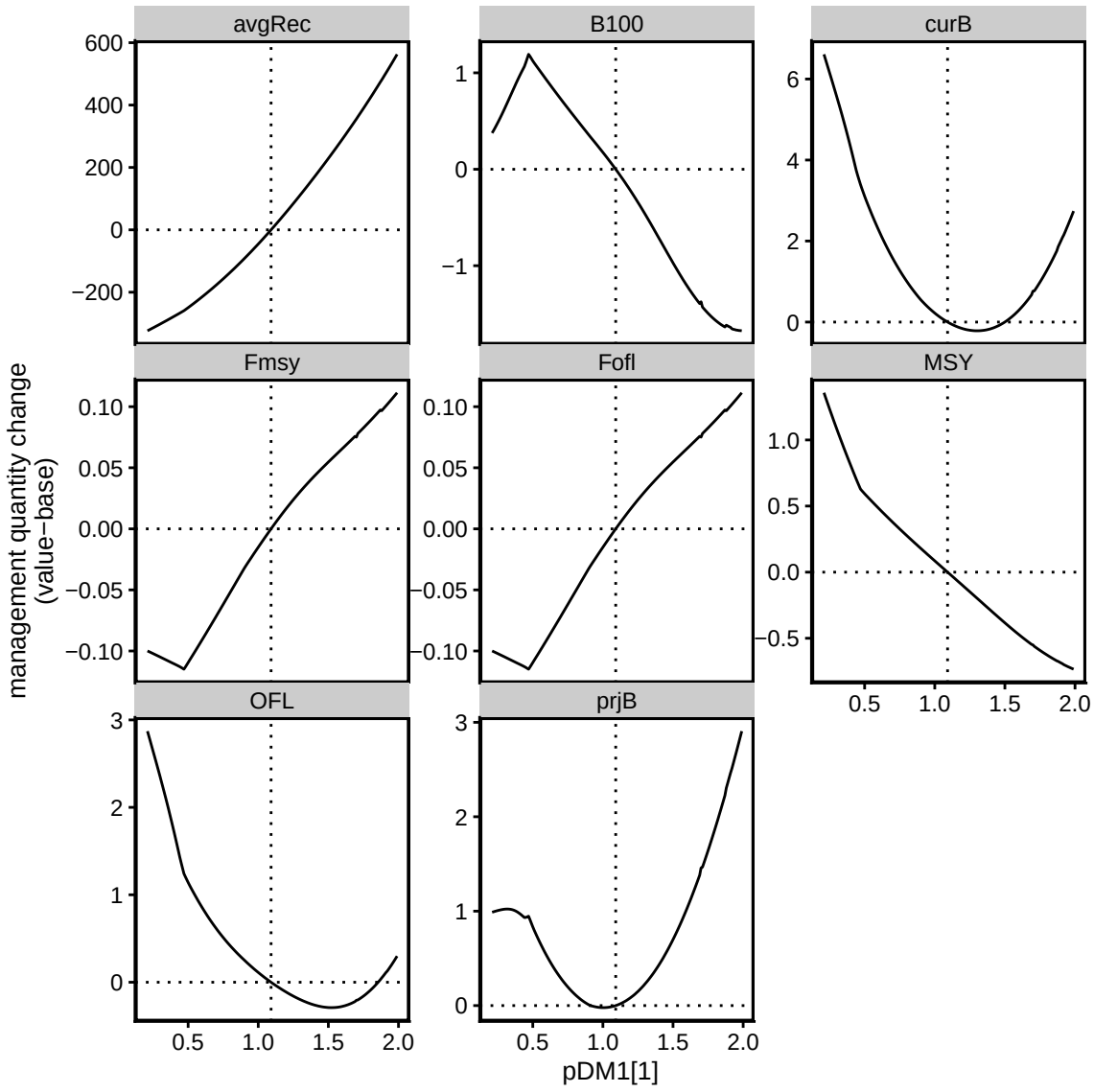

Figure 4. Differences in management quantity values relative to those for the unconditioned MLE. avgRec: average recruitment, B100: unfished biomass, curB: current biomass, Fmsy: directed fishing mortality that results in MSY, Fofl: directed fishing mortality that results in the OFL, MSY: maximum sustainable yield, OFL: overfishing limit, prjB: projected biomass. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

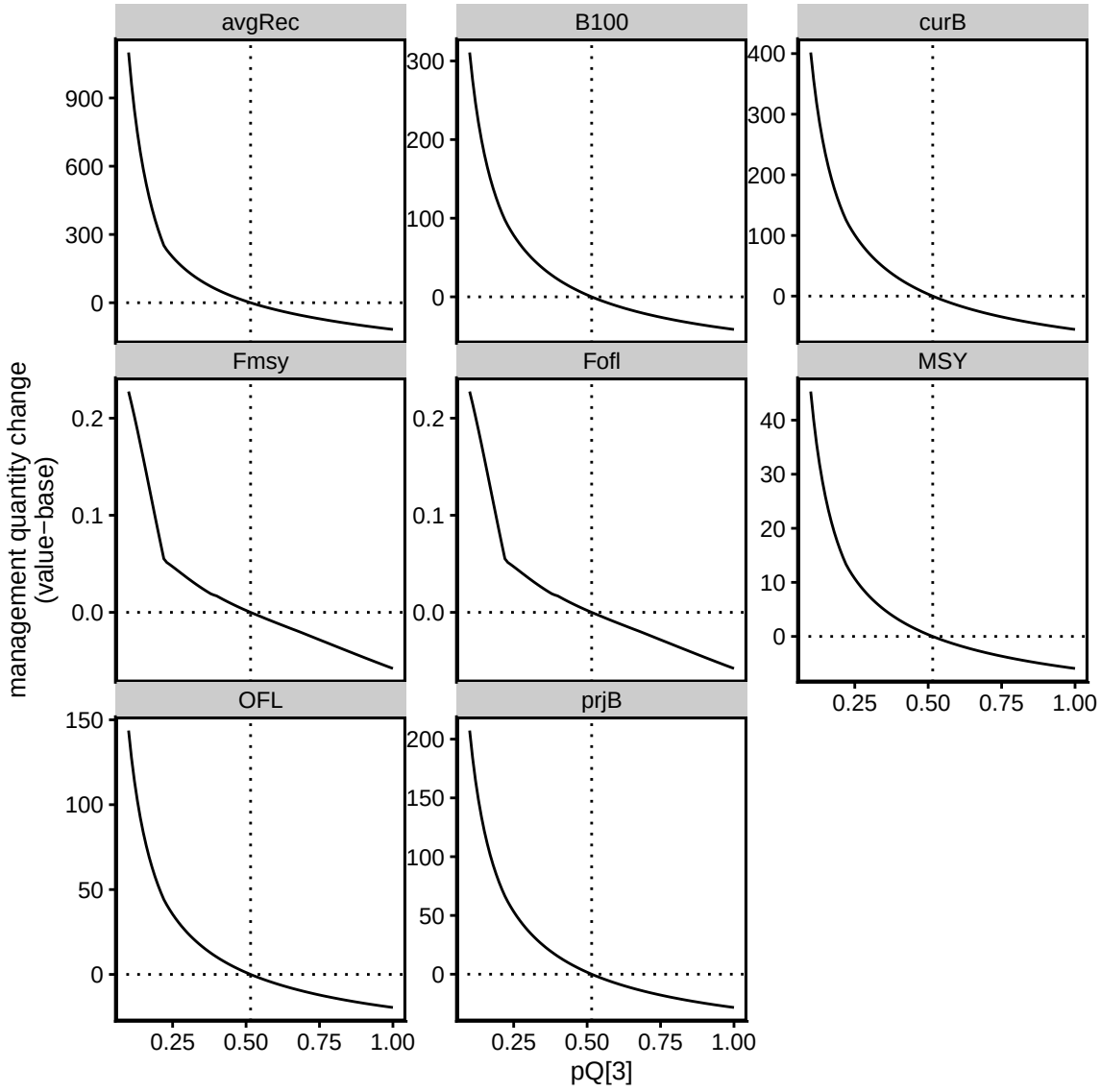

Figure 5. Differences in management quantity values relative to those for the unconditioned MLE. avgRec: average recruitment, B100: unfished biomass, curB: current biomass, Fmsy: directed fishing mortality that results in MSY, Fofl: directed fishing mortality that results in the OFL, MSY: maximum sustainable yield, OFL: overfishing limit, prjB: projected biomass. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

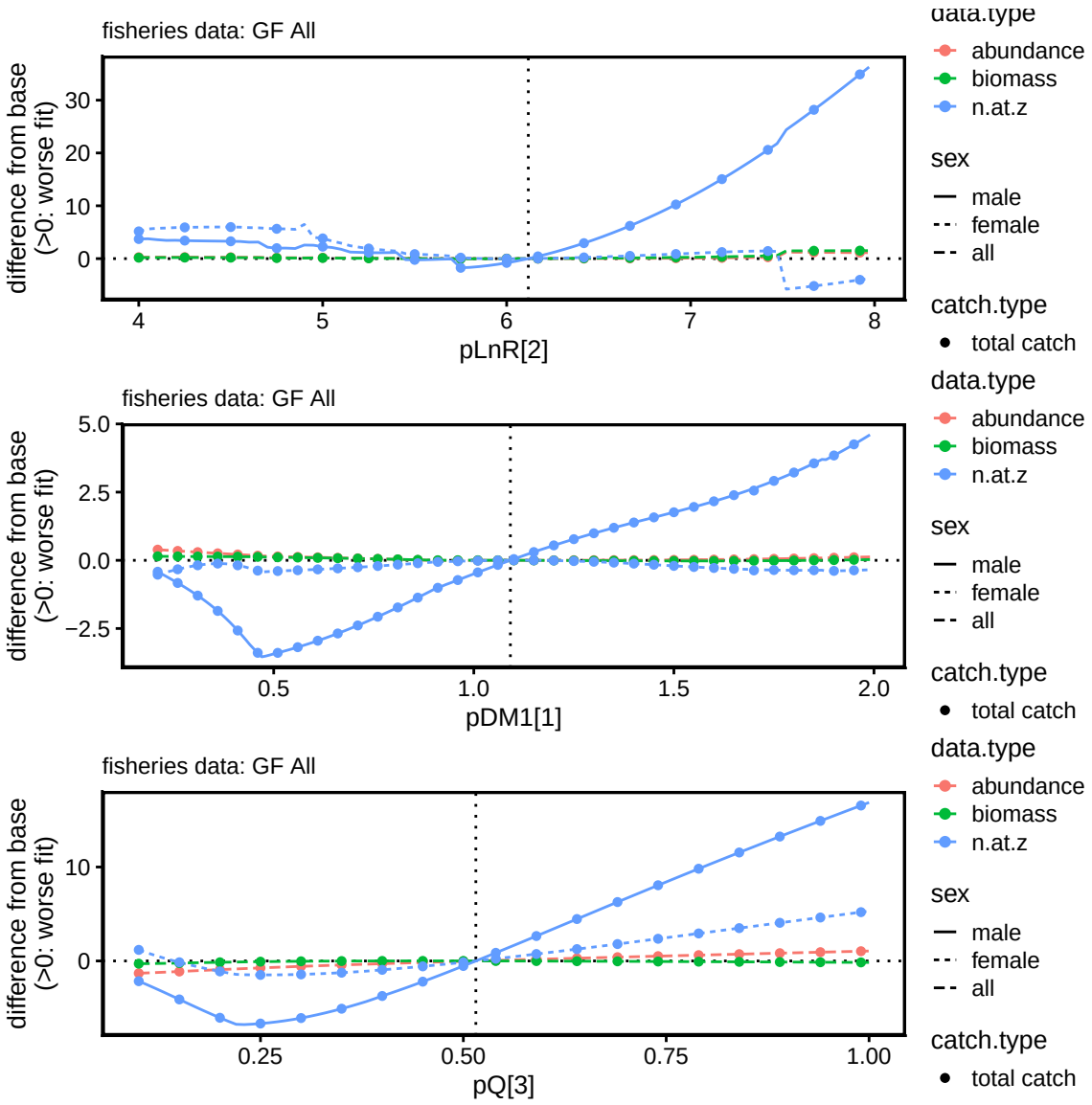

Figure 6. Objective function data components for "fisheries data" and fleet "GF All", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

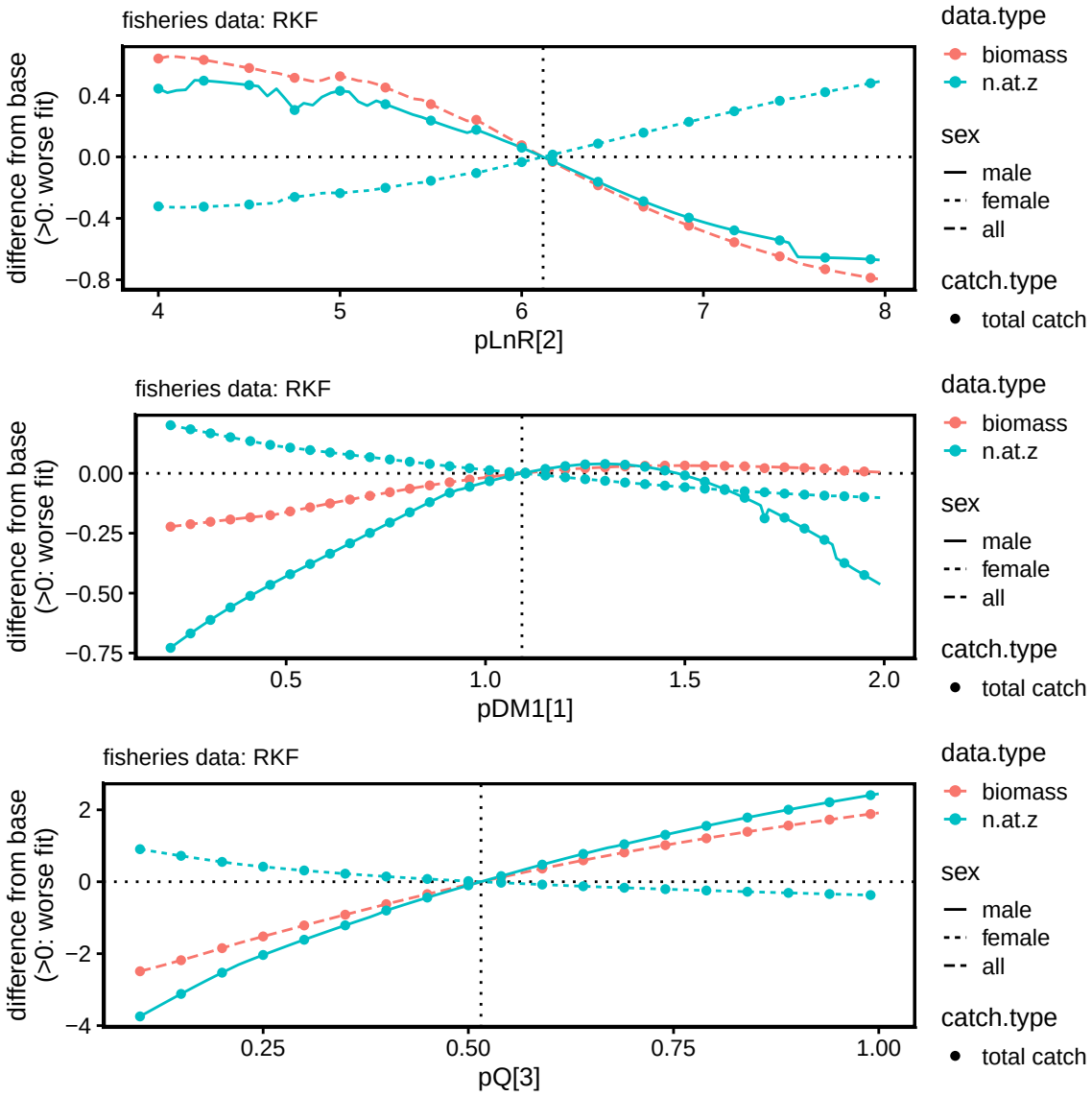

Figure 7. Objective function data components for "fisheries data" and fleet "RKF", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

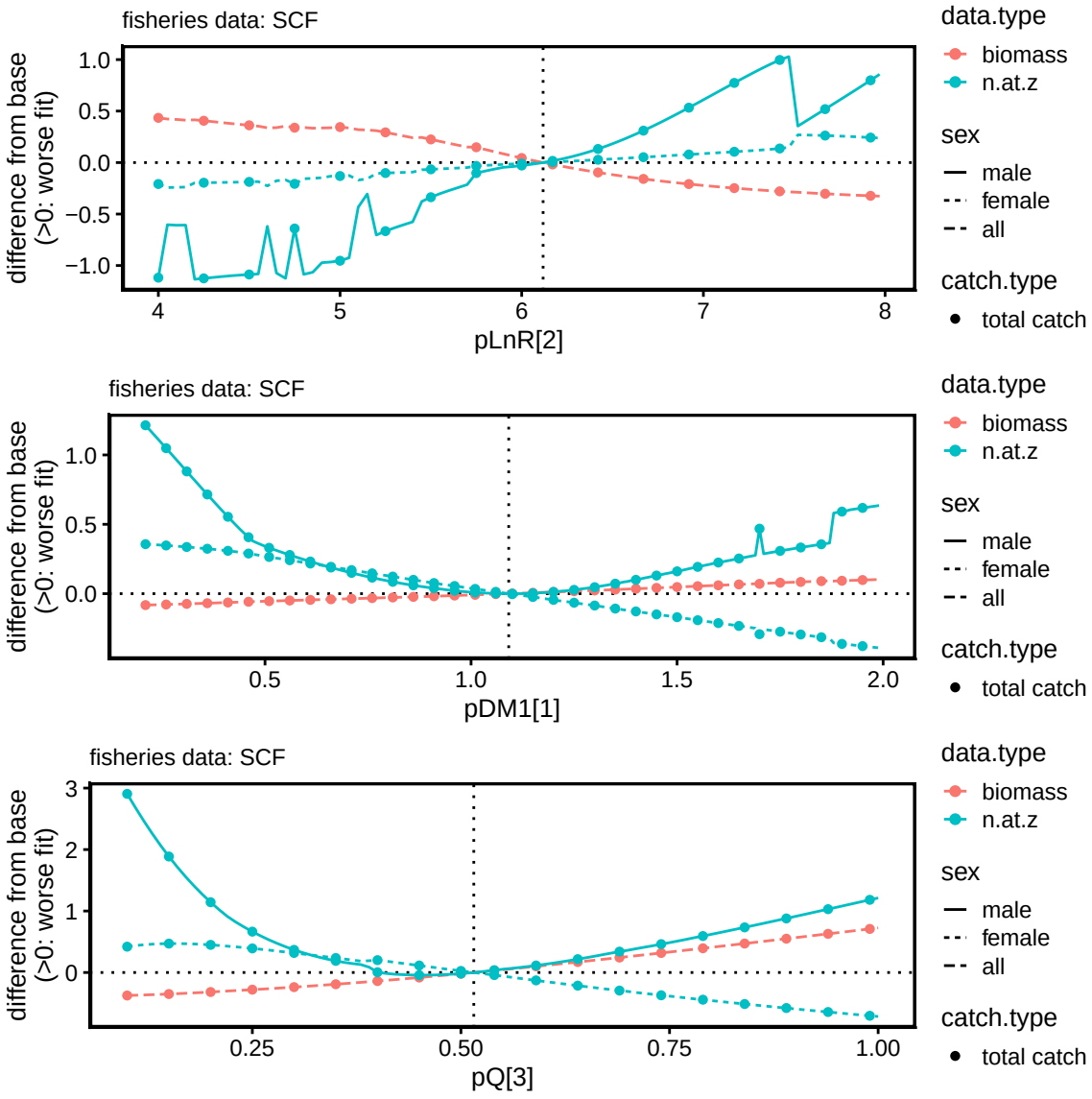

Figure 8. Objective function data components for "fisheries data" and fleet "SCF", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

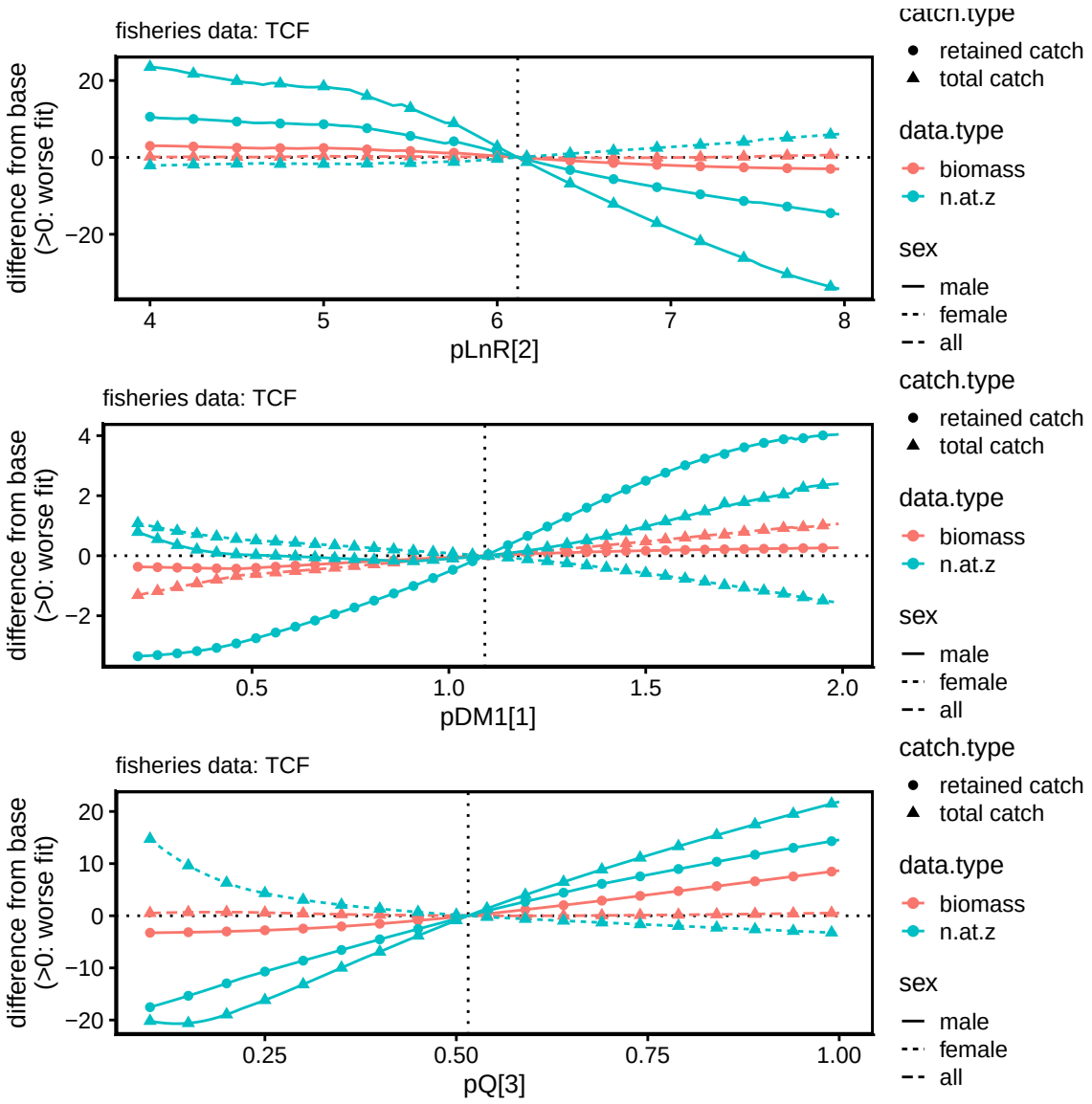

Figure 9. Objective function data components for "fisheries data" and fleet "TCF", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

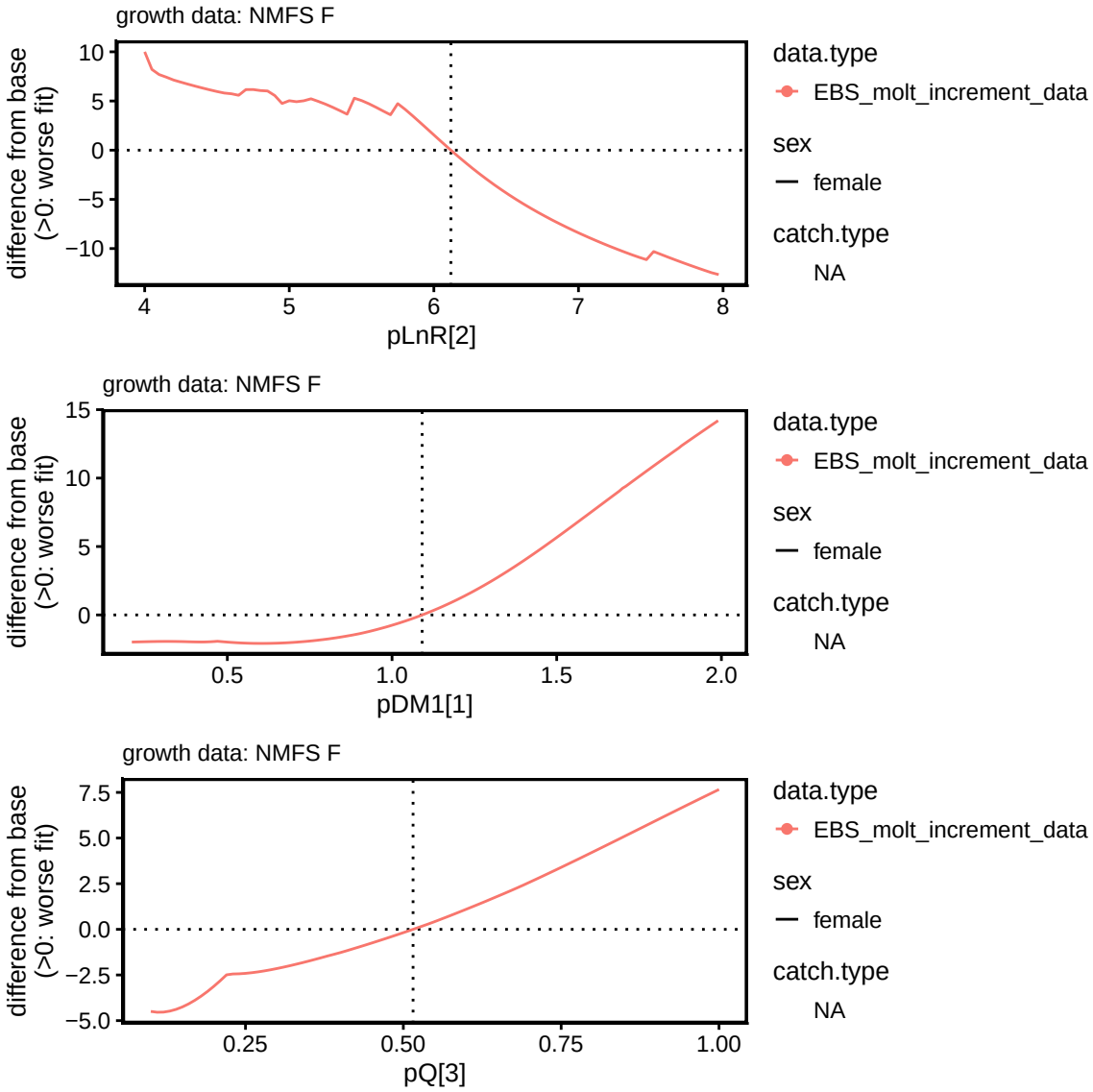

Figure 10. Objective function data components for "growth data" and fleet "NMFS F", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

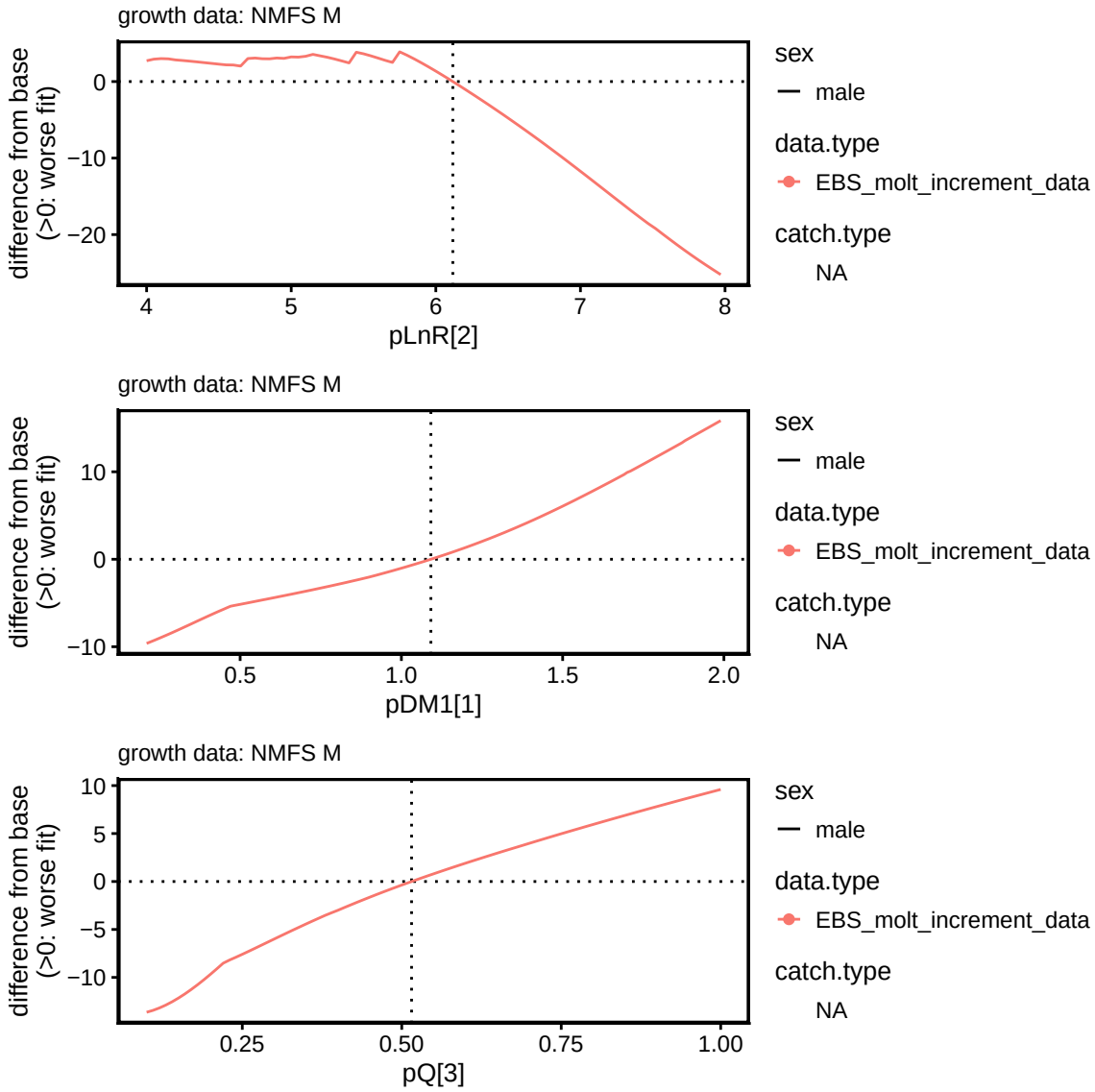

Figure 11. Objective function data components for "growth data" and fleet "NMFS M", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

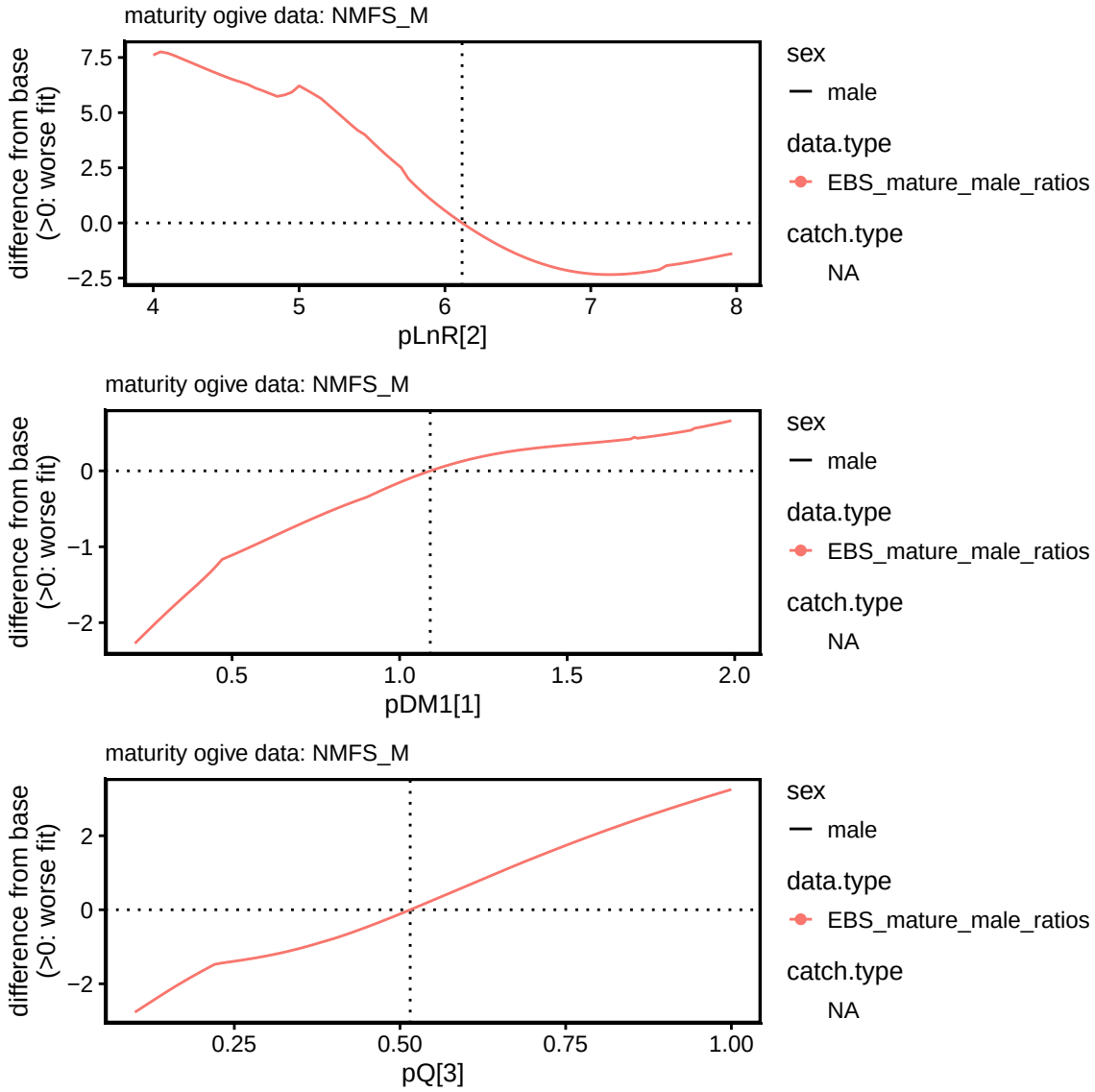

Figure 12. Objective function data components for "maturity ogive data" and fleet "NMFS_M", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

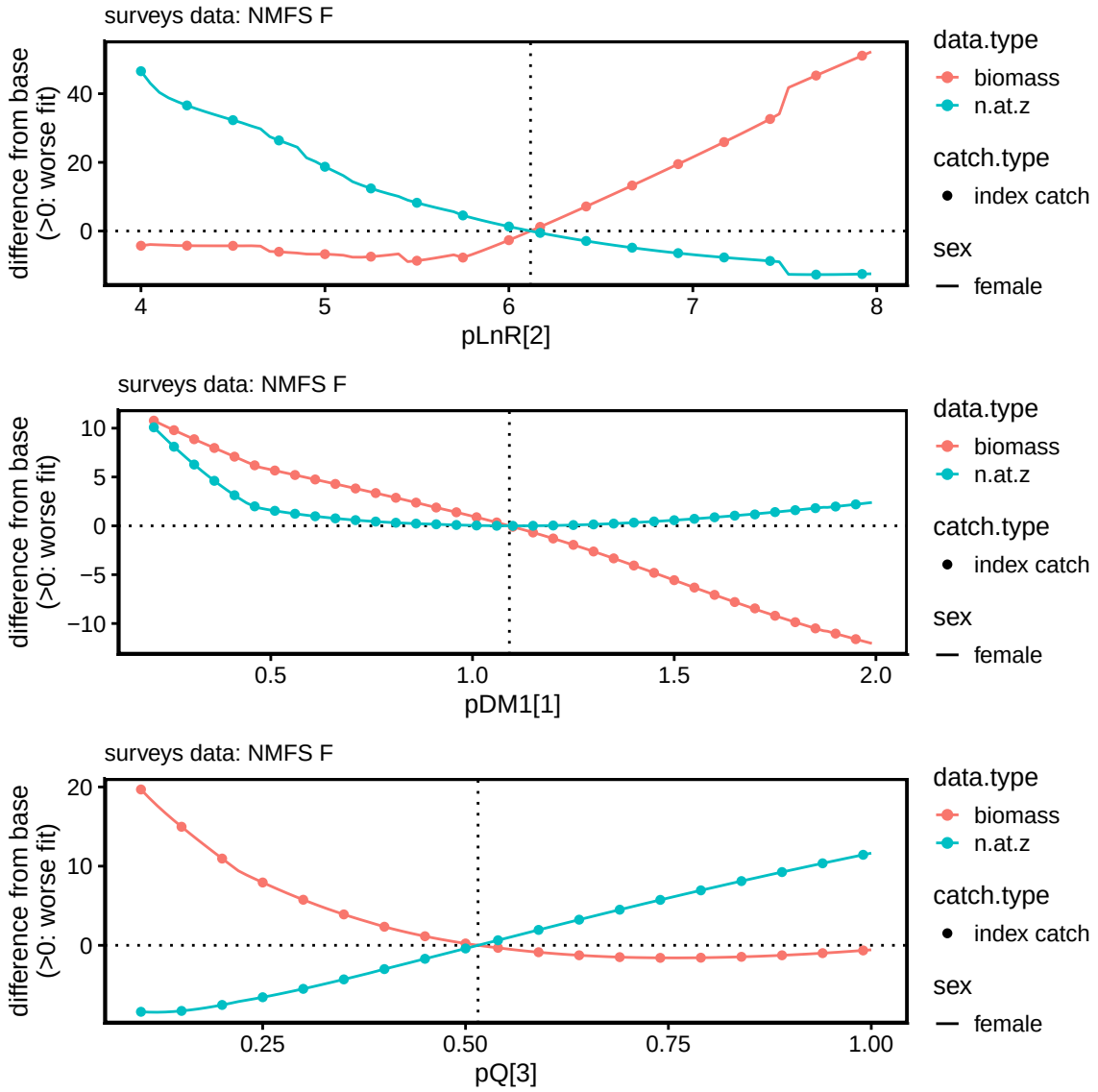

Figure 13. Objective function data components for "surveys data" and fleet "NMFS F", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

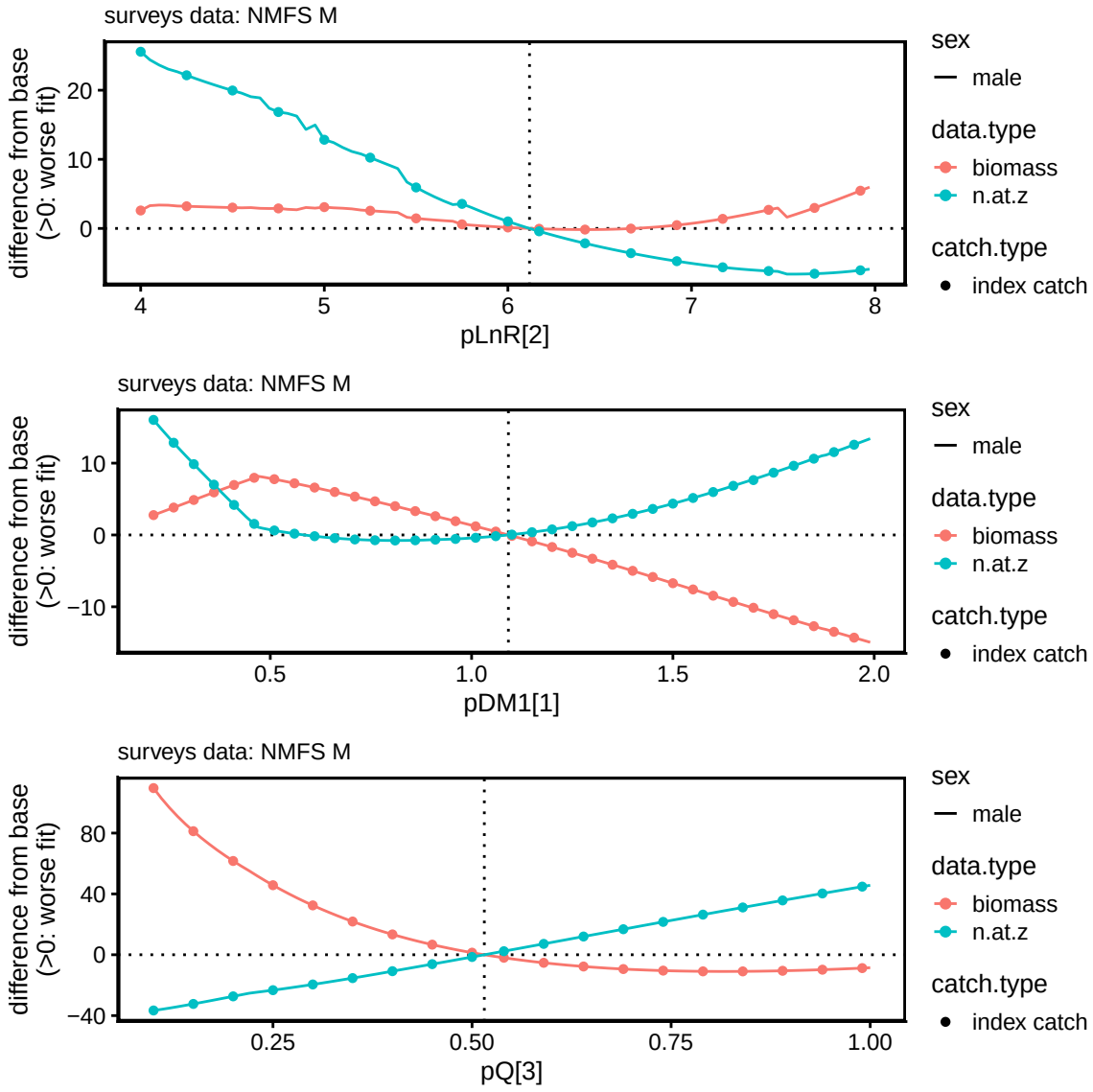

Figure 14. Objective function data components for "surveys data" and fleet "NMFS M", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

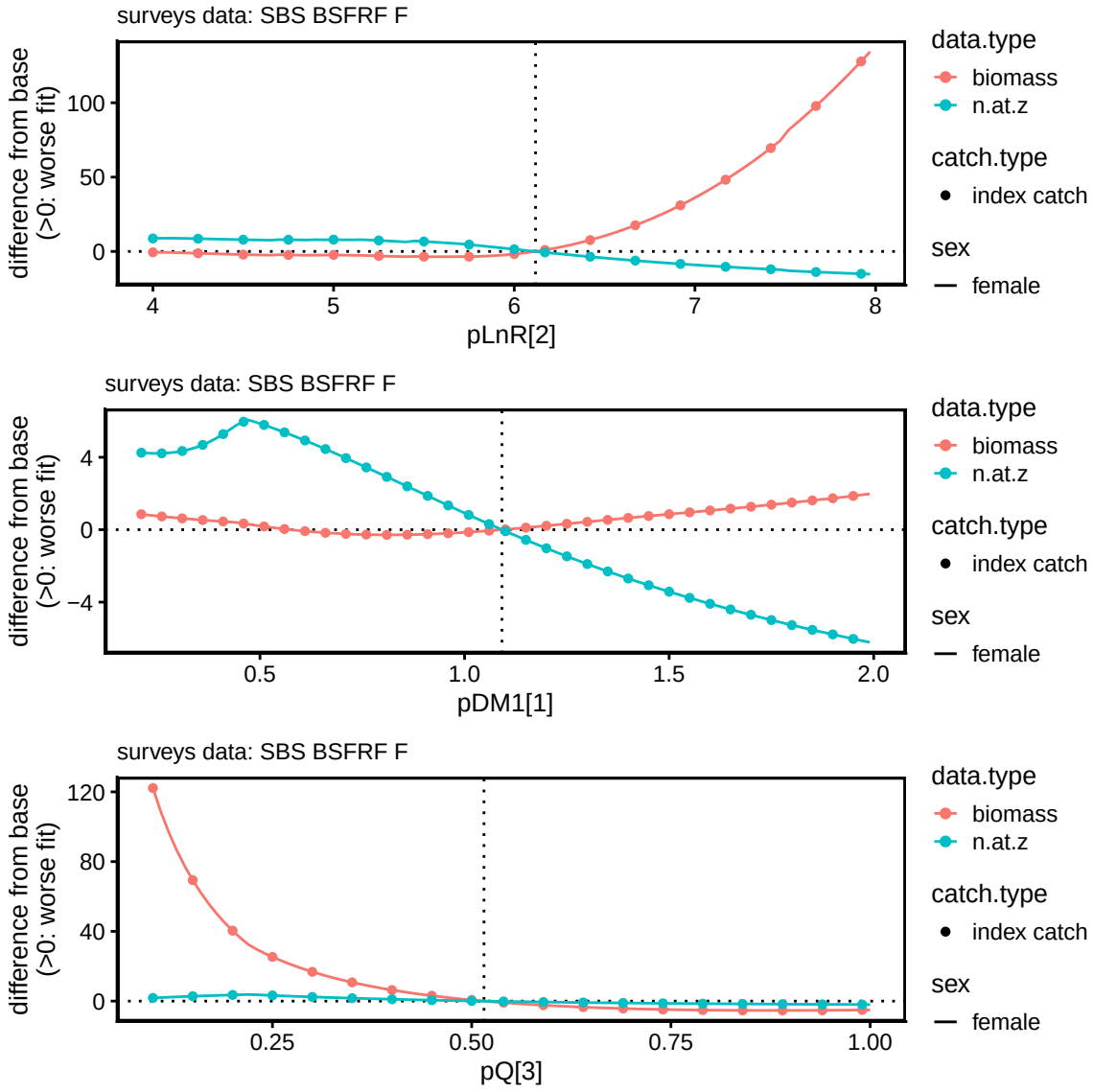

Figure 15. Objective function data components for "surveys data" and fleet "SBS BSFRF F", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value

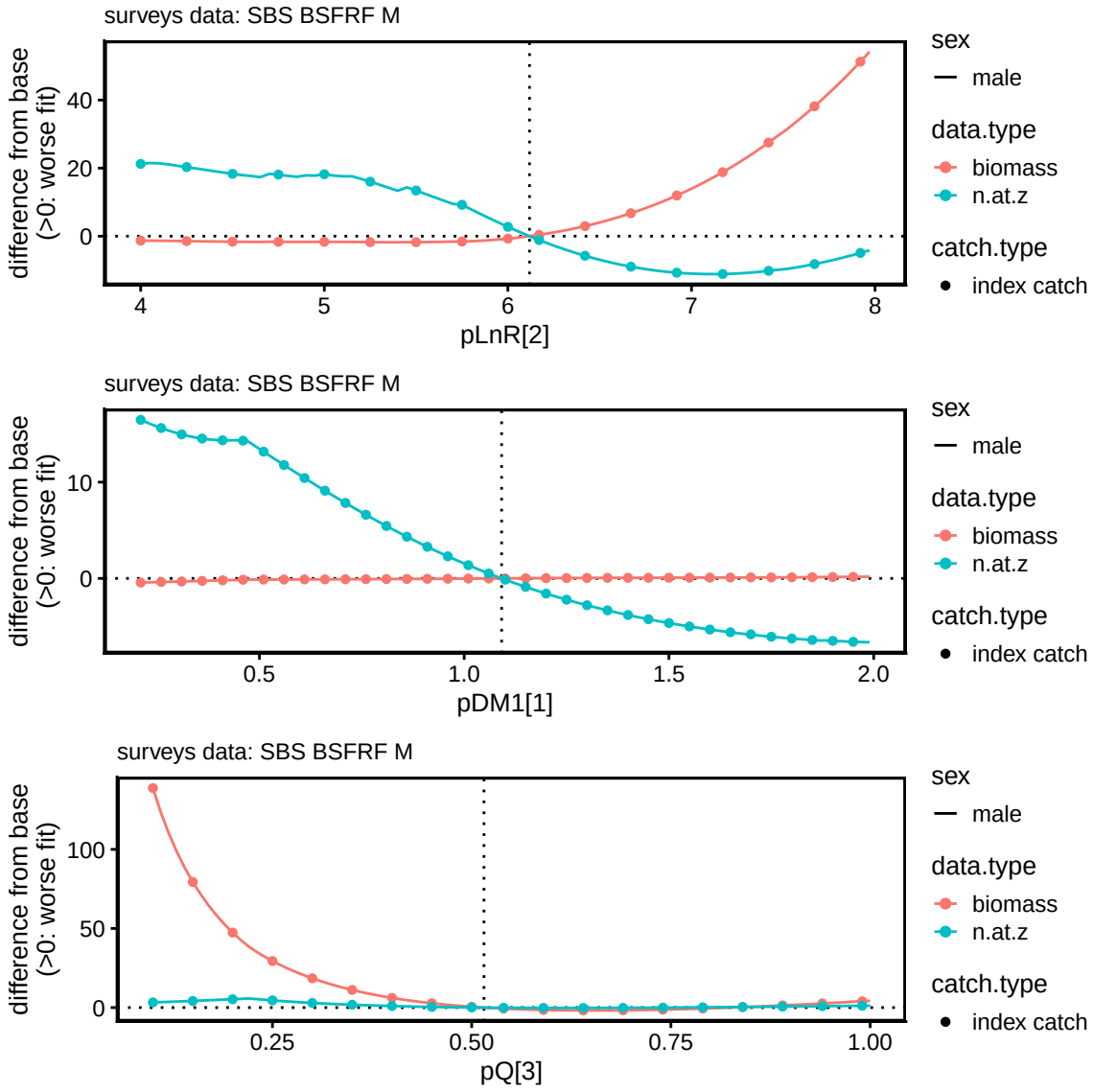

Figure 16. Objective function data components for "surveys data" and fleet "SBS BSFRF M", relative to the values for unconditioned MLE. pLnR[2]: post-1974 mean ln-scale recruitment; pDM1[1]: the multiplier on the base rate natural mortality (M=0.23) that determines M for immature crab; and pQ[3]: fully-selected catchability for males in the 1982+ NMFS EBS surveys. The dotted vertical line indicates the parameter's unconditional MLE value