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|  | **Topic** | **Morning Topic (Theory and Mechanisms)**  **1.5 hour** | **Late Morning - Case-Studies /Projects 1 hour** | **Afternoon Lab**  **3 hours** | **References** |
| **Monday** | Course introduction; Review model fitting; introduce TMB | Numerical optimization using derivatives; Finite differences vs autodiff; Refresher on Rstudio & R. | Maximum likelihood estimation; Fit LM in R by hand, using lm() and in TMB. | Exploring Beverton-Holt TMB model |  |
| **Tuesday** | Building TMB models | TMB/C++ syntax, workflow, factors, debugging, more examples | Estimating uncertainty: standard errors, Delta method, likelihood profile, bootstrapping | VBG for pooled samples and individual ones;  Formulate projects |  |
| **Wednesday** | Random effects in TMB | Types of mixed effects models; Marginal maximum likelihood, factors in TMB | Project time | Poisson GLM  Hierarchical VBG; |  |
| **Thursday** | GLMM and beyond | Model selection and validation; Predictions;  Zero-inflation models | Project time | Non-spatial CPUE standardization |  |
| **Friday** | More complex TMB models | Joint likelihoods, spatial extension of CPUE; stock assessment | Bayesian capabilities; Review | Project presentations |  |