Introduction
Subsequent to submission of the May 2021 Tanner crab report to the Crab Plan Team, additional analyses were completed using Model 21.13 as the base model. Model 21.13 had a number of parameters estimated at a bound. The model presented here, 21.22, builds on 21.13 by expanding the bounds on some of the parameters hitting a bound in 21.13 while fixing others to a value almost at the bound. This was an iterative process (documented below) that was repeated until the final version of Model 21.22 was able to converge with no estimated parameters at a bound. In most cases, the values chosen for parameters that were fixed at a bound can be justified.

Methods
Model 21.13 had 9 parameters, all related to selectivity, estimated at a bound:

Table 1. Parameters at a bound in Model 21.13.

<table>
<thead>
<tr>
<th>name</th>
<th>value</th>
<th>test</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pS1[4]</td>
<td>130</td>
<td>at upper bound</td>
<td>size at 1 for NMFS survey selectivity (females, 1982+)</td>
</tr>
<tr>
<td>pS1[10]</td>
<td>140</td>
<td>at upper bound</td>
<td>ascending z-at-1 for SCF selectivity (males, pre-1997)</td>
</tr>
<tr>
<td>pS1[22]</td>
<td>180</td>
<td>at upper bound</td>
<td>size at 1 for RKF selectivity (males, pre-1997)</td>
</tr>
<tr>
<td>pS1[23]</td>
<td>179.998</td>
<td>at upper bound</td>
<td>size at 1 for RKF selectivity (males, 1997-2004)</td>
</tr>
<tr>
<td>pS1[24]</td>
<td>180</td>
<td>at upper bound</td>
<td>size at 1 for RKF selectivity (males, 2005+)</td>
</tr>
<tr>
<td>pS1[25]</td>
<td>139.999</td>
<td>at upper bound</td>
<td>size at 1 for RKF selectivity (females, pre-1997)</td>
</tr>
<tr>
<td>pS3[2]</td>
<td>0.000</td>
<td>at lower bound</td>
<td>scaled increment for descending z-at-1 for SCF selectivity (males, 1997-2004)</td>
</tr>
<tr>
<td>pS3[3]</td>
<td>0.000</td>
<td>at lower bound</td>
<td>scaled increment for descending z-at-1 for SCF selectivity (males, 2005+)</td>
</tr>
</tbody>
</table>

In order to deal with these problematic parameters, the following steps were undertaken:

1. pS1[4]: fixed at 129.9
2. pS1[10]: upper bound increased from 140 to 180 mm CW
3. pS1[20]: lower bound decreased from 40 to 25 mm CW
4. pS1[22], pS1[23], and pS1[24] were all fixed at 179.9
5. no changes were made to pS1[25], pS3[2], pS3[3]

The results from this first round of iteration were that:

1. pS3[2] was again estimated at its lower bound
2. pS3[3] was again estimated at its lower bound
3. pLnDirMul[9], the Dirichlet-multinomial scaling parameter for female bycatch size compositions in the snow crab fishery, was estimated at its upper bound
4. pLnDirMul[13], the Dirichlet-multinomial scaling parameter for bycatch size compositions in the groundfish fisheries, was estimated at its upper bound

For the next (and final) iteration, the two remaining (and two new) problematic parameters were all fixed to values near the indicated bound. Setting pS3[2] and pS3[3] to their lower bounds was equivalent to using double normal functions with no plateau at 1, while setting the Dirichlet-multinomial parameters to...
their upper bounds was equivalent to reverting to multinomial likelihoods for the associated size compositions (but with different constants), with no adjustment of input sample sizes.

No parameters were estimated at bounds in the second iteration; this model was taken as Model 21.22. To summarize, Model 21.22 differs from 21.13 in the following:

1. \( pS1[4]\): fixed at 129.9
2. \( pS1[10]\): upper bound increased from 140 to 180 mm CW
3. \( pS1[20]\): lower bound decreased from 40 to 25 mm CW
4. \( pS1[22]\), \( pS1[23]\), and \( pS1[24]\) were all fixed at 179.9
5. \( pS3[2]\) and \( pS3[3]\) were fixed at 0.001
6. \( p\text{LnDirMul}[9]\) and \( p\text{LnDirMul}[13]\) were each fixed at 10 (on the ln-scale)

**Results: comparison with Model 21.13**

On the whole, the differences between the two models were very small (Table 2, Figures 1-20). The overall likelihood for 21.22 was larger than that for 21.13 by 63 likelihood units.

Table 2. Summary of model results. Units for average recruitment are millions of crab. Units for B100, Bmsy, current MMB, MSY, OFL, and projected MMB are 1,000’s t. Max gradient for 21.22 was the result of using ADMB’s new “hess_step” procedure to iteratively improve model convergence using the hessian matrix.

<table>
<thead>
<tr>
<th>case</th>
<th>objective function</th>
<th>max gradient</th>
<th>avg recruitment</th>
<th>B100</th>
<th>Bmsy</th>
<th>current MMB</th>
<th>Fmsy</th>
<th>MSY</th>
<th>Fofl</th>
<th>OFL</th>
<th>projected MMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.13</td>
<td>6089.74</td>
<td>0.06988745</td>
<td>359.13</td>
<td>107.91</td>
<td>37.77</td>
<td>74.12</td>
<td>0.95</td>
<td>16.85</td>
<td>0.95</td>
<td>23.80</td>
<td>39.15</td>
</tr>
<tr>
<td>21.22</td>
<td>6153.67</td>
<td>0</td>
<td>349.48</td>
<td>107.76</td>
<td>37.72</td>
<td>74.91</td>
<td>0.94</td>
<td>16.75</td>
<td>0.94</td>
<td>24.01</td>
<td>39.67</td>
</tr>
</tbody>
</table>

The overall likelihood for 21.22 was larger than that for 21.13 by 63 likelihood units.

The largest contributor to this was the difference in likelihood value for the fit to bycatch size compositions in the groundfish fisheries (~18 likelihood units), while combined likelihoods for fits to survey size compositions and survey biomass made up the remainder. However, 21.22 has no estimated parameters at a bound and the maximum gradient at the converged solution is truly zero.

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Figure 20. Model fits to maturity growth data
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NMFS

BSFRF

male

female

all shell

all shell

all shell

all shell

immature

mature

immature

mature

mean survey size comps

mean survey size comps

observed

predicted

21.13

21.13

21.22
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growth data