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**Approximating  $F_{MSY}$  using the State-Space Stock Assessment Model developed for for Greenland Halibut in NAFO Subarea 2 and Divisions 3KLMNO**

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Here we outline the method used to find  $F_{MSY}$  using the State-Space Stock Assessment Model developed for for Greenland Halibut in NAFO Subarea 2 and Divisions 3KLMNO. Standard calculations were not possible for model M1 since it did not rely on a stock-recruitment relationship, rather it modeled recruitment as a random effect.

## Introduction

Exploratory analyses and initial modelling of the dynamics of the Greenland halibut stock from NAFO Subarea 2 and Divisions 3KLMNO showed little sign of a stock-recruitment relationship. Recruitment was therefore treated as a random effect in the state-space model developed for this stock and described in Regular et al. (2017). This formulation, however, precluded the standard analytical approach to calculating  $F_{MSY}$  from stock-recruitment curves.

## Methods

Parameters estimates from model M1\_03 were used to project the population out 100 years to obtain deterministic estimates of  $F_{MSY}^{5-9}$ . Whole time series averages of recruitment, 10 year averages of weight at age and three year averages of selectivity at age were carried forward in the projections. An optimization function was used to profile across a range of  $F_{5-9}$  values to find the point at which the yield is maximized. This is technically  $F_{max}$  but we assume it is an approximation of  $F_{MSY}^{5-9}$ .

## Results

See Figure 1 and Table 1 for estimates from this procedure.



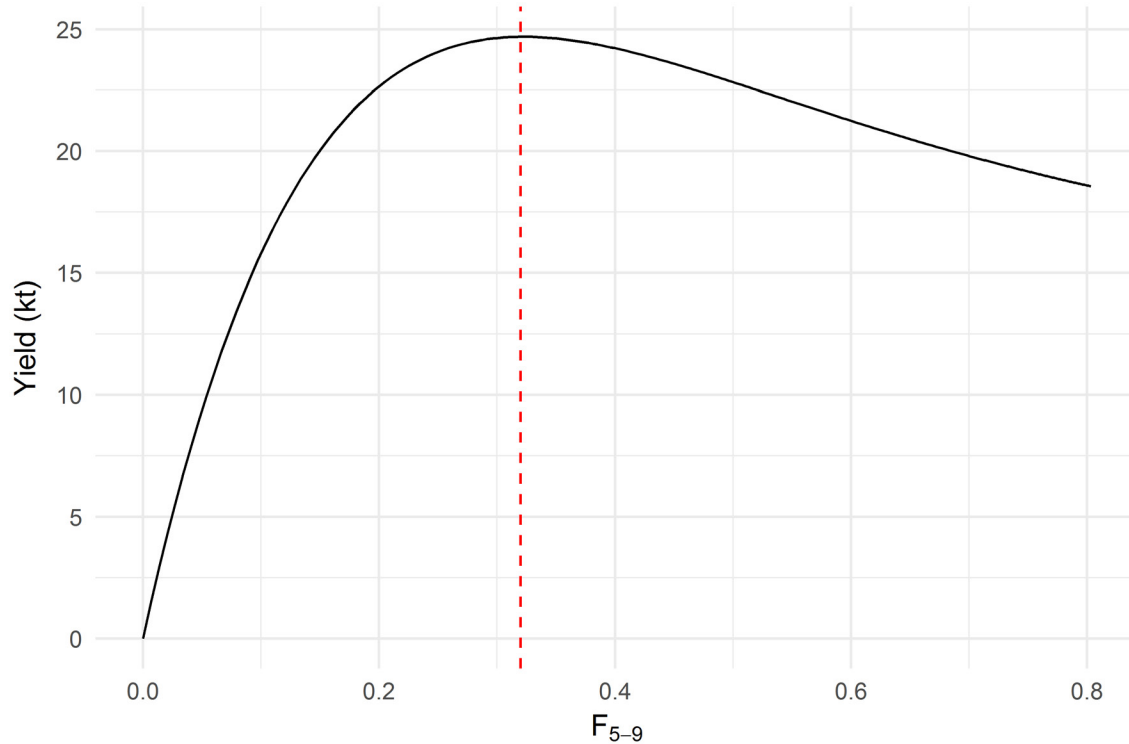


Fig.1. Profile of yield across a range of  $F_{5-9}$  values. Dotted red line indicates approximation of  $F_{MSY}^{5-9}$ . A three year average of recruitment, weight at age and F at age values were assumed for this projection.

Table 1 Estimates of reference points, with 95% confidence intervals, from model M1\_03.

	Estimate	95% CI
$B_{MSY}$	128.25	(81.65,201.45)
$B_{MSY}^{5-9}$	73.65	(50.05,108.37)
$B_{MSY}^{10+}$	38.39	(13.64,108.05)
$MSY$	24.69	(16.66,36.6)
$F_{MSY}^{5-9}$	0.32	(0.23,0.44)

## References

Regular, Paul M, Noel G Cadigan, M Joanne Morgan, and Brian P Healey. 2017. "A Simple Sam-Style State-Space Stock Assessment Model for Greenland Halibut in Nafo Subarea 2 and Divisions 3KLMNO." *NAFO SCR 17/10* (Ser. No. N6659.): 35p.