Analyses of CPUE from the four islands of the Tristan da Cunha group to examine effects of trip length and period of rest between trips on CPUE performance

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Introduction

Cursory examination of CPUE data as well as anecdotal evidence from skippers and fishermen have suggested that two important mechanisms may be at play concerning the behavior of CPUE values over time. Firstly, it has been suggested that CPUE falls off fairly rapidly during a single fishing trip. Secondly, by leaving the fishing ground to "rest" for a period improves the catch rates on return. The analysis presented here explores these two possibilities.

Data

Daily catch rate data (CPUE) from the longline fishery were obtained from the Edinburgh records for Gough, Inaccessible and Nightingale. Powerboat data (collected from ?? Edinburgh or Tristan fishermen) from Tristan were also obtained. Data for the 2010-2014 seasons were examined. Note that the 2014 season is not yet complete. Note also that as there was no fishing in 2011 at Nightingale, the 2009 data were used instead for this island. The basic approach here was to examine catch rate data from a fairly recent (2010+) period only.

A summary of the data analysed for each island is reported in Tables 1a-d.

Method

A model was fitted to the CPUE data which takes into account both the number of days since last fished, as well as the day into the trip, with the first day being called "Day0", the second "Day1" and so on. The first trip of the season has an arbitrary large number associated with it as the number of days since last fished – we used 1000 here.

The model fitted is:

$$\widehat{CPUE} = \bar{a}\left(1 - e^{-\mu d'}\right)e^{-\lambda d} \qquad (1)$$

where $\bar{a}, \mu, \lambda$ are estimable parameters,

$\widehat{CPUE}$ is the model estimated CPUE value,

$\bar{a}$ is the expected CPUE value before any fishing has taken place (taken to be independent of year),

d is the number of days into the fishing trip, with the first day being 0, and

d' is the number of days since the last fishing trip.

The $e^{-\lambda d}$ models the effect of CPUE decline (or increase) over time (*d*) during the trip, and the $\left(1 - e^{-\mu d'}\right)$ models the effect of the length of time since the last fishing trip.

The model parameter $\bar{a}, \mu, \lambda$ are estimated by maximizing the following –*ln*L function:

$$-lnL = \sum_n \left[\{ln(CPUE^{obs}) - \ln(\widehat{CPUE})\}^2 / 2\sigma^2\right] \quad (2)$$

where

n is the total number of CPUE data values, and

$$\sigma = \sqrt{\frac{1}{n}\sum_n \{ln(CPUE^{obs}) - \ln(\widehat{CPUE})\}^2} \quad \text{(its MLE)} \quad (3)$$

Results

Table 2 reports the estimated parameter values for each island. The implications of these values are more readily shown in Figures 1a and b. Here the CPUE values have been rescaled to have a maximum value of 1.0 for each island. Figure 2 shows the estimated CPUE trends for each fishing trip at Inaccessible island. Inaccessible has been used for illustrative purposes here. In the legend, it is clear which line is represented by which trip, as well as the number of days since last fished (which is indicated in parentheses). Finally, Figure 3 shows for Inaccessible 2012 (again for illustrative purposes) the individual model estimated CPUE values for each trip along with the observed or reported values. It should be noted, however, that only for Inaccessible are the results clearly significant at the 5% level (see Table 1).

Discussion

For the outer three islands there is a clear relationship between the number of days into a fishing trip and the CPUE, with CPUE declining around 4% per day for Inaccessible and Nightingale, and around 3% per day for Gough (see Figure 1a). It would appear that the opposite trend is observed at Tristan, but note that this fishery operates somewhat differently, with most trips being of a single day, so that the model of equation (1) is not necessarily that appropriate.

The other interesting relationship is that between the number of days since the last trip and the CPUE of the first day of the next trip (see Figure 1b). For both Tristan and Inaccessible, this effect is only evident if the number of days since last fished is 2 or less. As long as there is at least a 2 day rest, there appears to be no negative impact on the CPUE. A rather different result is observed at Nightingale, where CPUE

starts to decline if days left prior to the start of the next trip is as much as around 14 days. This indicates that one would need to wait around 14/15 days between trips at Inaccessible to prevent this effect. Table 1b indicates that this is how the fishery generally operates at this island, so it is not an issue here. Although the results at Gough seem similar, with an even longer recovery period between trips, neither the μ nor the λ parameter estimate differs significantly from zero. For μ this is because in nearly all cases, the time elapsed between trips is about 50 days, so that there is insufficient contrast for precise estimation.

Implication for Management

The possibility that this impacts the GLM standardization for CPUE should be explored, possibly first for Inaccessible.

Table 1a: Summary of Inaccessible CPUE data analysed.

Season	**# days since last fished**	**# days in trip**
2010	*1000*	5
2010	36	8
2010	49	14
2010	7	4
2010	6	9
2010	63	3
2011	*1000*	12
2011	23	1
2011	33	11
2011	58	9
2012	*1000*	12
2012	2	2
2012	21	3
2012	28	7
2012	62	9
2012	18	3
2013	*1000*	5
2013	5	8
2013	13	4
2013	40	5
2013	13	5
2013	41	5
2014	*1000*	10
2014	23	8

Table 1b: Summary of Nightingale CPUE data analysed.

Season	# days since last fished	# days in trip
2009	***1000***	**9**
2009	**36**	**3**
2009	**28**	**8**
2009	**35**	**10**
2010	***1000***	**7**
2010	**53**	**4**
2010	**1**	**5**
2010	**26**	**6**
2012	***1000***	**2**
2012	**26**	**2**
2012	**33**	**7**
2012	**13**	**2**
2013	***1000***	**5**
2013	**26**	**8**
2013	**25**	**7**
2014	***1000***	**6**
2014	**16**	**7**

Table 1c: Summary of Gough CPUE data analysed.

Season	# days since last fished	# days in trip
2010	*1000*	25
2010	59	7
2011	*1000*	21
2011	47	12
2012	*1000*	19
2012	47	7
2012	57	12
2013	*1000*	10
2013	52	11
2013	53	20
2013	5	4
2014	*1000*	7

Table 1d: Summary of Tristan CPUE data analysed.

Season	# days since last fished	# days in trip	Season	# days since last fished	# days in trip	Season	# days since last fished	# days in trip
2010	*1000*	2	2011	5	4	2013	*1000*	1
2010	2	1	2011	1	3	2013	10	2
2010	2	1	2011	4	3	2013	2	1
2010	18	1	2011	1	1	2013	10	1
2010	8	1	2011	4	1	2013	19	1
2010	10	2	2011	49	3	2013	11	1
2010	1	3	2011	2	1	2013	11	2
2010	1	2	2011	5	2	2013	13	1
2010	10	1	2011	10	1	2013	9	1
2010	3	1	2011	2	1	2013	4	2
2010	2	2	2011	1	2	2013	5	4
2010	14	1	2011	19	1	2013	8	1
2010	9	3	2011	12	1	2013	13	2
2010	8	1	2011	1	1	2013	6	1
2010	6	2	2011	6	1	2013	6	1
2010	1	5	2011	3	1	2013	1	2
2010	3	3	2011	13	1	2013	2	2
2010	38	2	2012	*1000*	1	2013	55	2
2010	4	4	2012	16	2	2013	9	1
2010	2	1	2012	4	1	2013	10	2
2010	1	1	2012	1	2	2013	1	1
2010	7	2	2012	3	1	2013	1	1
2010	3	2	2012	2	1	2013	9	1
2010	5	1	2012	11	1	2013	1	1
2010	14	1	2012	7	1	2013	5	2
2010	6	1	2012	8	1	2013	11	1
2010	1	1	2012	4	3	2013	1	1
2010	1	1	2012	11	1	2013	1	3
2010	1	1	2012	3	1	2013	19	1
2010	8	2	2012	24	1	2013	1	1
2010	8	1	2012	3	1	2014	*1000*	2
2011	*1000*	1	2012	1	2	2014	13	1
2011	5	1	2012	3	2	2014	15	1
2011	35	1	2012	4	1	2014	18	1
2011	10	2	2012	13	1	2014	2	1
2011	11	2	2012	27	1	2014	7	1
2011	1	1	2012	2	1	2014	7	1
2011	19	2	2012	4	5	2014	12	3
2011	11	2	2012	5	2	2014	2	1
2011	2	1	2012	2	1	2014	9	1
2011	4	1	2012	2	1	2014	11	4
2011	5	4	2012	12	1			
2011	1	3	2012	11	1			
2011	4	3	2012	29	2			
2011	1	1						
2011	4	1						

Table 2: Results of the estimable parameters for the four islands. The values in parentheses are the Hessian based standard deviations.

	$\bar{a}$	μ	λ
Inaccessible	4.96	0.275 (0.060)	0.045 (0.012)
Nightingale	7.35	2.294 (2.093)	0.040 (0.024)
Gough	5.40	0.071 (0.363)	0.029 (0.026)
Tristan	1.10	2.659 (0.899)	-0.036 (0.032)

Figure 1a: Expected CPUE trends over a period of fishing. Values have been rescaled to have a value of 1.0 for the first day of fishing. (The trend for Tristan ends after 5 days fishing as this has been the maximum period of continuous fishing that has ever occurred).

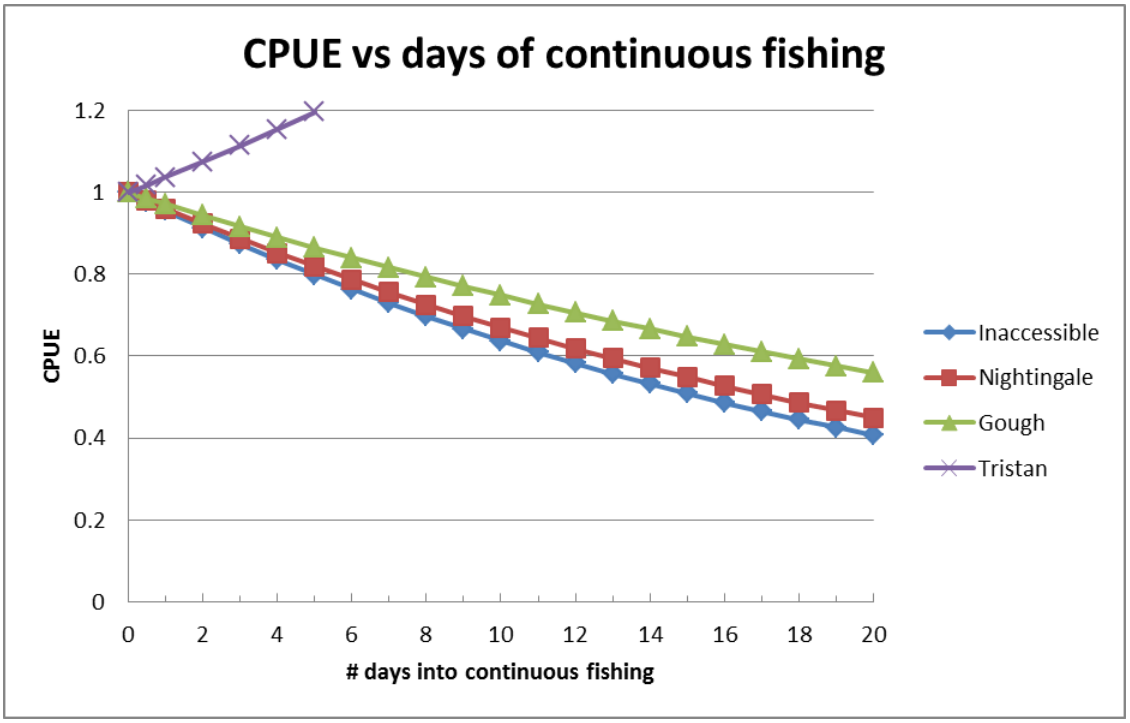

Figure 1b: Expected CPUE values for the first day of a fishing trip relative to the number of days since the last fishing trip. CPUE values are scaled to have a maximum of 1.0 for ease of comparison.

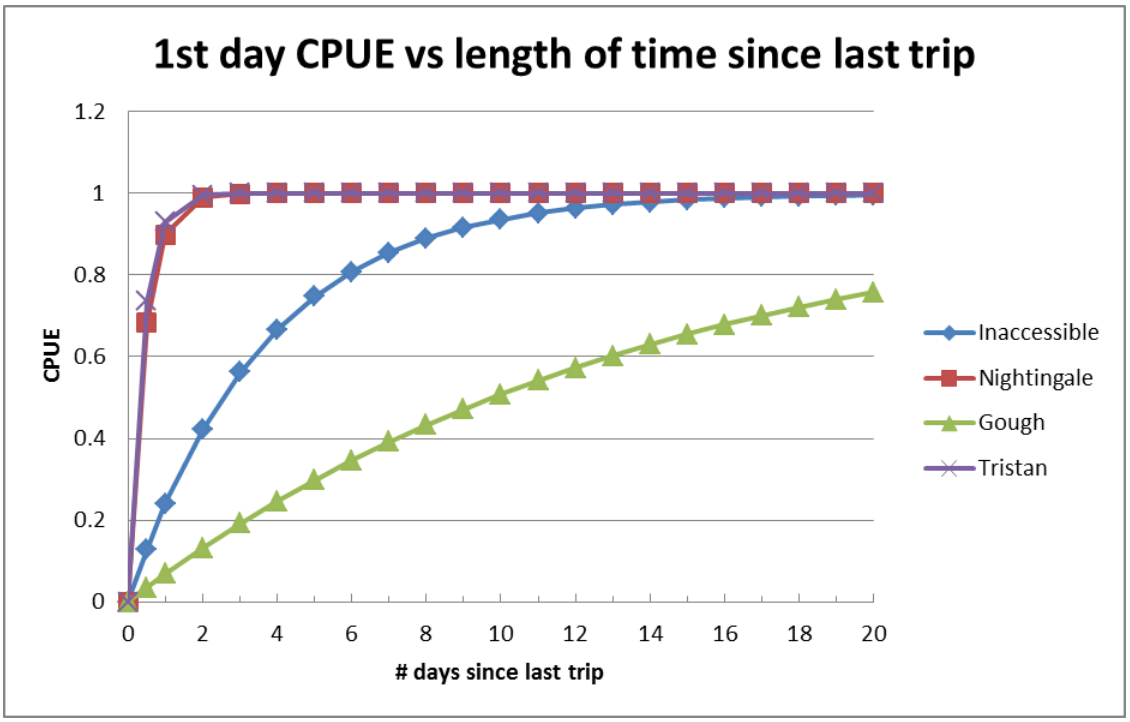

Figure 2: The estimated CPUE trends for each fishing trip at Inaccessible. The legend indicates the trip number and the number in parenthesis indicates the number of days since last fished.

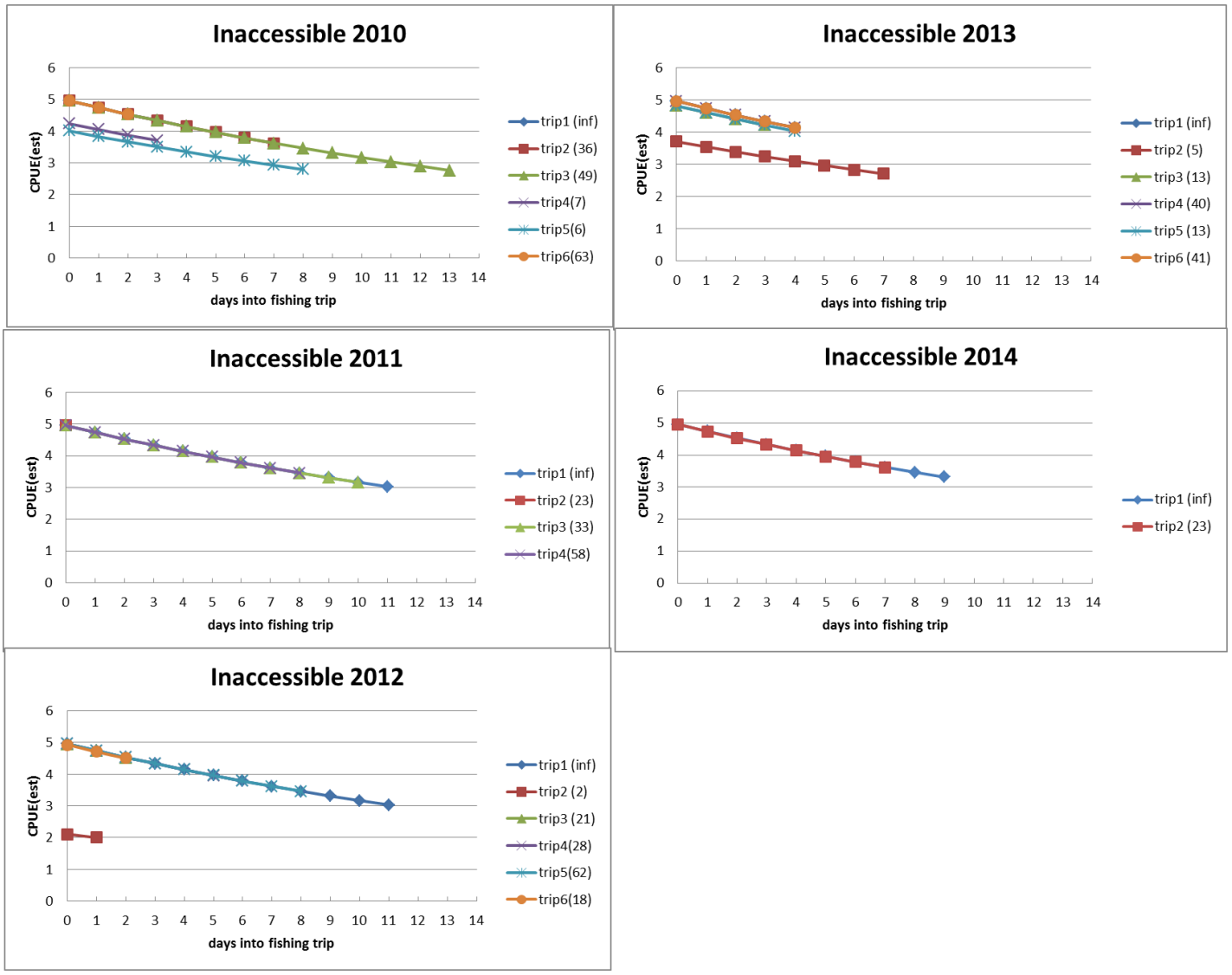

Figure 3: Inaccessible model estimated CPUE values compared with observed CPUE values for 2012 (shown here as an example).