Equivalence analysis of UCK in MHS and conventional gear

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NOTE:

Here, SNX is given in kg, and hence UCK is kg of SNX per kg of SNA. In the Kaharoa inshore trials, UCK was numbers of SNX per kg of SNA. In those trials the conventional and MHS gears both had average SNX weight of 270 gm (cf., a 24.5 cm SNX has expected weight of 340 gm). Using an average weight of 270 gm, 1 kg of SNX equates to 3.7 SNX by number. (In the Kaharoa trials the UCKs (by kg) equate to 0.137 and 0.177 for conventional gear and MHS, respectively.)

The FMA1 data are partitioned into areas 002, 003, 004, 005, 006, 008, 009 and 010, and span from October 2015 to June 2018.

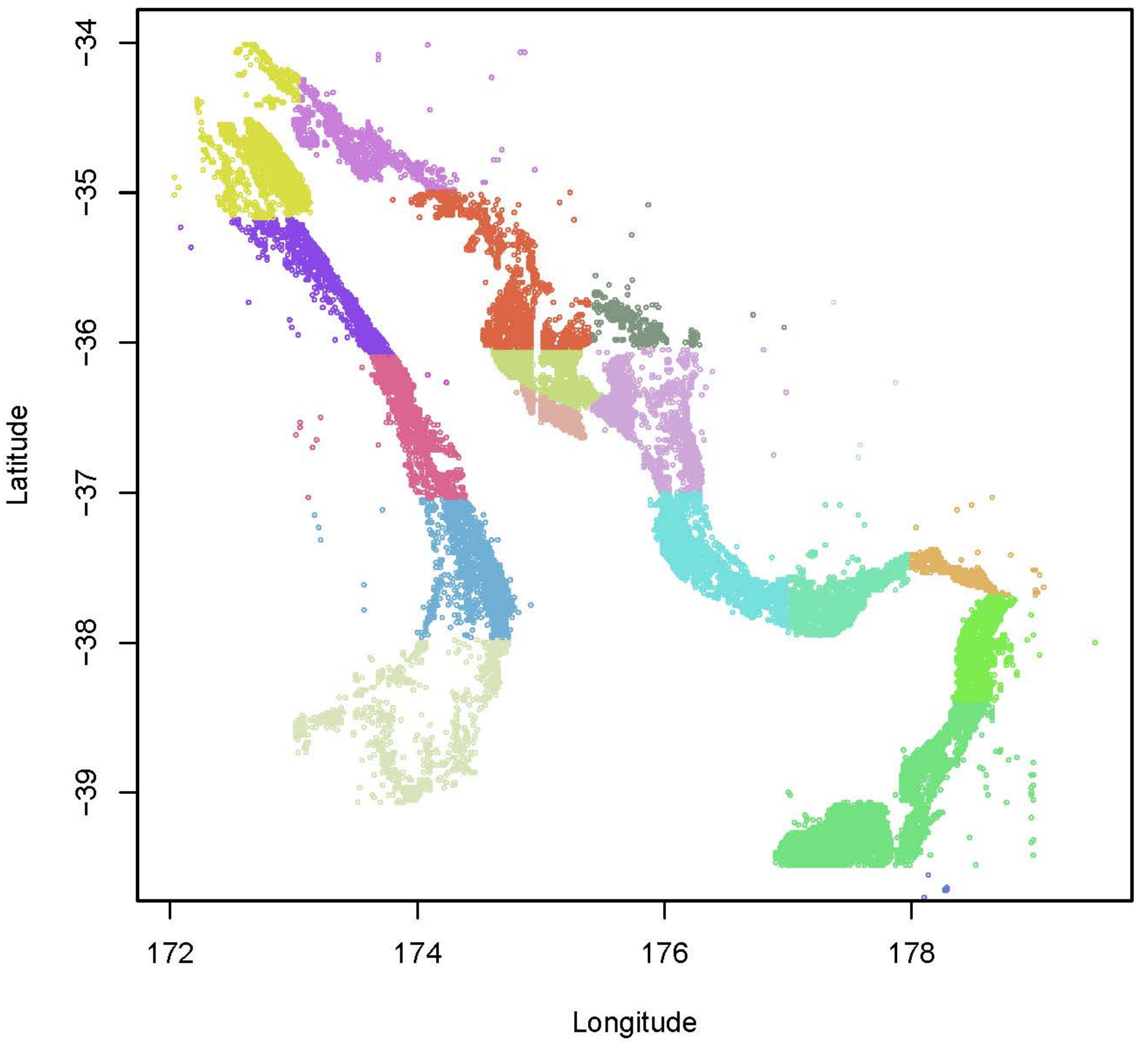

Fig. 1. The locations of all tows, coloured-coded by area

Summary statistics

In the tables of averages below, nTows is the total number of tows. The quantity SNA.Wgt is the average total weight of SNA (over the tows). SNA.Depth is the average depth at which SNA were caught, whereas Tow.Depth is the average tow depth. Gear code BT is conventional bottom trawl, and BRT is the MHS gear.

Summary statistics for tows targeting SNA in FMA1

Number of tows is 5927

Table 1a: Averages:

Gear	nTows	UCK	Tow.Durn	SNA.Wgt	Tow.Wgt	Tow.Depth	SNA.Depth
BT	3565	0.0550	2.3567	391.2646	595.1592	60.4283	53.8075
PRB	2362	0.0713	2.3873	403.8847	629.3594	62.7392	60.9515

Table 1b: Averages by area:

Area	Gear	nTows	UCK	Tow.Durn	SNA.Wgt	Tow.Wgt	Tow.Depth	SNA.Depth
002	BT	184	0.010	3.198	251.000	521.158	84.603	80.705
002	PRB	101	0.011	3.824	614.535	1118.693	75.079	46.777
003	BT	752	0.036	2.668	312.230	446.497	79.015	72.323
003	PRB	369	0.034	3.107	338.912	486.821	95.312	100.072
004	BT	15	0.048	2.950	386.133	580.133	127.400	125.251
004	PRB	2	0.072	3.942	312.000	513.000	118.000	117.333
005	BT	611	0.087	1.973	368.046	533.498	51.224	50.571
005	PRB	733	0.110	1.981	317.701	436.759	54.176	58.596
006	BT	478	0.089	1.396	437.515	515.064	43.594	42.683
006	PRB	472	0.136	1.495	354.943	418.305	46.945	47.827
008	BT	470	0.062	2.538	360.469	585.040	73.658	72.561
008	PRB	344	0.057	2.687	298.643	477.866	73.735	76.525
009	BT	459	0.033	2.749	341.726	749.319	53.595	50.524
009	PRB	199	0.031	3.412	717.397	1527.126	55.131	51.568
010	BT	596	0.039	2.408	583.564	823.698	45.595	37.673
010	PRB	142	0.038	2.375	847.338	1457.944	49.268	47.980

Summary statistics for all tows in FMA1

Number of tows is 17591

Table 1c: Averages

Gear	nTows	UCK	Tow.Durn	SNA.Wgt	Tow.Wgt	Tow.Depth	SNA.Depth
BT	13797	0.0488	3.1618	207.0910	627.4358	118.4974	63.7809
PRB	3794	0.0578	3.1224	382.7698	846.4463	84.7240	64.3126

Table 1d: Averages by area:

Area	Gear	nTows	UCK	Tow.Durn	SNA.Wgt	Tow.Wgt	Tow.Depth	SNA.Depth
002	BT	1792	0.009	3.707	120.031	549.191	160.447	95.068
002	PRB	475	0.007	4.422	404.379	1202.581	107.048	75.577
003	BT	2465	0.035	3.162	206.358	399.939	95.114	80.059

003	PRB	538	0.043	3.844	284.302	514.056	108.013	101.893
004	BT	373	0.027	5.265	30.878	726.214	255.239	157.487
004	PRB	74	0.038	7.384	19.315	1213.919	268.932	180.496
005	BT	1733	0.086	1.913	257.068	440.031	56.208	55.160
005	PRB	847	0.111	2.163	304.435	446.240	55.267	58.626
006	BT	703	0.089	1.358	369.515	467.816	45.372	43.960
006	PRB	472	0.136	1.495	354.943	418.305	46.945	47.827
008	BT	1990	0.064	3.959	181.157	798.039	175.443	78.221
008	PRB	565	0.056	3.172	269.190	668.664	99.768	77.754
009	BT	2352	0.038	3.277	192.756	763.703	111.980	57.551
009	PRB	616	0.029	3.626	632.242	1667.073	78.446	54.973
010	BT	2389	0.030	3.083	252.331	813.367	115.493	48.052
010	PRB	207	0.037	2.746	670.634	1418.754	91.411	48.055

Comments

Restricted to tows that were targeting snapper, the UCK of MHS is 30% higher than that of conventional gear. Over all tows, UCK of MHS is 18% higher. All UCKs are lower than the those observed in the Kaharoa experiment, especially outside the Hauraki Gulf areas 005 and 006.

As a potential avoidance strategy, the summary statistics were also calculated for FMA1 excluding the Hauraki Gulf, and are shown below.

Summary statistics with Hauraki Gulf (areas 005 and 006) excluded

Number of tows is 3633

Table 2a: Averages for tows targeting SNA

Gear	nTows	UCK	Tow.Durn	SNA.Wgt	Tow.Wgt	Tow.Depth	SNA.Depth
BT	2476	0.0399	2.6370	388.0655	625.8875	65.9494	56.9861
PRB	1157	0.0357	3.0088	478.4512	837.4788	74.6076	65.9145

Number of tows is 13836

Table 2b: Averages for all tows

Gear	nTows	UCK	Tow.Durn	SNA.Wgt	Tow.Wgt	Tow.Depth	SNA.Depth
BT	11361	0.0364	3.4639	189.4171	665.9639	132.5239	67.9581
PRB	2475	0.0319	3.7612	414.8845	1065.0554	102.0097	68.4302

Outside of the Hauraki Gulf, for tows that were targeting snapper the UCK of MHS is 11% lower than that of conventional gear. Over all tows outside of the Hauraki Gulf, the UCK of MHS is 12% lower.

There are some notable “imbalances” in some of the catch variables. On average, MHS tows targeting snapper tend to be at greater depths than conventional tows targeting snapper. Moreover, MHS tows tend to have considerabley higher catch weights and to be of somewhat longer duration. (This imbalance is a consequence of the data being observational, and not having been subject to an experimental design that would have ensured some form of matching of the MHS and conventional gears.) Over all tows, the average tow depth of conventional gear is 133 m, and is is considerably higher than the 102 m average depth for MHS gear. However, as very few SNA are caught at large depths, the average depth at which SNA are caught is about 68 m for both gear. Average total tow weight, and particularly average tow weight of snapper, are considerably higher.

Methodology for analysing UCK

The primary feature of the model approach used herein is that it ***does not*** model UCK directly. Being a ratio, the UCK variable has highly undesirable properties, including inhomogenous variance. Moreover, an average of UCK values from a set of tows does not equal the overall UCK of those tows.

Here, SNX was used as the response variable, and SNA was used as an offset variable. This is analogous to catch-per-unit-effort analysis, whereby catch is the response variable and effort is an explanatory variable. That is, the appropriate way to conduct UCK analysis is to perform SNX-per-unit-SNA analysis.

After substantial consideration and evaluation of model options, a GLMM (generalized linear mixed model) method of analysis was chosen. In this model, the weight of SNX (rounded to the nearest integer) was assumed to be an overdispersed count variable. These models are sufficiently flexible to handle occassional extremely large SNX catches, and also the frequent zero catches of SNX.

The imbalance of the catch variables makes the task of model fitting somewhat of a challenge since variables such as depth, catch weight and month are confounded with the gear type. One has to very careful when interpreting any difference between MHS and conventional gears, since it may be (partly) due to differences in depths of deployments, catch weights and dates of deployment, rather than differences in the gears themselves.

Since the datasets have several thousand tows, the approach taken here was to fit a model that included as many covariates as possible while retaining model parsimony by requiring a reduction in BIC (Bayesian Information Criterion). This model can then be used to infer the change in SNX due to one variable while keeping all other variables fixed.

The preferred models are presented below. They fit gear, area and year as fixed effects, and also haul duration, catch size (both total tow weight and total SNA weight), and a cubic polynomial in depth. Vessel, trip, tow, and calendar month were included as random effects.

Results: Identical gear usage

Table 3a: Model coefficients, SNA-targeted tows

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-4.3162	0.3142	-13.7394	0.0000
GearPRB	0.0736	0.0987	0.7462	0.4555
Area003	1.4341	0.1327	10.8038	0.0000
Area004	2.1286	0.2979	7.1448	0.0000
Area008	1.5693	0.1374	11.4245	0.0000
Area009	0.7713	0.1479	5.2148	0.0000
Area010	0.8181	0.1516	5.3955	0.0000
Year2016	0.7458	0.1470	5.0723	0.0000
Year2017	1.0575	0.1523	6.9416	0.0000
Year2018	1.2627	0.1936	6.5222	0.0000
log(Durn)	-0.1690	0.0592	-2.8546	0.0043
log(TotWgt + 1)	0.1515	0.0505	3.0030	0.0027
log(SNA + 1)	-0.3933	0.0382	-10.2869	0.0000
Depth	3.2765	0.4948	6.6219	0.0000
I(Depth^2)	-5.3680	0.5136	-10.4509	0.0000

I(Depth^3)	1.3903	0.1599	8.6971	0.0000

Table 3b: Model coefficients, all tows

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.5941	0.2347	-11.0517	0.000
GearPRB	0.1595	0.0792	2.0144	0.044
Area003	1.5841	0.0843	18.7845	0.000
Area004	1.1200	0.2041	5.4872	0.000
Area008	1.5992	0.0885	18.0794	0.000
Area009	0.9898	0.0944	10.4812	0.000
Area010	0.5661	0.1009	5.6131	0.000
Year2016	0.7067	0.1086	6.5090	0.000
Year2017	0.9397	0.1137	8.2677	0.000
Year2018	1.2888	0.1396	9.2319	0.000
log(Durn)	-0.3880	0.0419	-9.2588	0.000
log(TotWgt + 1)	0.1947	0.0267	7.2913	0.000
log(SNA + 1)	-0.4133	0.0181	-22.8675	0.000
Depth	-3.1479	0.1036	-30.3797	0.000
I(Depth^2)	0.5207	0.0428	12.1719	0.000
I(Depth^3)	-0.0220	0.0027	-8.1420	0.000

Comments

The GearPRB p-values in Table 3a show that there is not a statistically significant difference between the UCK of MHS and conventional gears when restricted to tows targetting snapper. There is a marginal significant effect of gear type over all tows. These fits are on the log scale, so the estimated gear effect is on the multiplicative scale, and is given by exponentiating the GearPRB coefficient. Keeping all covariates (e.g., depth, duration, tow weight) equal, and when targetting SNA, it is estimated that MHS catches *7.64%* more SNX (per kg SNA) than conventional gear. For all tows, MHS catches *17.3%* more SNX. The confidence intervals are *-11.3%* to *30.6%* more SNX when targeting SNA, and *0.43%* to *37%* more SNX over all tows.

It is notable that, despite the lower observed UCK of the MHS gear in Tables 2a and 2b, it is the case that MHS is estimated to have higher UCK. This apparent conflict arises due to the imbalance of the explanatory covariates. The above gear differences estimate the difference in UCK between two identical vessels fishing side-by-side, with one using MHS and the other using conventional trawl (and assumes that they have the same catch weights).

Results: Observed gear usage and catch

The MHS and conventional gear varied considerably in the tow covariates (Tables 2a and 2b). For example, in Table 2a it was seen that SNA-targeted tows caught snapper at an average depth of 56.99 m using conventional gear, and 65.91 m using MHS. There is a strong depth effect (Fig 2), and if the differences in depths is taken into account, then the UCK of MHS is **lower** than that of conventional gear by about 8%. That is, if the MHS deployments of SNA-targeted tows continue to have an average snapper depth of about 9 m higher than that of deployments of conventional gear, then the MHS tow will have lower UCK by about 8%.

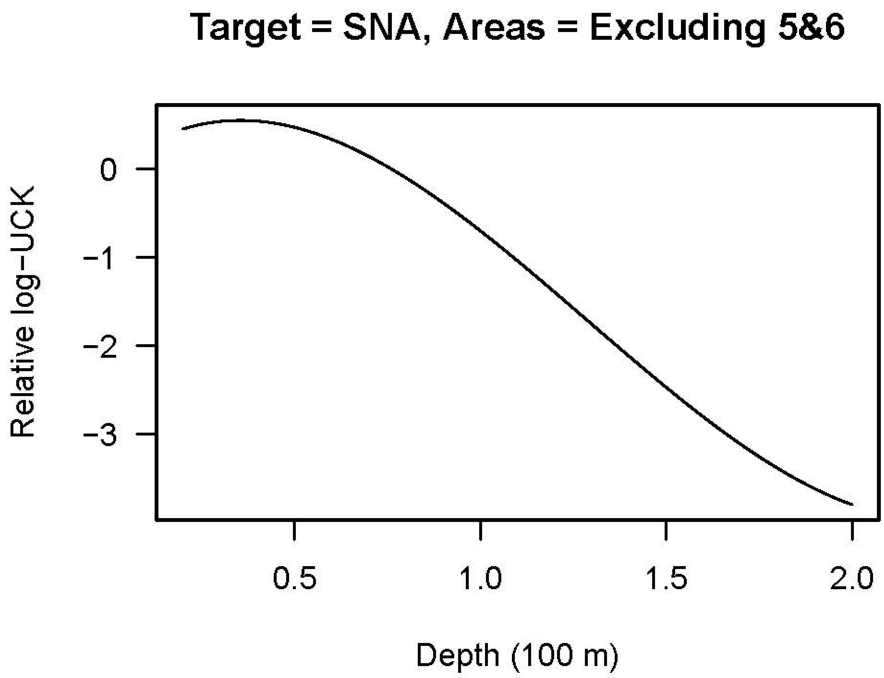

Fig. 2. Effect of depth on UCK

More generally, the above example of using the differing values of the snapper depths was extended to utilize differences in all of the relevant covariates in Tables 2a and 2b. That is, depth, tow duration, total tow weight and total SNA weight.

Using the gear-specific covariates (e.g., depth, duration, weights) from Tables 2a and 2b, when targetting SNA, it is estimated that MHS catches *-13.2%* less SNX (per kg SNA) than conventional gear. For all tows, MHS catches *-10.9%* less SNX. The confidence intervals are *-28.5%* to *5.43%* change in SNX when targeting SNA, and *-23.8%* to *4.19%* change over all tows.

Equivalence statements

The estimates and confidence intervals from the above results can be re-expressed as equivalence statements for UCK (kg SNX per kg SNA).

Identical gear usage

Probability of exceeding a given percentage difference in UCK
(i.e., kg SNX per kg SNA

Table 4q: SNA-targeted tows

	-50%	-25%	-10%	-5%	0%	5%	10%	25%	50%
Probability >	1	1	0.965	0.897	0.772	0.599	0.413	0.065	0

Table 4b: All tows

	-50%	-25%	-10%	-5%	0%	5%	10%	25%	50%
Probability >	1	1	1	0.996	0.978	0.919	0.791	0.211	0.001

For example, under identical gear usage of SNA-targeted tows, the probability that the UCK of MHS is higher is 0.772, and that it is 10% or more higher is 0.413. Over all tows, these probabilities are 0.978 and 0.791. (From Tables 2a and 2b, a 10% higher UCK corresponds to an additional 4.0 kg of SNX per t. SNA for SNA-targeted tows, and 3.6 kg of SNX per t. SNA over all tows.)

Observed gear usage

Probability of exceeding a given percentage difference in UCK

Table 4c: SNA-targeted tows

	-50%	-25%	-10%	-5%	0%	5%	10%	25%	50%
Probability >	1	0.93	0.358	0.181	0.077	0.028	0.008	0	0

Table 4d: All tows

	-50%	-25%	-10%	-5%	0%	5%	10%	25%	50%
Probability >	1	0.985	0.451	0.211	0.074	0.02	0.004	0	0

For example, when SNA-targeted tows are deployed under the gear usage and catch weights that were observed in that fishery, the probability that the UCK of MHS is higher is 0.077, and that it is 10% or more higher is 0.008. Over all tows, these probabilities are 0.074 and 0.004.