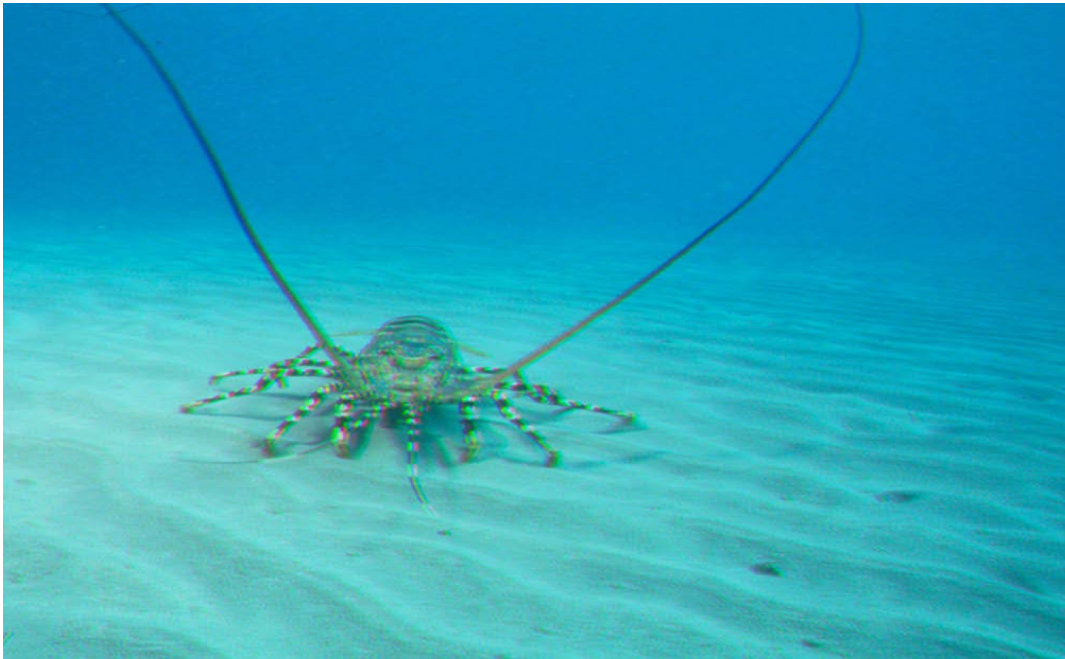




CPUE-Based Annual Abundance Indices for Torres Strait Rock Lobster

Robert Campbell, Darren Dennis, , Eva Plaganyi, Roy Deng
13 December 2016

CSIRO Oceans and Atmosphere Flagship
www.csiro.au



Abundance Indices

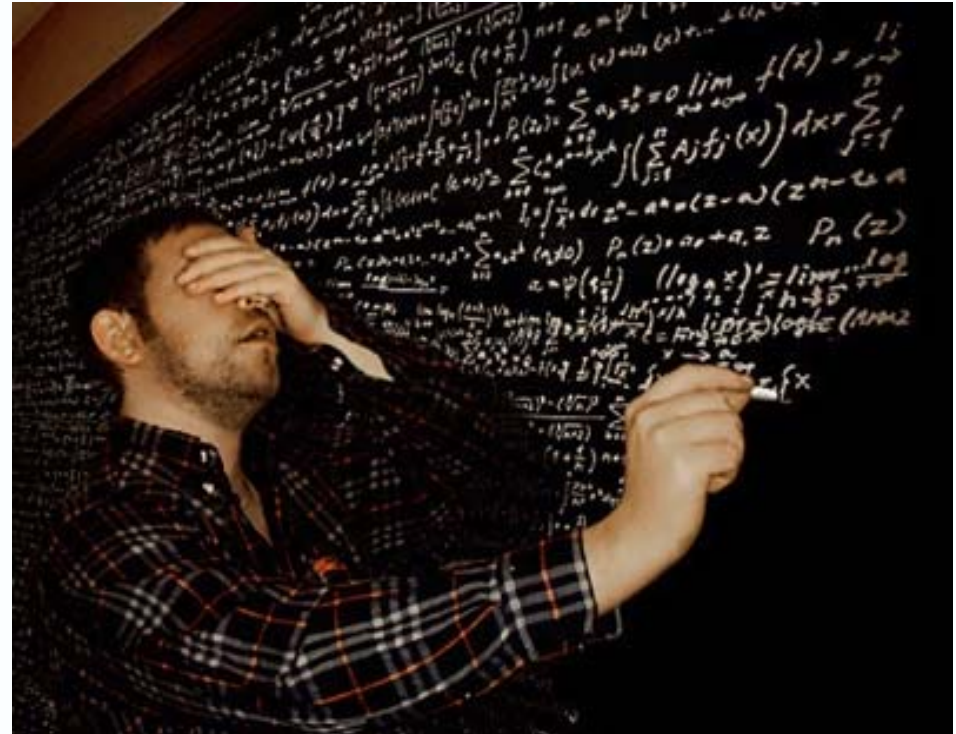
- Stock assessments rely on an index of stock abundance
- Indices can be obtained either by fishery independent means (i.e. surveys) or by fishery-dependent means (i.e. catch and effort recorded in logbooks)
- Mid-year & pre-season surveys are examples of the former
- Standardised CPUE is an example of the latter

CPUE Standardisation – why?

Need to account for factors which influence catches & catch-rates apart from the underlying abundance of the fished resource.

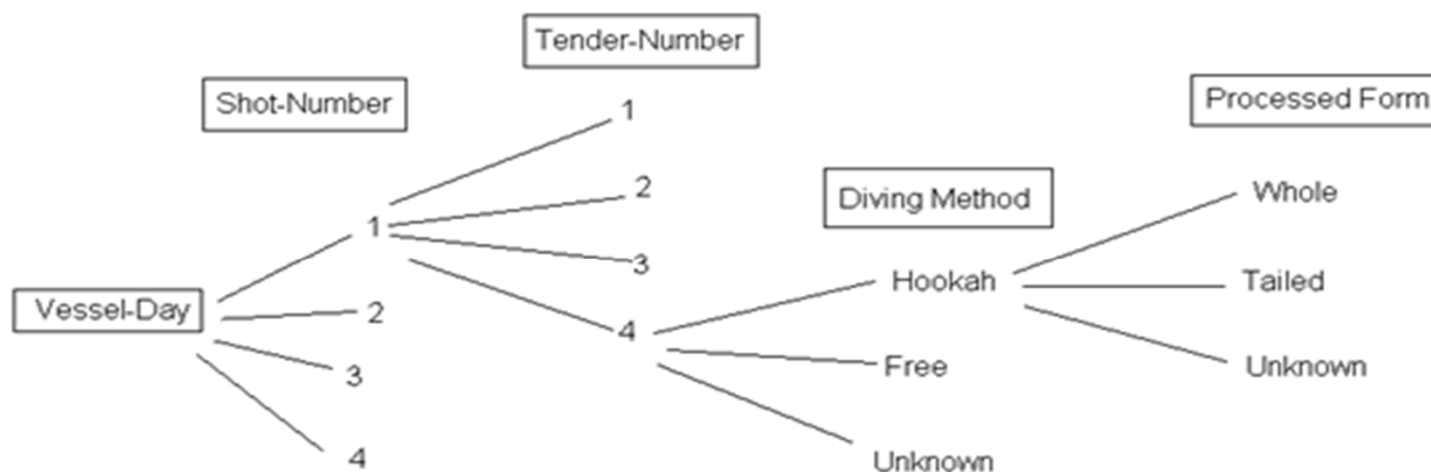
e.g. changes in fishing efficiency, changes in spatial-temporal aspects of the fishery, etc

Aim is to estimate abundance had all other factors remained constant apart from underlying abundance.



TVH Data

- The TVH fishery provides the most comprehensive set of data
- 96,215 records from 1994 to 2016
- Data structure as follows (up to 8 tenders per shot)



- Data aggregated by vessel-day, shot, tender, method – 66,366 records

TVH Data - 2

Identify core part of fishery to include in analysis

- Months fished
- Areas fished
- Methods

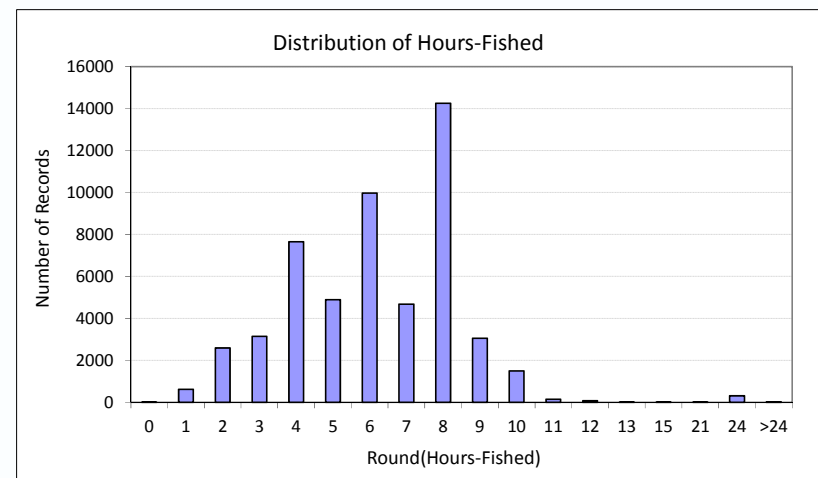
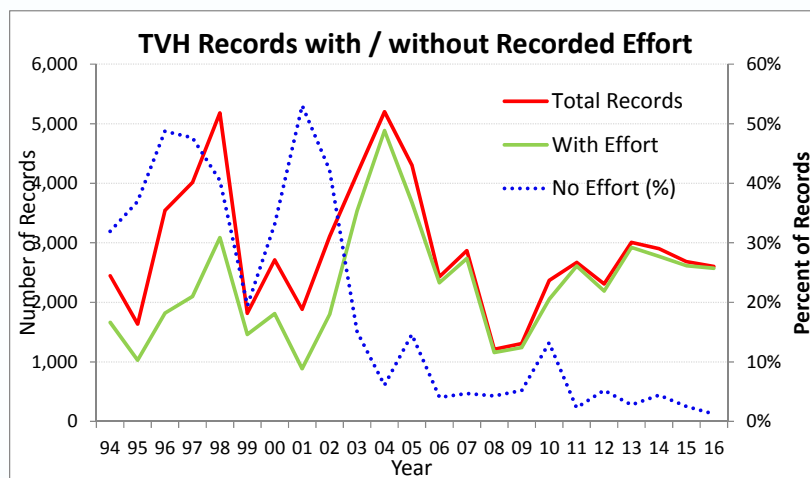
Year	Hookah	Free	Unknown	Records
1994	1,505	136	804	2,445
1995	947	59	629	1,635
1996	1,609	87	1,851	3,547
1997	1,890	112	2,009	4,011
1998	2,681	169	2,331	5,181
1999	1,412	38	365	1,815
2000	2,330	114	267	2,711
2001	812	26	1,047	1,885
2002	1,721	10	1,380	3,111
2003	3,958	104	100	4,162
2004	5,045	154	1	5,200
2005	4,101	199	2	4,302
2006	2,307	119	2	2,428
2007	2,829	39	1	2,869
2008	1,205	6	0	1,211
2009	1,281	27	0	1,308
2010	2,356	12	0	2,368
2011	2,668	1	1	2,670
2012	2,311	0	0	2,311
2013	3,006	2	0	3,008
2014	2,901	0	0	2,901
2015	2,678	1	4	2,683
2016	2,592	12	0	2,604
Total	54,145	1,427	10,794	66,366

YEAR	Northern	Mabuiag	Badu	Thurs Is.	Central	Warrior	Warraber	Kirkaldie	Adolphus	East TS	East TS	GBR	East Coast	A-99	TOTAL
	A101	A102	A103	A104	A105	A106	A107	A108	A109	A201	A202	A401	A0		
1994	51	257		11	119	252	926	64	89	106	177	1		392	2445
1995	106	289	2	41	83	187	487	111	26	36	32	4	8	223	1635
1996	620	1152	2	11	51	269	719	41	37	1	32		4	608	3547
1997	425	1324	21	21	73	524	881	4	21	52	33	2		630	4011
1998	463	1681	51	130	107	661	1042	160	16	31	45			794	5181
1999	158	457	34	33	66	254	348	177	17	14	30	15		212	1815
2000	137	252	66	48	51	825	605	229	59	7	22	35	5	370	2711
2001	42	70	5	44	26	712	366	83	40	3	41	44	4	405	1885
2002	107	278	18	176	44	692	592	718	48		17	16	4	401	3111
2003	808	719	115	317	344	404	432	832	96	7	49	3	3	33	4162
2004	921	765	209	163	551	344	980	970	205	11	58	4	10	9	5200
2005	682	588	164	196	164	203	511	1680	90	3	18	1	2		4302
2006	301	332	21	130	187	300	440	355	276	34	48	4			2428
2007	362	417	42	146	134	323	367	980	62	10	24	2			2869
2008	227	63	6	91	53	238	240	206	48	2	31	3	1	2	1211
2009	272	42	5	80	145	371	231	47	26	23	59	7			1308
2010	493	138	101	102	31	197	206	997	43	12	32	14	2		2368
2011	389	111	34	83	17	159	430	1406	25		14		2		2670
2012	417	217		14	46	155	1166	267	18	5	5	1			2311
2013	719	239	34	16	63	168	469	1267	6	6	21				3008
2014	777	263	15	27	165	268	780	445	47	14	93		7		2901
2015	176	173	45	5	116	876	660	486	25		121				2683
2016	57	12	62	7	202	681	454	914	18	131	46		20		2604
Total	8,710	9,839	1,052	1,892	2,838	9,063	13,332	12,439	1,338	508	1,048	156	72	4,079	66,366

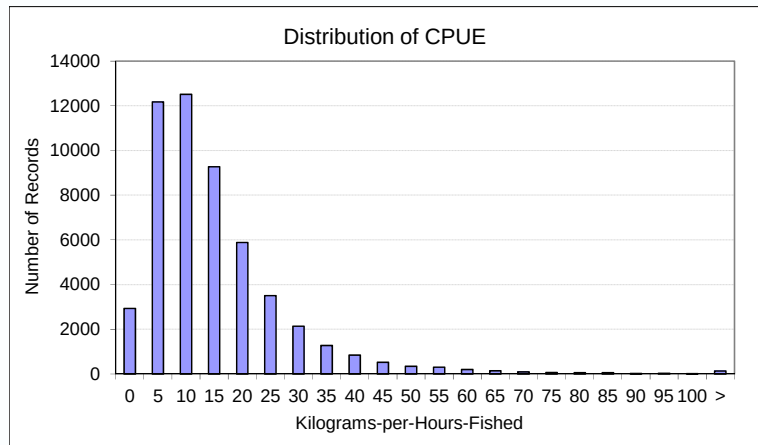
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1994	84	105	236	448	347	364	227	310	270			54	2445
1995	23	116	123	147	185	220	121	239	238	3		220	1635
1996	366	237	447	247	378	264	356	517	411			324	3547
1997	383	232	307	239	598	333	438	538	327	18		598	4011
1998	445	739	551	484	486	587	553	603	493		9	231	5181
1999	117	98	262	242	208	214	161	132	146			235	1815
2000	196	240	349	215	328	370	342	232	99		66	274	2711
2001	375	97	223	65	259	270	206	174	119	9	1	87	1885
2002	26	285	365	295	401	400	360	492	398			89	3111
2003	100	461	488	393	490	518	527	596	413			176	4162
2004	24	607	712	571	662	761	729	633	395			106	5200
2005	13	662	615	543	519	538	552	533	323			4	4302
2006		409	436	361	286	206	349	289	92				2428
2007		288	427	446	542	489	402	184	91				2869
2008		133	222	113	161	96	159	175	152				1211
2009		148	227	174	201	200	125	163	70				1308
2010		255	333	302	324	292	309	294	253		6		2368
2011		286	384	371	322	380	356	310	261				2670
2012		166	344	371	311	336	318	264	201				2311
2013		461	383	414	424	324	374	385	243				3008
2014		357	395	297	433	408	445	274	291		1		2901
2015		419	408	441	355	313	253	357	137				2683
2016	12	500	444	315	379	334	313	183	124				2604
Total	2,164	7,301	8,681	7,494	8,599	8,217	7,975	7,877	5,547	30	83	2,398	66,366

TVH : Measure of Effort

- Data allows effort to be measured at the tender level
- 52,944 (79.8%) records list tender effort in hours fished
- Analysis uses 48,030 records where hours fished between 0.5 and 12 hrs

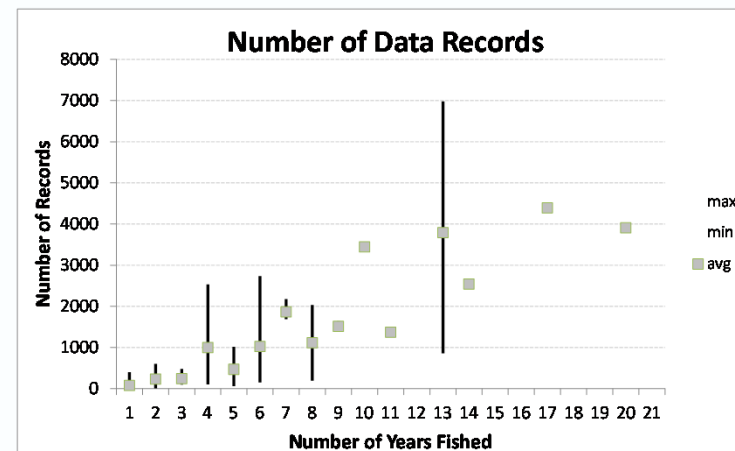
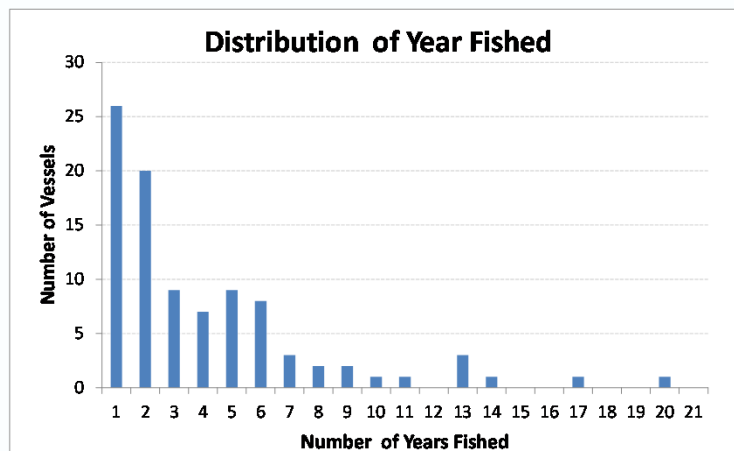


TVH: CPUE & Changes in data

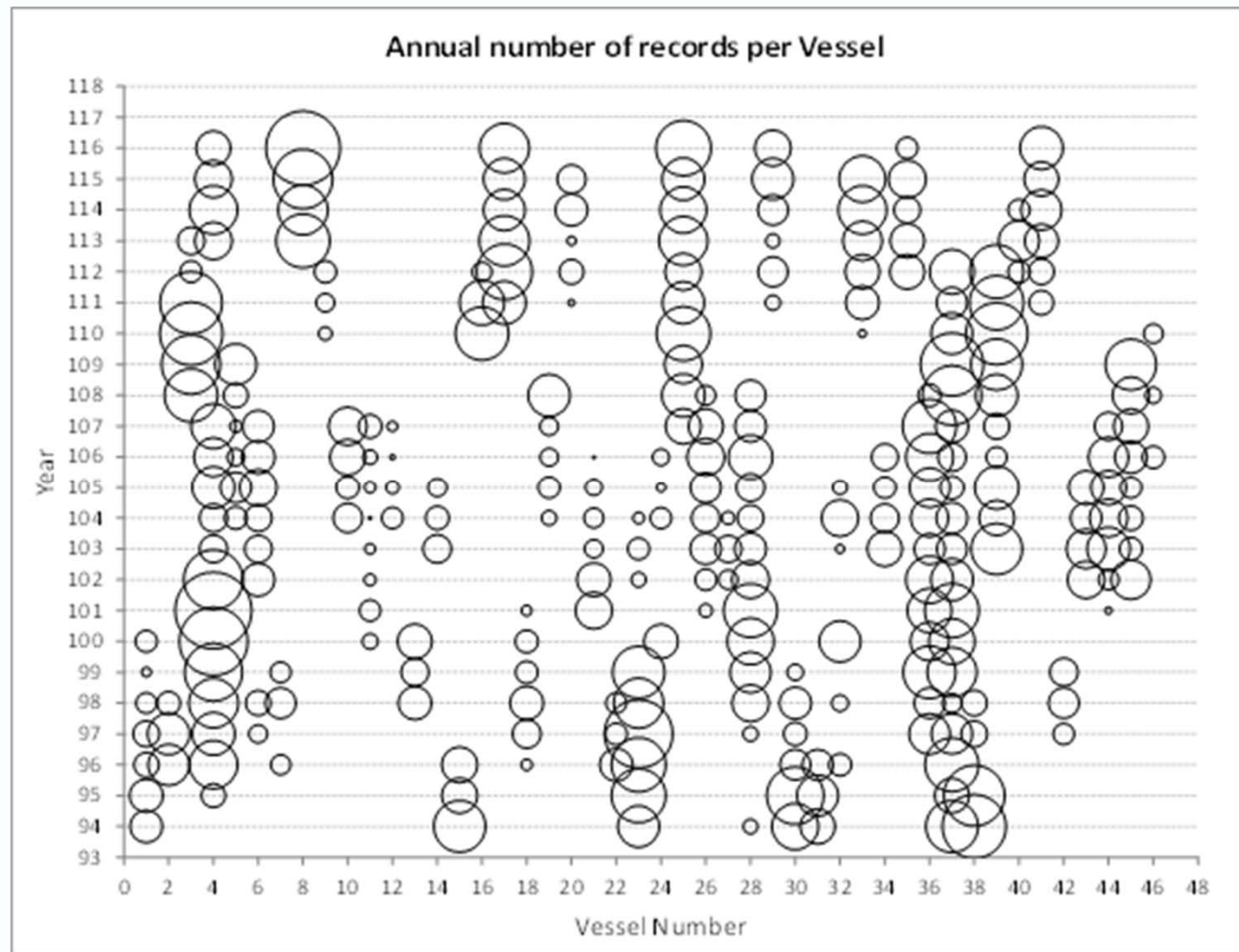


Selection of Vessels

- 94 separate 'vessels' identified by Vessel-name & Symbol in the data
- Selected 46 'vessels' which had fished for 3 or more years and for which there were more than 50 records
- Also delete records where CPUE=0 or CPUE>150 kg/hour
- Number of records fitted to GLMs = 41,882 records



Temporal Distribution of 'Vessels'



General Linear Models

General Linear Models (GLMs) were fitted to the data:

- Base Model:

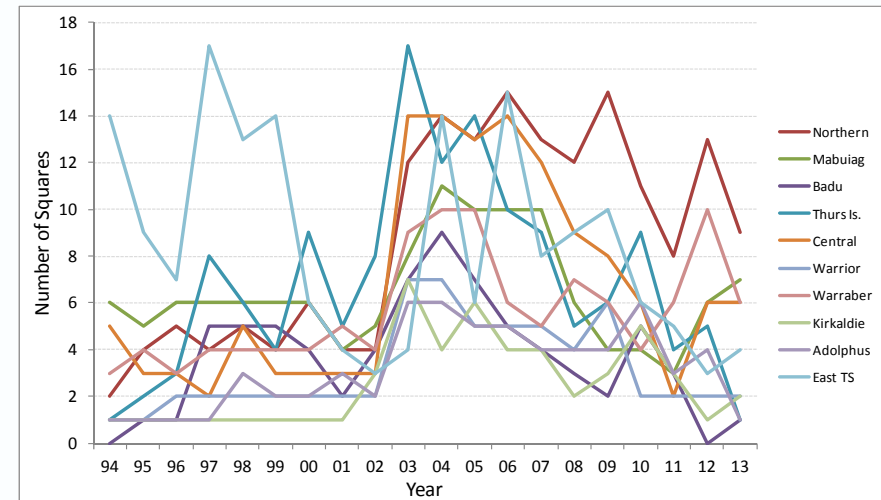
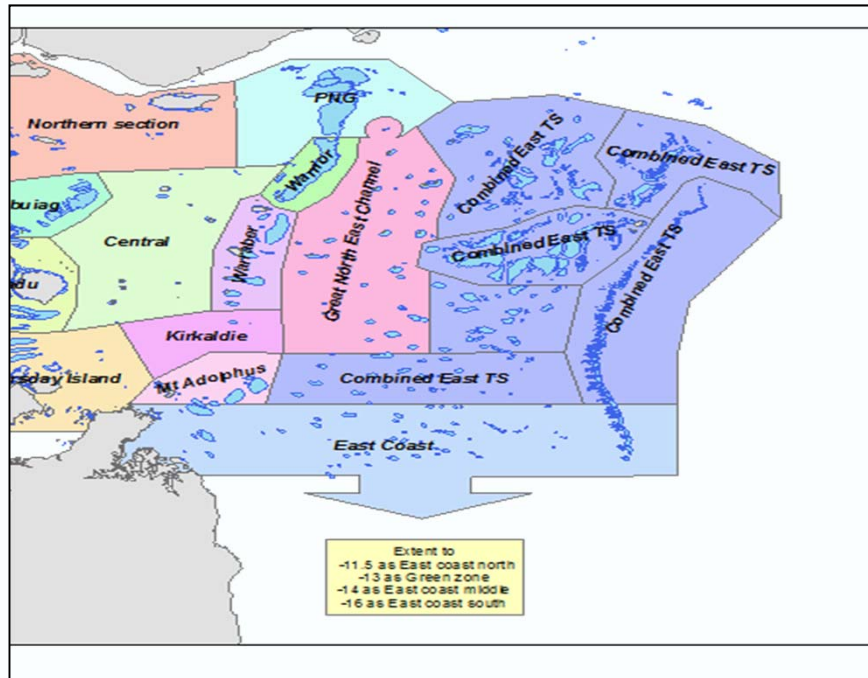
$$\begin{aligned} \text{CPUE} = & \text{Intercept} + \text{Year} + \text{Month} + \text{Area} \\ & + \text{Vessel} + \text{Fishing-Method} + \text{Proportion-Tails (in Catch)} \\ & + \text{Southern-Oscillation-Index} + \text{error} \end{aligned}$$

- Variance distribution of error term:

$$\text{Gamma, } \text{var}(y) \propto \mu^2$$

- Link function: *log*
- Alternative Models: Add Interaction effects
- Parameter estimates used to calculate annual index of abundance

Area Sizes

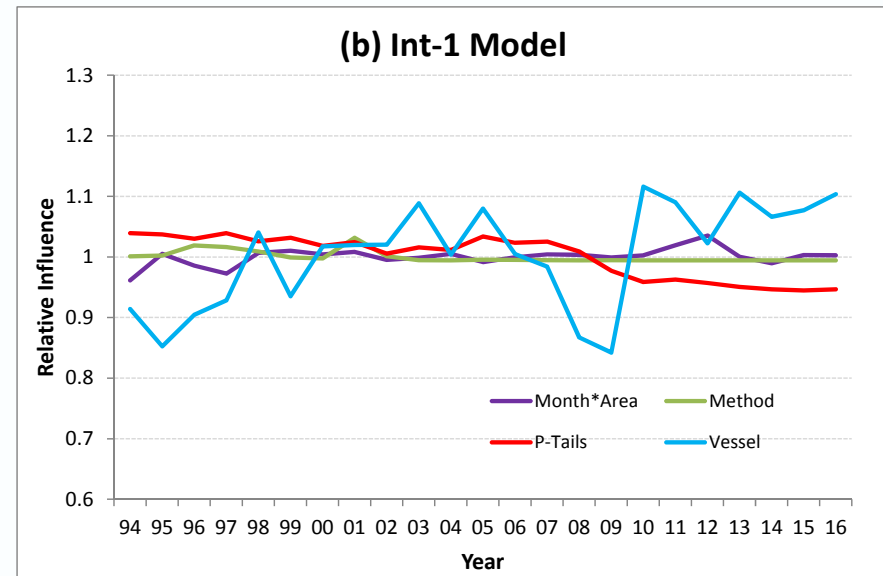
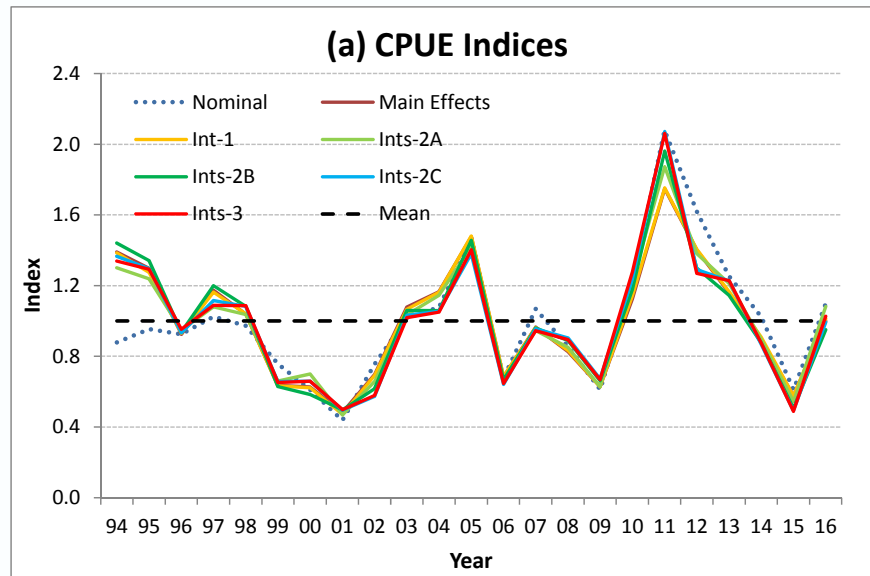


Area Type	101 Northern	102 Mabuiag	103 Badu	104 Thurs Is.	105 Central	106 Warrier	107 Warraber	108 Kirkaldie	109 Adolphus	110 East TS	Total
Total Area*	39.39 11.0%	12.21 3.4%	17.59 4.9%	27.77 7.7%	34.43 9.6%	6.69 1.9%	11.52 3.2%	10.8 3.0%	8.8 2.4%	190.17 52.9%	359.37 100%
Fished Sqs [#]	22.23 12.0%	11.47 6.2%	12.40 6.7%	21.70 11.7%	25.36 13.7%	8.90 4.8%	10.01 5.4%	8.20 4.4%	6.90 3.7%	57.84 31.3%	185.00 100%

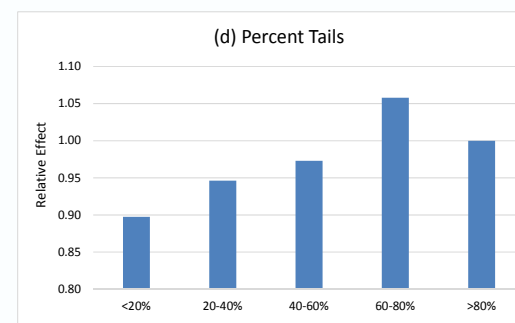
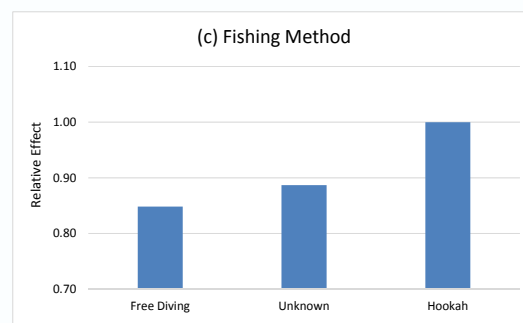
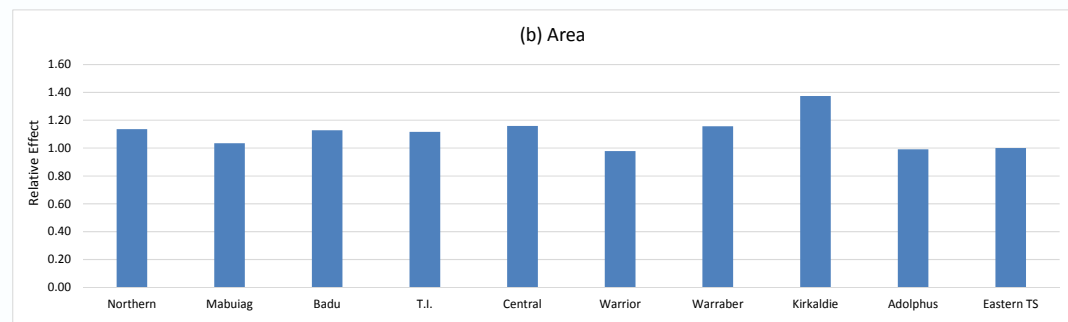
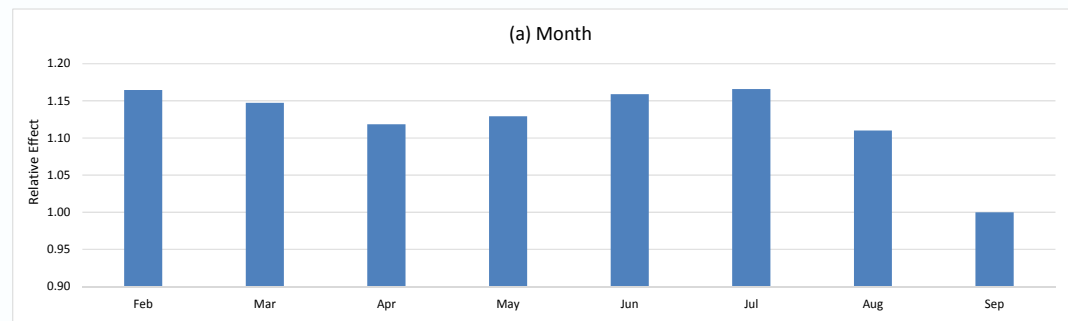
* hectares x 10,000

[#] Number of 0.1x0.1-degree squares

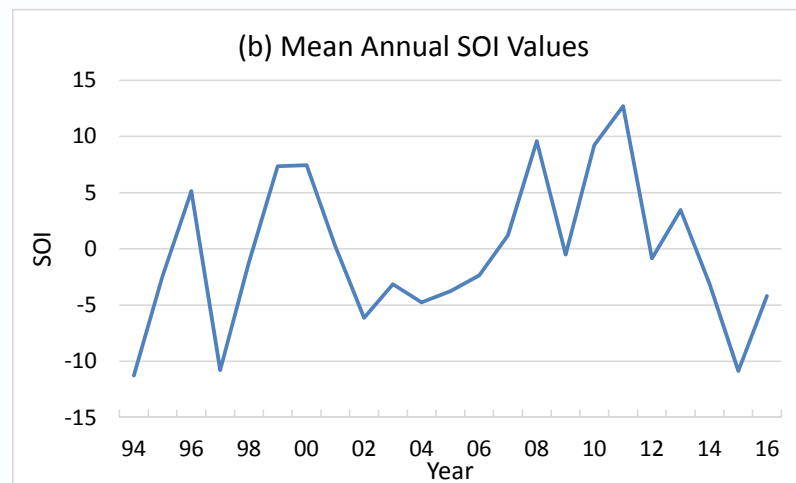
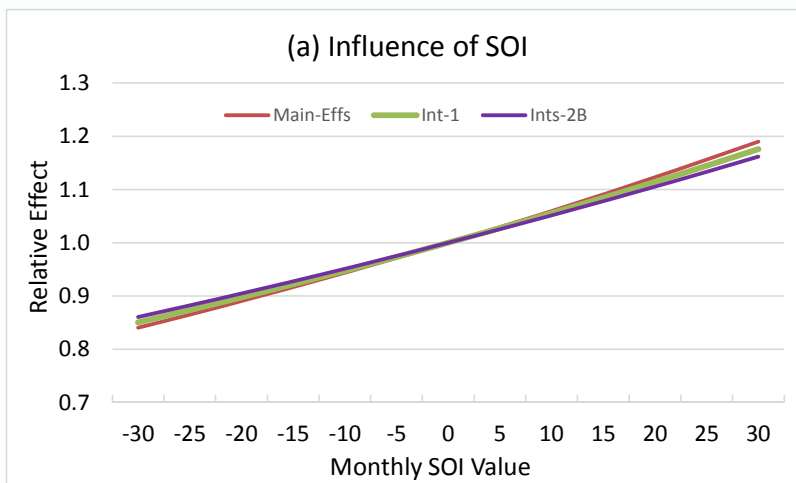
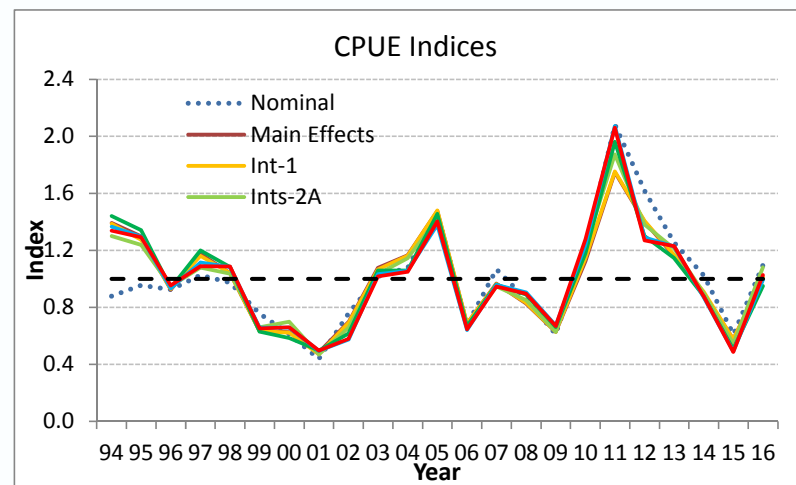
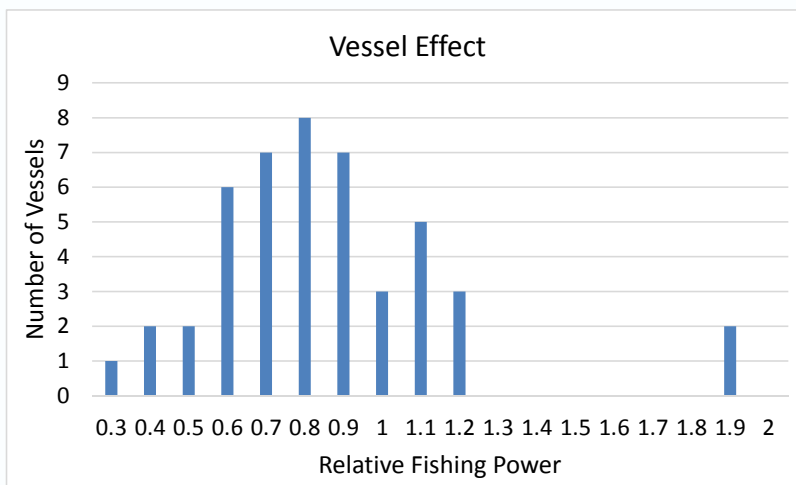
Results



Relative Effects: 1



Relative Effects: 2



Further work

- Investigate potential for effort creep
 - Is vessel a proxy for divers?
 - Increase in boat size (larger boats can search more)
 - Other changes in fishing gears leading to increased CPUE
- Investigate different spatial effects
- Incorporate effects of oceanographic conditions
 - El Nino / La Nina
 - Lunar influences

TIB-data

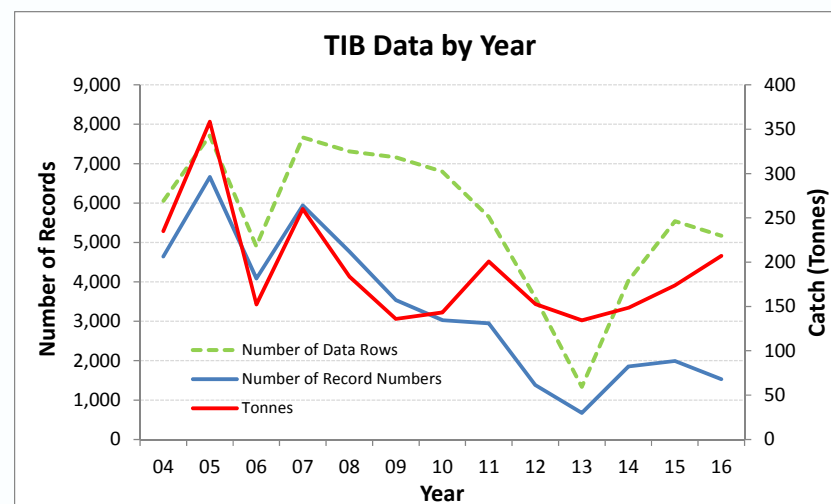
- Buyers and Processors Docket Book (TDB01) records the catch sold by fishers (known as sellers on the docket-book) at the end of a fishing trip.
- This information can be used to estimate an overall CPUE for the trip: weight of lobsters caught per days-fished
- However, due to the finer-scale nature of the catch and effort information, the use of the TVH logbook data has been preferred for constructing abundance indices for this fishery.
- Nevertheless, in recent year there has been interest as to whether the data recorded on the TIB docket-book can also be used for this purpose.

TIB-data - 2

- There are a number of issues with the docket-book system which create problems estimating the total catch and effort in the TIB fishery
 - 1. completion of the docket-book is only voluntary;
 - 2. catches recorded in the docket-book can also be reported elsewhere;
 - 3. processors can also record catches in the docket-book.
- Given the duplication of catch information, several filters need to be applied to this data to remove these duplicates.
- Considerable effort has gone into understanding the nature of both the docket-book and logbook data so as to identify the catch records that should be assigned to the TIB fishery

TIB: Annual Summary

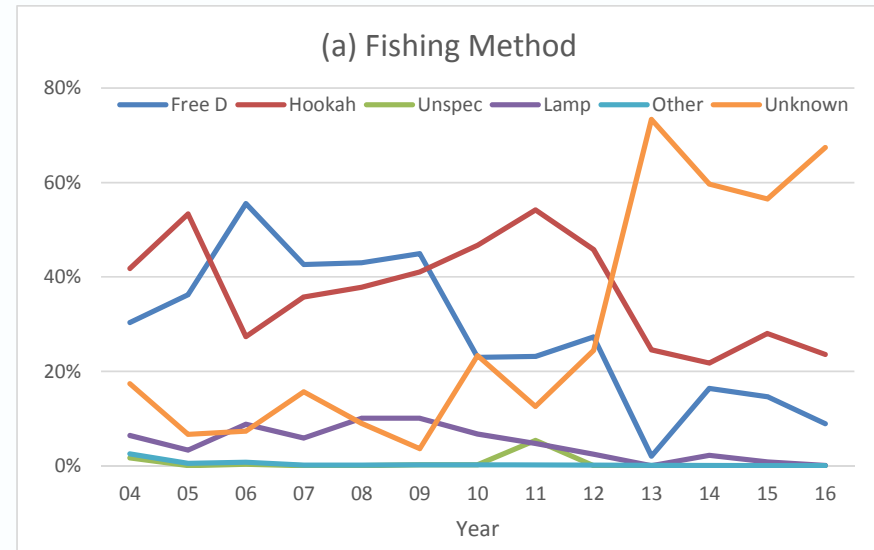
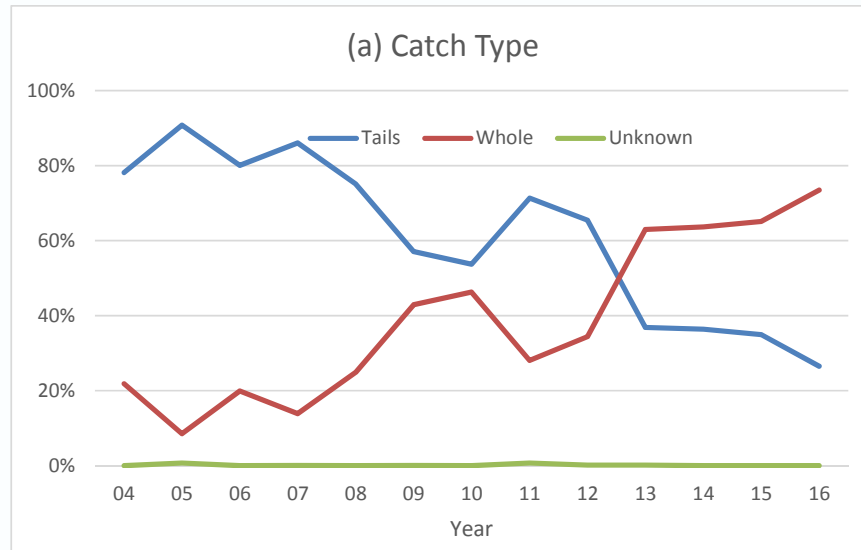
Year	Catch Records	Unique Record-Nos	Catch	
			(kg)	Tonnes
2004	6,057	4,643	234,933	235
2005	7,715	6,664	358,474	358
2006	4,907	4,084	152,259	152
2007	7,663	5,938	260,011	260
2008	7,314	4,769	183,948	184
2009	7,159	3,540	135,898	136
2010	6,798	3,029	143,319	143
2011	5,648	2,950	200,691	201
2012	3,593	1,379	152,859	153
2013	1,336	675	134,212	134
2014	4,029	1,852	148,538	149
2015	5,540	1,991	173,873	174
2016	5,171	1,528	207,074	207
Total	72,930	43,042	2,486,089	2,486



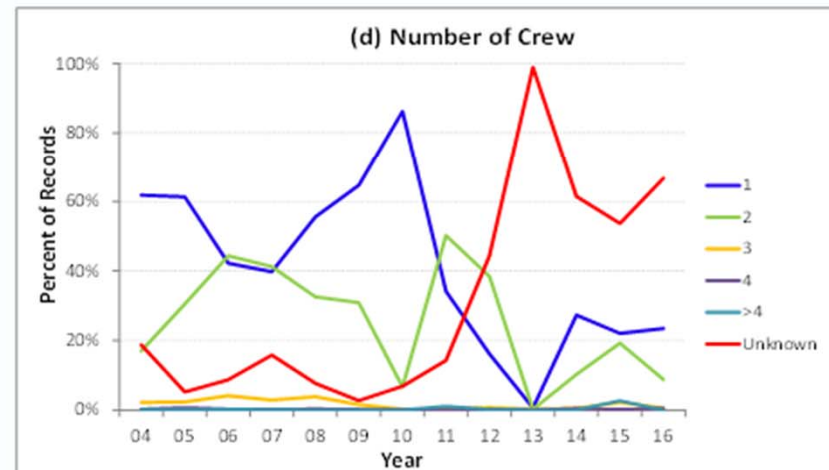
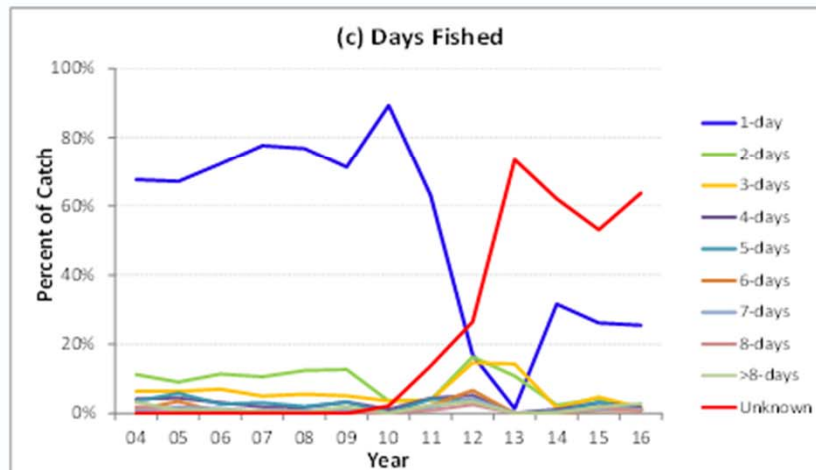
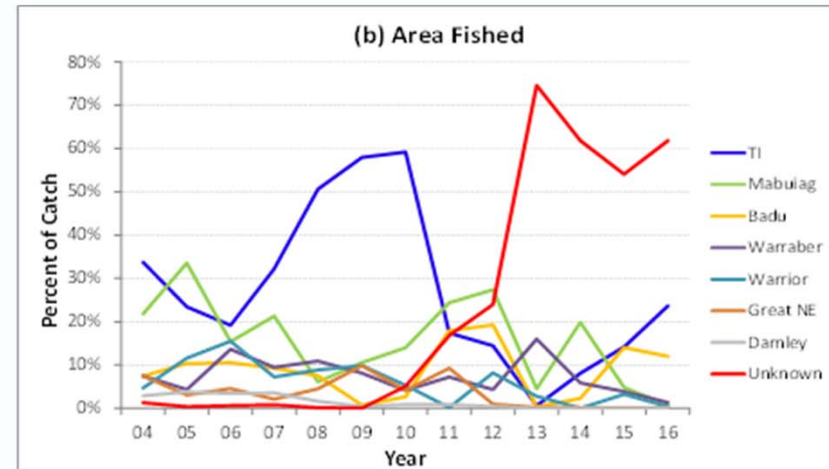
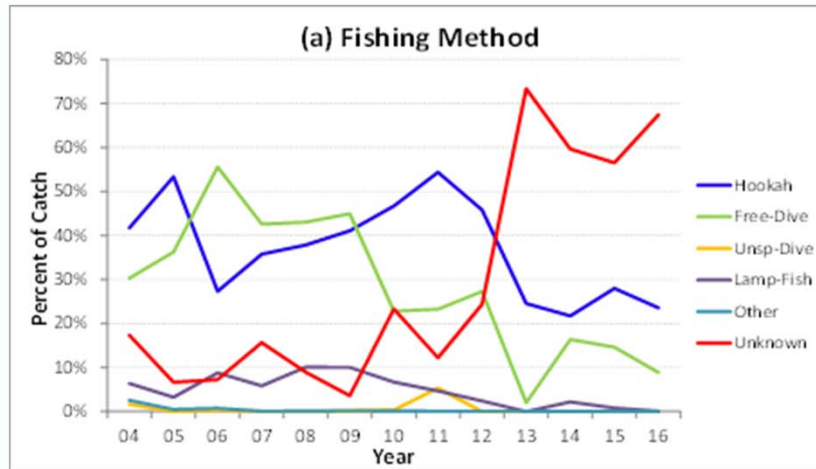
Area	Area-Name	N-recs	%	Catch	%
9	Thursday Island	18083	42.01%	676,185	27.20%
0	Unknown	1848	4.29%	498,944	20.07%
7	Mabuiag	5832	13.5%	431,970	17.4%
8	Badu	4988	11.59%	231,713	9.32%
12	Warraber	3849	8.94%	176,282	7.09%
11	Warrior	2782	6.46%	155,249	6.24%
14	Great NE Channel	1566	3.64%	89,465	3.60%
13	Mt Adolphus	673	1.6%	52,614	2.1%
17	Cumberland	779	1.81%	42,662	1.72%
16	Darnley	1211	2.81%	42,272	1.70%
10	Central	621	1.44%	29,126	1.17%
3	Northern Section	219	0.51%	23,120	0.93%
15	South East	117	0.27%	10,897	0.44%
1	Turu Cay	226	0.53%	10,753	0.43%
21	GBR	155	0.36%	10,083	0.41%
2	Deliverance Island	29	0.07%	1,348	0.05%
4	Bramble Cay	12	0.03%	1,091	0.04%
6	Western	21	0.05%	1,078	0.04%
18	Seven Reefs	8	0.02%	475	0.02%
20	Barrier	10	0.02%	345	0.01%
5	Anchor Cay	9	0.02%	238	0.01%
19	Don Cay	5	0.01%	179	0.01%
Total		43,043	1	2,486,089	1

METHOD	N-recs	%	Catch	%
HOOKAH DIVING	17872	41.5%	955,085	38.4%
FREE DIVING	16461	38.2%	685,594	27.6%
UNKNOWN	3790	8.8%	656,422	26.4%
LAMP FISHING	3874	9.00%	114,876	4.62%
FREE DIVING-LAMP FISHING	305	0.71%	22,334	0.90%
FREE DIVING-HOOKAH DIVING	201	0.47%	19,752	0.79%
DIVING UNSPECIFIED	213	0.49%	15,879	0.64%
HANDLINING-FREE DIVING	141	0.33%	7,182	0.29%
HOOKAH DIVING-LAMP FISHING	26	0.06%	2,798	0.11%
TROLLING-FREE DIVING	44	0.102%	1,293	0.052%
UNKNOWN-HOOKAH DIVING	18	0.042%	968	0.039%
HANDLINING	30	0.070%	812	0.033%
HANDLINING-TROLLING-FREE DIVING	18	0.042%	561	0.023%
UNKNOWN-FREE DIVING	13	0.030%	419	0.017%
FREE DIVING-UNKNOWN	12	0.028%	659	0.027%
HOOKAH DIVING-UNKNOWN	3	0.007%	284	0.011%
FREE DIVING-HOOKAH DIVING-LAMP FISHING	3	0.007%	272	0.011%
UNKNOWN-LAMP FISHING	3	0.007%	49	0.002%
UNKNOWN-FREE DIVING-LAMP FISHING	3	0.007%	228	0.009%
TROLLING	3	0.007%	202	0.008%
LAMP FISHING-FREE DIVING	1	0.002%	53	0.002%
UNKNOWN-FREE DIVING-HOOKAH DIVING	1	0.002%	18	0.001%
TROLLING-DIVING UNSPECIFIED	2	0.005%	146	0.006%
HANDLINING-FREE DIVING-UNKNOWN	2	0.005%	30	0.001%
DIVING UNSPECIFIED-LAMP FISHING	1	0.002%	33	0.001%
HANDLINING-TROLLING	2	0.005%	22	0.001%
HANDLINING-DIVING UNSPECIFIED	1	0.002%	2	0.000%
ROD AND REELING-FREE DIVING	1	0.002%	30	0.001%
UNKNOWN-TROLLING-FREE DIVING	1	0.002%	74	0.003%
FREE DIVING-TROLLING	1	0.002%	13	0.001%
Total	43,046	1	2,486,089	1

Annual Trends



Unknown Fields



Selection of data

- The TIB data was aggregated over vessel-symbol, date and seller-name. Where the vessel-symbol or seller-name was null these fields were set to 'Unknown';
- Only data records having a unique Record-No were selected;
- A number of other filters were applied to remove possible data errors or where a field was null;
- This process resulted in 31,377 GLM records.

Year	N-Recs	CPUE
2004	3,208	35.3
2005	5,349	40.8
2006	3,196	27.1
2007	4,894	32.6
2008	3,736	32.0
2009	2,833	28.6
2010	2,041	36.1
2011	1,690	52.1
2012	683	47.0
2013	12	38.9
2014	1,246	26.3
2015	1,470	25.4
2016	1,019	35.4
Total	31,377	

Month	N-Recs	CPUE
1	2,211	31.9
2	4,261	39.3
3	5,121	40.2
4	3,718	38.3
5	3,734	36.3
6	3,345	36.0
7	3,155	33.2
8	2,108	31.9
9	1,551	29.5
10	27	24.5
11	6	23.7
12	2,140	28.1
Total	31,377	

Qtr	N-Recs	CPUE
1	11,593	38.3
2	10,797	36.9
3	6,814	32.0
4	2,173	28.0
Total	31,377	

GLM-data

TIB-Area	GLM-Area	N-Recs
1	6	82
2	6	21
3	6	168
4	16	11
5	16	3
6	6	15
7	7	4,806
8	8	4,399
9	9	13,124
10	10	323
11	11	2,237
12	12	2,609
13	13	469
14	14	1,234
15	15	103
16	16	929
17	17	701
18	15	8
19	16	2
20	15	10
21	15	123
Total		31,377

GLM-Area	N-Recs	CPUE
6	286	47.5
7	4,806	43.4
8	4,399	30.9
9	13,124	34.2
10	323	40.2
11	2,237	42.9
12	2,609	25.6
13	469	55.0
14	1,234	37.1
15	244	46.6
16	945	31.1
17	701	37.2
Total	31,377	

%-Tails	N-Recs	CPUE
<20%	5,266	23.3
20-40%	2,282	36.9
40-60%	2,158	37.1
60-80%	2,017	39.8
>80%	19,654	38.4
Total	31,377	

Method	N-Recs	CPUE
FREE	14,965	32.3
HOKAH	15,914	38.7
MIXED	498	43.5
Total	31,377	

Days	N-Recs	CPUE
1	26,767	36.4
2	2,177	33.6
3	1,041	29.2
4	514	30.3
5	422	30.5
6	146	36.9
7	121	29.3
8	71	35.4
9	54	32.5
10	27	22.8
11	17	25.6
12	6	10.5
13	7	18.5
14	3	8.0
15	1	5.8
16	3	10.9
Total	31,377	

Analysis

- Defined catch rate as:

$$CPUE = \frac{\text{Weight of landed lobsters}}{\text{Number of days – fished}}$$

- Base model:

$$\begin{aligned} \text{Log}(CPUE) = & \text{Intercept} + \text{Year} + \text{Quarter} + \text{Area} + \text{Fishing-Method} \\ & + \text{Proportion-Tails (in Catch)} \\ & + \text{Southern-Oscillation-Index} + \text{error} \\ & / \text{distribution} = \text{gamma, link=log} \end{aligned}$$

- Alternative models with Qtr*Area effect and/or Seller effect (3 or more years and 30 or more records)
- The data coverage for many of the GLM-areas has been poor since 2012 with only four areas having a reasonable data coverage => the analysis was repeated where the above models were fitted only to the data for GLM-areas 7 (Mabuiag), 8 (Badu), 9 (Thursday Island) and 12 (Warraber)

Summary of Fitted Models

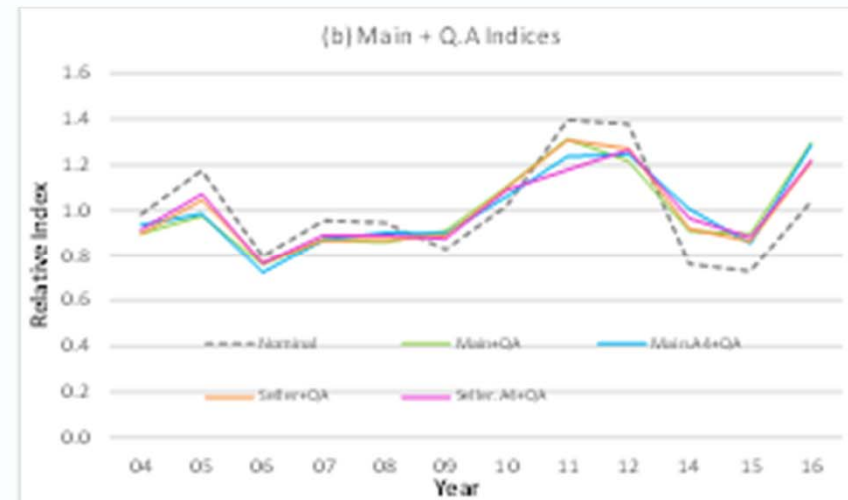
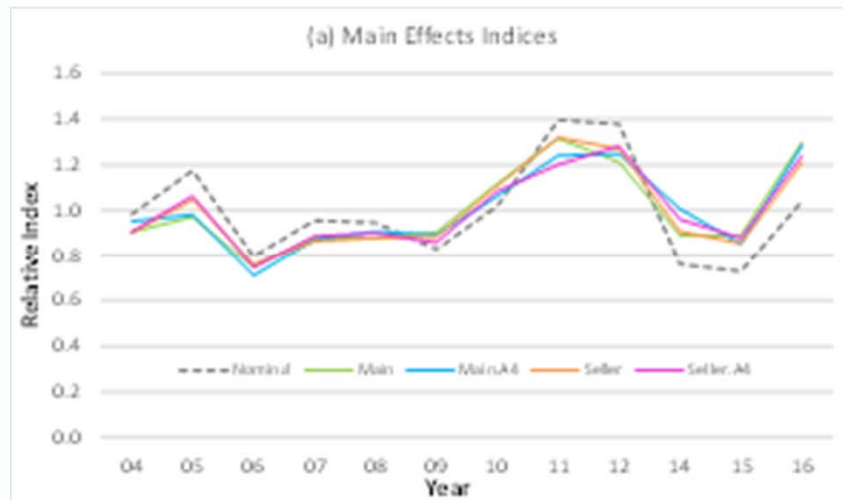
(a) All Areas

Model		Degree of Freedom	# Sellers Parameters	Records	AIC
1	Main Effects	34	0	31,016	282,216
2	Main Effects + Q.A	67	0	31,016	280,960
3	Model 1 + Seller-Name	267	234	25,848	229,582
4	Model 2 + Seller-Name	300	234	25,848	229,216

(b) Four Areas only

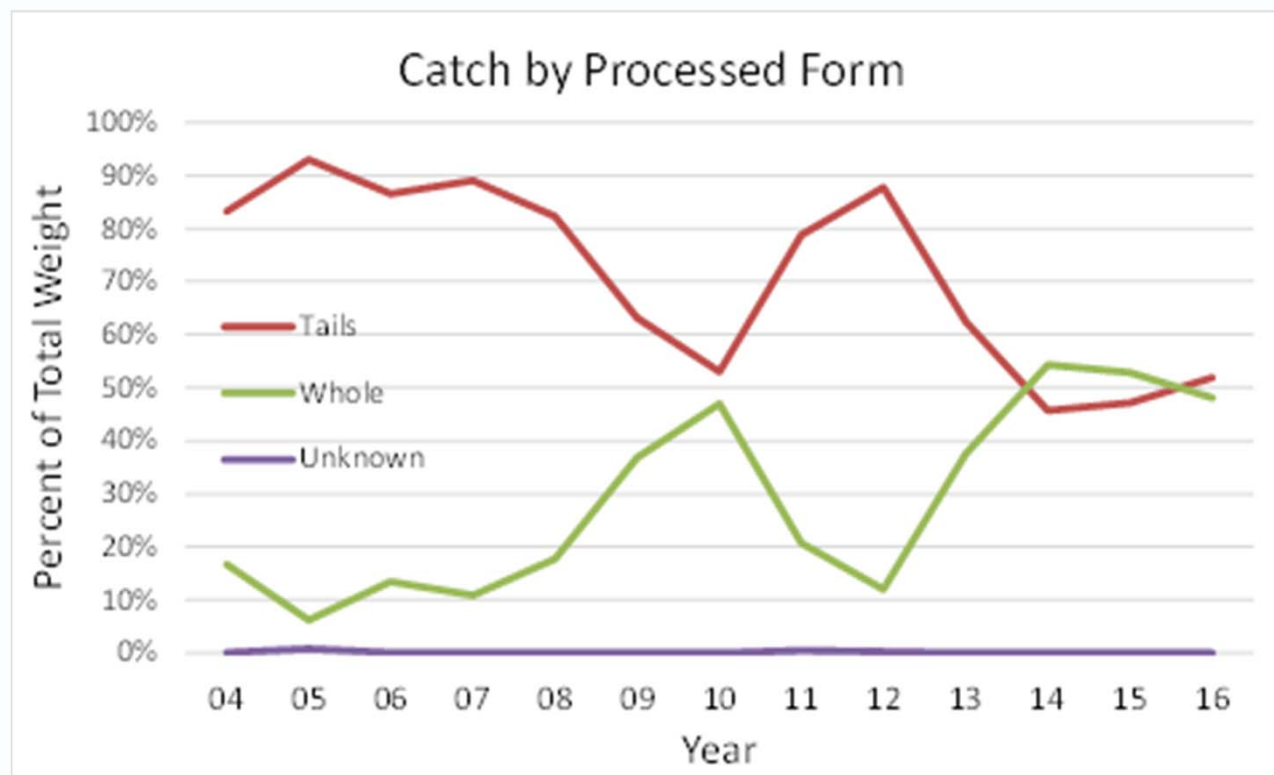
Model		Degree of Freedom	# Sellers Parameters	Records	AIC
1	Main Effects	26	0	24,655	219,930
2	Main Effects + Q.A	35	0	24,655	219,280
3	Model 1 + Seller-Name	199	174	19,841	172,334
4	Model 2 + Seller-Name	208	174	19,841	172,166

Annual Index

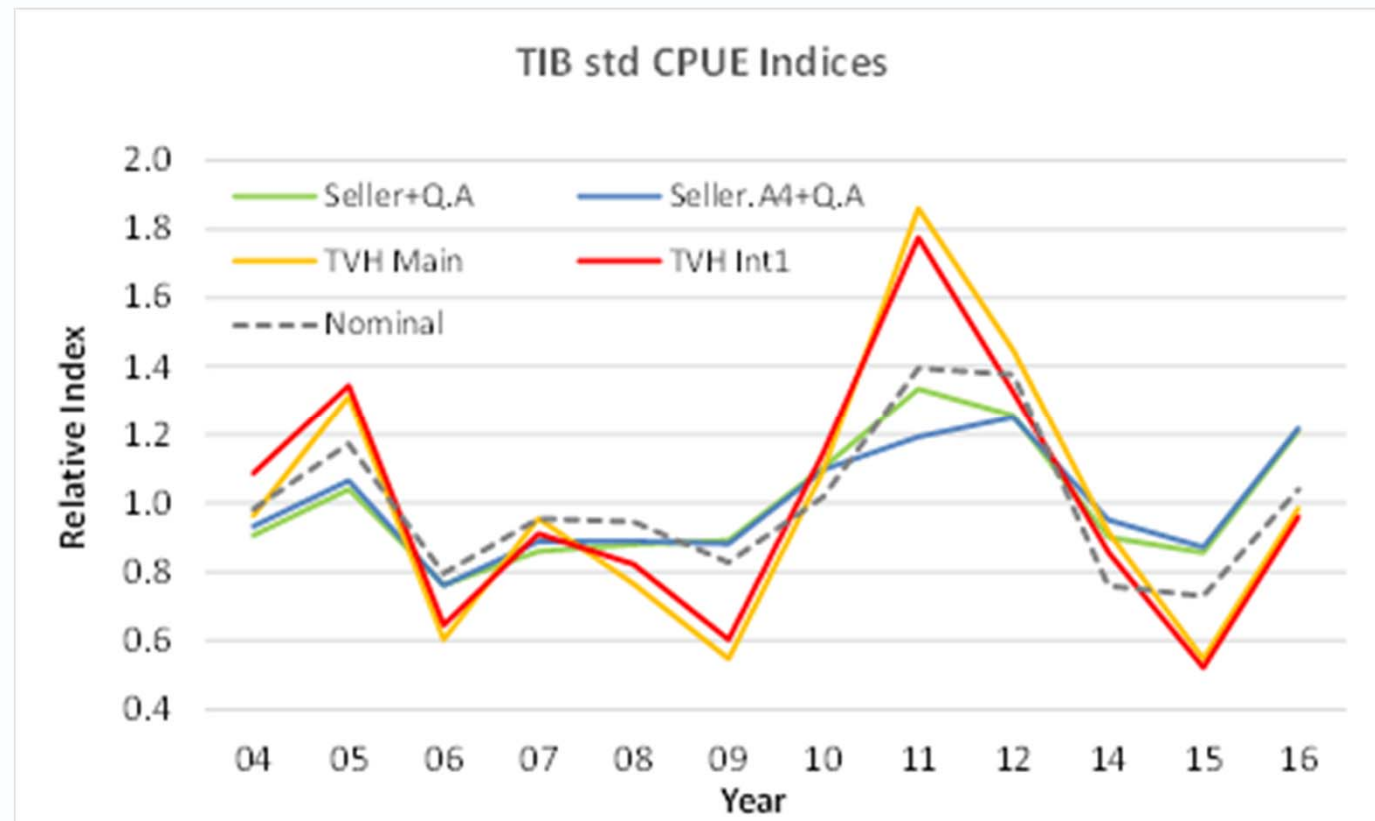


- There are a number of substantive differences between Nominal and Standardised Indices
- These changes are likely due to shifts in the percentage of the catch which are processed as tailed or whole lobsters.

Results



Comparison with TVH Indices



Further work

- The analyses presented here are first attempt to use TIB data to construct annual indices. However, need to:
 1. Better understand structure of docket-book data
 2. Explore alternative model structures
 3. Environmental influences
- There is also a need to improve the reporting of data in docket-books (especially having all fields completed).

Thank you

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