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Summary of logbook and observer data pertaining to the catch of blue sharks off eastern Australia

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Abstract

This document presents some summaries and initial analyses of logbook and observer data relating to the catch of blue sharks off eastern Australia. In particular, the following data sets were used: i) logbook, observer and size-sampling data pertaining to the Eastern Tuna and Billfish Fishery (ETBF) between 1996 and 2012 and ii) logbook and observer data pertaining to the Japanese longline fishery operating off eastern Australia between 1991 and 1997. Logbook reported catches of blue sharks in the ETBF varied between 1,978 and 14,115 with the large majority of these fish recorded as being discarded. A comparison of the logbook and observer data over the period 2003-11 indicated that the retention of blue sharks during the period 2003-11 was similar for both logbook and observer data, being around 10% and 11.5% respectively while the annual nominal catch rate of blue sharks was substantially higher according to observer data, averaging around 11.5 fish per 10,000 hooks compared to the logbook recorded average catch rate of 4.35 fish per 10,000 hooks. Between 1992 and 1996 the annual catch of blue sharks reported by Japanese longliners fishing off eastern Australia varied between 10,114 and 86,936 fish while the average annual nominal catch rate was 35.6 fish per 10,000 hooks. The higher catch rates compared to the Australian longliners appears to be due to differences between the spatial distribution of effort in relation to the distribution of blue sharks, with the majority of the Japanese effort between 1991 and 1995 being south of 40^{o}S where blue shark catch rates are highest. Estimates of possible levels of under-reporting of catches on logbooks in the ETBF indicated that actual catches may be around 180 percent higher than reported. Finally, some analyses to standardise catch rates to ascertain annual indices of resource availability indicated large trends over time which, if correct, may be reflective of substantial changes in the available of blue sharks off eastern Australia. These changes could be related to movements of fish in and out of the AFZ or alternatively changes in the size of the resource in response to trends in annual recruitment. Alternatively the index may be an unreliable measure of blue shark availability off eastern Australia and greater effort needs to be placed on reporting and understanding the factors which influence both catch rates and inter-annual changes in the availability of this species off eastern Australia (e.g. inter-annual variability in oceanographic conditions).

Summary of logbook and observer data pertaining to the catch of blue sharks off eastern Australia

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1. Introduction

This document presents some summaries and initial analyses of logbook and observer data relating to the catch of blue sharks off eastern Australia. The following five data sets were used:

1. Logbook data pertaining to the Eastern Tuna and Billfish Fishery (ETBF)
2. Observer data from the Eastern Tuna and Billfish Fishery
3. Logbook data pertaining to the Japanese longline fishery operating off eastern Australia
4. Observer data pertaining to the Japanese longline fishery operating off eastern Australia
5. Size sampling from the Eastern Tuna and Billfish Fishery

Estimates of possible levels of unreporting of catches on logbooks and some analyses of catch rates to ascertain annual indices of resource availability are also presented.

2. Logbook data pertaining to the Eastern Tuna and Billfish Fishery

Logbooks used in the ETBF require that fishers record the number of hooks deployed for each longline set together with the number of fish caught and retained and the number of fish caught and discarded. However, despite logbook data being available since the late 1980s, catch data pertaining to blue sharks has only being recorded since 1996. A summary of the total annual effort and catch of blue sharks recorded in ETBF logbooks since this year is shown in Table 1 and Figures 1 -2.

There was a large increase in longline fishing effort in the ETBF between 1996 and 2003 when the number of hooks deployed increased from 4.4 million to 12.7 million. Despite this continuous increase in effort the number of blue shark recorded on logbook peaked in 1998 at 14115 fish before declining to 7706 fish in 2003. The practice of shark finning at sea (prohibiting the possession or landing of fins separate from carcasses) was banned in Australian waters in 2000 and it remains uncertain whether this ban had an influence on reported catches. Since 2003 there has been a steady decline in longline effort in the ETBF with the number of hooks deployed in 2011 and 2012 being around 6.7 million hooks. During this time the number of blue sharks in the catch has declined to around 2000 fish in 2008 before increasing to around 3500 in more recent years (averaging 3178 fish between 2007 and 2011).

For all years the majority of blue shark catch has been discarded with the annual percentage of fish retained and discarded averaging 15.2% and 82.8% respectively between 1996 and 2012. The nominal catch rate of blue sharks has also varied from 16.35 fish per 10,000 hooks in 1997 to 2.44 fish per 10,000 hooks in 2008, averaging 4.03 fish per 10,000 hooks over period from 2007 to 2011.

Table 1. Annual summary of logbook data pertaining to deployed effort and the catch of blue sharks in the ETBF. Note: CPUE = number of fish per 10,000 hooks.

YEAR	SETS	HOOKS	RETAIN	DISCARD	TOTAL	%_RET	%_DIS	CPUE
1996	6377	4491369	1829	4969	6798	26.9%	73.1%	15.14
1997	8784	6199314	2907	7229	10136	28.7%	71.3%	16.35
1998	11450	9676864	2456	11659	14115	17.4%	82.6%	14.59
1999	11551	10227730	3644	6925	10569	34.5%	65.5%	10.33
2000	11051	9524918	797	2093	2890	27.6%	72.4%	3.03
2001	12546	11274740	852	4808	5660	15.1%	84.9%	5.02
2002	12867	11894691	795	7999	8794	9.0%	91.0%	7.39
2003	13227	12690383	336	7370	7706	4.4%	95.6%	6.07
2004	10676	10007351	583	4686	5269	11.1%	88.9%	5.27
2005	9118	8970972	244	4174	4418	5.5%	94.5%	4.92
2006	7688	8852411	273	2193	2466	11.1%	88.9%	2.79
2007	6845	8454082	268	1879	2147	12.5%	87.5%	2.54
2008	6416	8097722	171	1807	1978	8.6%	91.4%	2.44
2009	6633	8896032	656	2769	3425	19.2%	80.8%	3.85
2010	5812	7883067	379	4441	4820	7.9%	92.1%	6.11
2011	5016	6779171	336	3183	3519	9.5%	90.5%	5.19
2012*	4699	6761675	331	3058	3389	9.8%	90.2%	5.01
Avg 07-11	6144	8022015	362	2816	3178	11.5%	88.5%	4.03

*Incomplete

Figure 1. Annual longline effort deployed in the ETBF and percentage of effort observed (note: observer data for 2012 is incomplete).

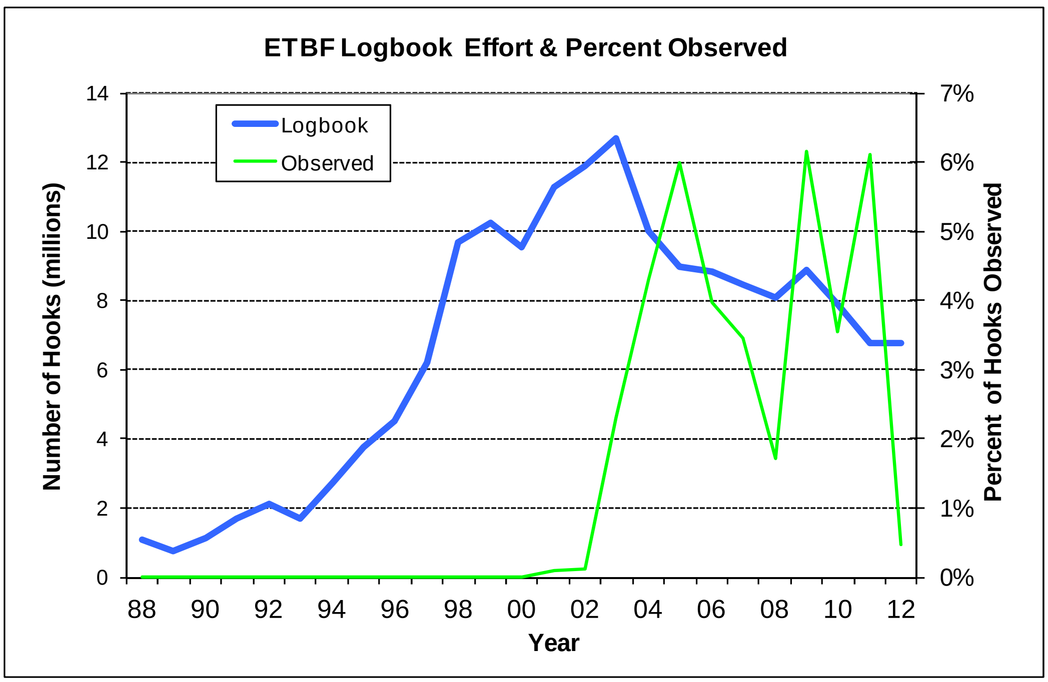


Figure 2. Annual catch of blue sharks recorded in ETBF logbooks.

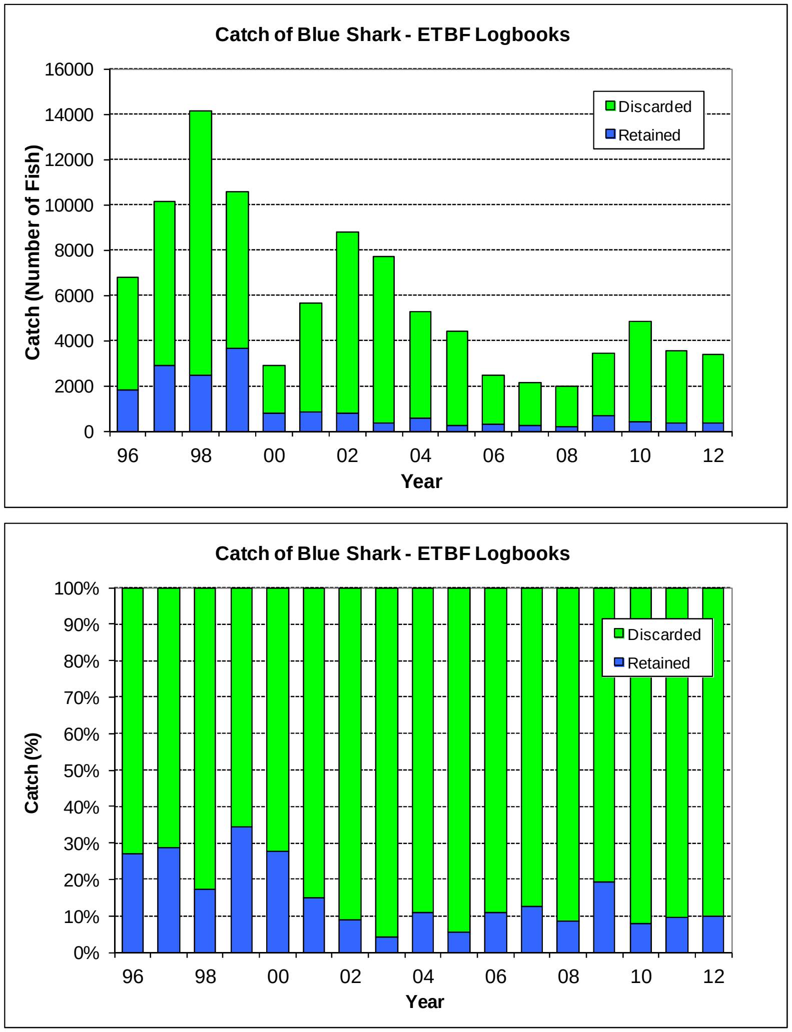


Figure 3. Annual catch of blue sharks observed in ETBF.

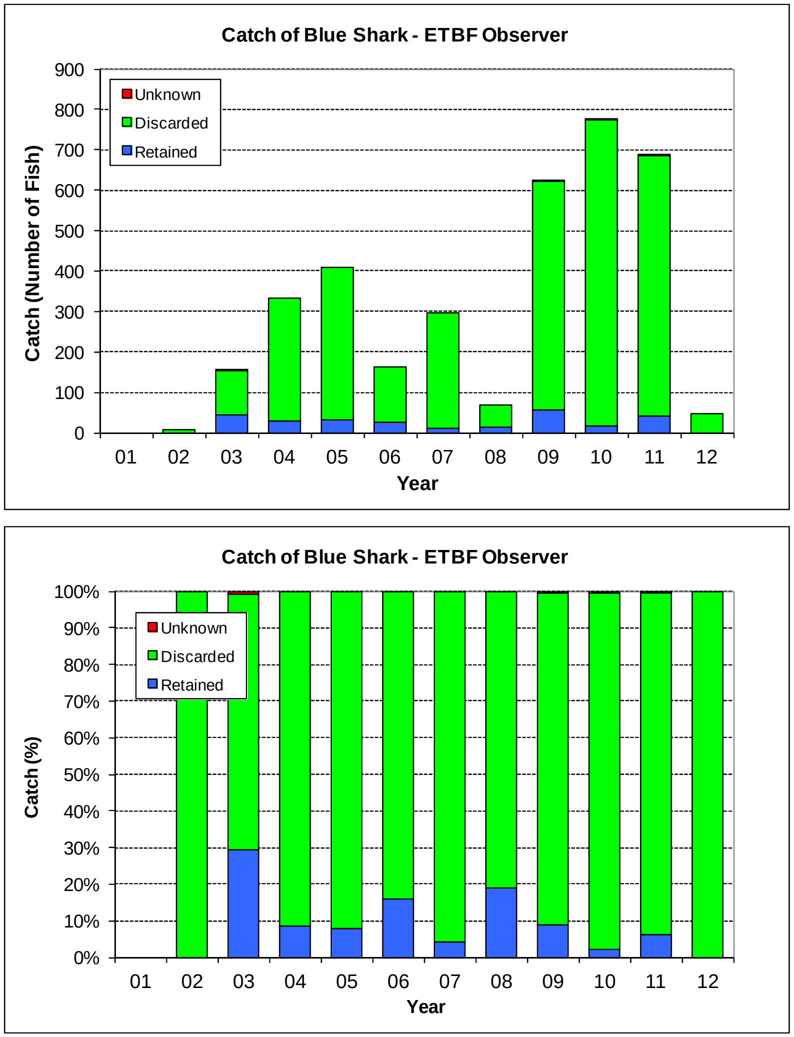
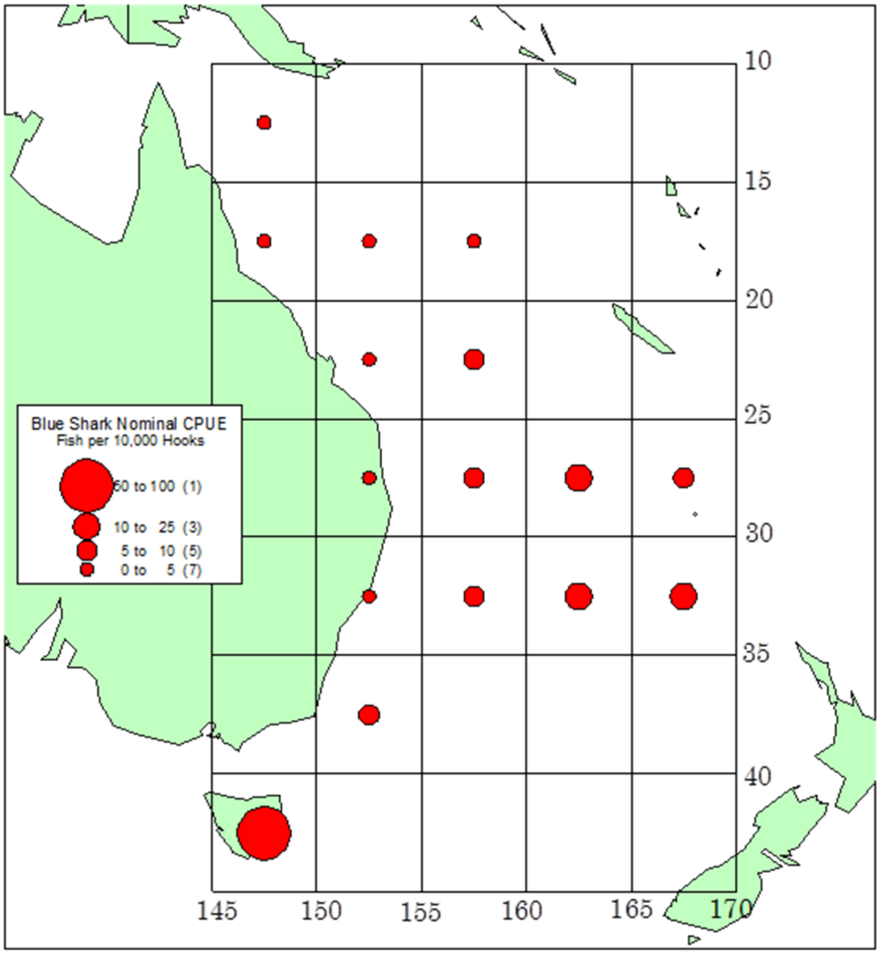


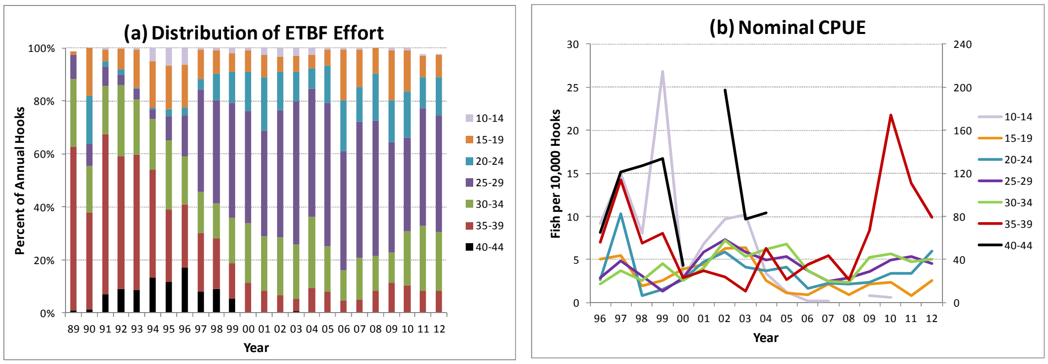
Figure 4. Nominal CPUE of blue sharks within each 5x5-degree area based on ETBF logbooks between 1996 and 2011.



The spatial distribution of nominal CPUE of blue shark in the ETBF is shown in Figure 4. A region of high catch rates is observed south of 40°S (>50 fish per 10,000 hooks) while north of this latitude catch rates are appreciably lower (generally <10 fish per 10,000 hooks). Catch rates closest to the coast between 150-155°E (0-5 fish per 10,000 hook) are also generally lower than those further offshore (10-25 fish per 10,000 hooks).

The spatially heterogeneous distribution of catch rates in the ETBF also helps to explain the three-fold decline in annual nominal CPUE observed in the fishery since 1996 as there has been a shift in the distribution of effort to regions having lower catch rates of blue shark. The annual distribution of ETBF longline effort within each 5-degree latitudinal band off eastern Australia is shown in Figure 5a whilst the corresponding nominal CPUE is shown in Figure 5b.Before 1995 the majority of longline effort in the ETBF was distributed south of 35°S while the percentage of annual effort south of 40°S (where blue shark CPUE is highest) peaked in 1996 at 17.2%. Although the percentage of total annual effort in this region declined after this time (being less than 1% since 2000) the number of hooks deployed south of 40°S nevertheless did not peak until 1998 when 866,000 hooks were deployed in this

Figure 5. (a) The annual distribution of longline effort within the ETBF within each 5-degree latitudinal band off eastern Australia, and (b) the corresponding nominal CPUE within each latitudinal band (Note, the CPUE for the band 40-44^{o}S is shown by the right-hand side axis). .



region. This declined to 535,000 hooks in 1999 and has generally been less than 50,000 hook since 2000 (and less than 4000 since 2005). Since 2000 the percentage of total annual effort south of 35^{o}S has also generally been less than 10% with a large proportion of the effort being in the region between 25-30^{o}S.

3. Observer data pertaining to ETBF longline operations

Observer data pertaining to longline vessels fishing in the ETBF exists for the years 2001 to 2012. Information on the number of observed hooks and the catch of blue sharks exists for 4306 sets, however the analysis of these data is limited to the 2889 sets for which the observed effort per set is 500 hooks or more. A summary of the total annual effort and catch of blue sharks for these sets is shown in Table 2 while the annual observer coverage rate represented by these sets (expressed as the percentage of total hooks deployed in the ETBF which were observed) is shown in Figure 1.

Observers also record the life-status, fate and sex of fish caught in the ETBF and a summary of these data for the 3826 blue sharks for which such data exists is provided

Table 2. Annual summary of observer data pertaining to deployed effort and the catch of blue sharks in the ETBF. Note: only includes sets where the observed effort per set was 500 hooks or more. CPUE = number of fish per 10,000 hooks.

YEAR	SETS	HOOKS	RETAIN	DISCARD	UNK	TOTAL	%RET	%DIS	%UNK	CPUE
2001	11	9800	0	0	0	0				
2002	18	14055	0	8	0	8	0.0%	100.0%	0.0%	5.69
2003	294	286310	45	101	46	192	23.4%	52.6%	24.0%	6.71
2004	433	429999	29	304	29	362	8.0%	84.0%	8.0%	8.42
2005	511	527960	32	377	32	441	7.3%	85.5%	7.3%	8.35
2006	343	349256	26	137	26	189	13.8%	72.5%	13.8%	5.41
2007	250	292371	12	284	12	308	3.9%	92.2%	3.9%	10.53
2008	102	140016	13	57	13	83	15.7%	68.7%	15.7%	5.93
2009	382	538336	54	556	57	667	8.1%	83.4%	8.5%	12.39
2010	217	279029	18	755	21	794	2.3%	95.1%	2.6%	28.46
2011	302	410966	42	623	44	709	5.9%	87.9%	6.2%	17.25
2012	26	31476	0	46	0	46	0.0%	100.0%	0.0%	14.61
Avg 07-11	251	332144	28	455	29	512	7.2%	85.4%	7.4%	14.91

Table 3. Summary of information recorded by observers on the life-status, fate and sex of fish of blue sharks caught by longliners operating in the ETBF. (%-k represents the percentage of all fish in each category for which the relevant status of fish is known).

LIFE-STATUS	NFISH	%	NFISH-k	%-k
Alive & vigorous	2491	65.1%	2491	65.5%
Alive & sluggish	713	18.6%	713	18.7%
Alive, just	185	4.8%	185	4.9%
Dead & flexible	342	8.9%	342	9.0%
Dead & in rigour	47	1.2%	47	1.2%
Dead & damaged	26	0.7%	26	0.7%
Unknown	22	0.6%		
	3826	100%	3804	100%
FATE	NFISH	%	NFISH-k	%-k
Escaped - bitten off	200	5.2%	200	5.2%
Flicked free without landing	676	17.7%	676	17.7%
Cut free without landing	1817	47.5%	1817	47.6%
Landed and discarded	687	18.0%	687	18.0%
Landed, tagged and returned to sea alive	130	3.4%	130	3.4%
Retained	307	8.0%	307	8.0%
Unknown	9	0.2%		
	3826	100%	3817	100%
SEX	NFISH	%	NFISH-k	%-k
Male	387	10.1%	387	44.0%
Female	384	10.0%	384	43.7%
Indeterminate	108	2.8%	108	12.3%
Unknown	574	15.0%		
Not recorded	2373	62.0%		
	3826	100%	879	100%

in Table 3. Of the 3804 blue sharks where the retrieved life-status is known, most (around 89%) were retrieved alive, with nearly 66% retrieved in an alive and vigorous state. Of the 3817 sharks with a known fate, 70.6% escaped or were cut or flicked free before being landed while a further 18% were landed and then discarded and only 8% were retained. Finally, of the879 blue sharks for which a sex was recorded, 44% were male, 44% were female and 12% were indeterminate.

A comparison of the logbook and observer data over the period 2003-11 highlights the following:

1. The retention of blue sharks during the period 2003-11 was similar for both logbook and observer data, being around 10% and 11.5% respectively.
2. The annual nominal catch rate of blue sharks during the period 2003-11 was substantially higher according to observer data, averaging around 11.5 fish per 10,000 hooks compared to the logbook recorded average catch rate of 4.35 fish per 10,000 hooks.

4. Logbook data pertaining to Japanese longline operations

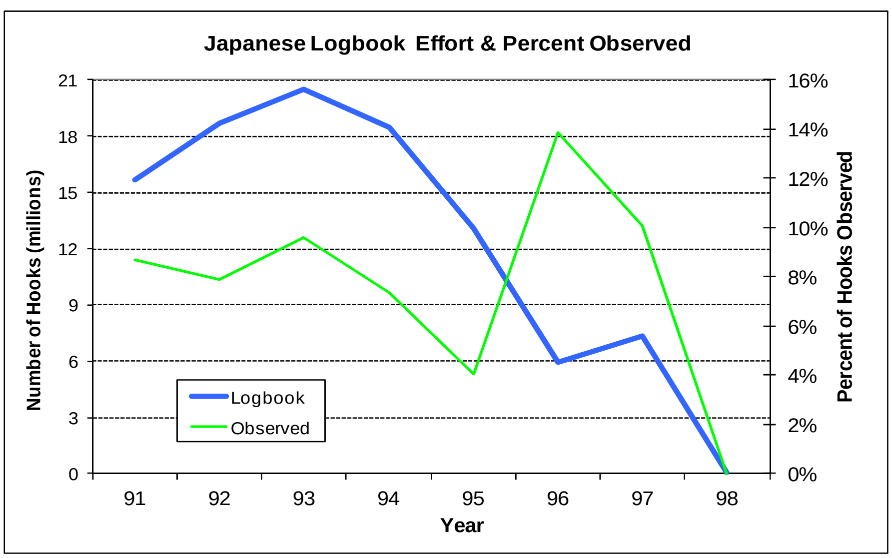
With the declaration of the 200 mile exclusive economic zone by the Australia Government in 1979, Japanese vessels licensed to fish within the Australian Fishing Zone (AFZ) were required to complete and return logbooks to Australia. These logbooks recorded the number of hooks deployed for each longline set together with the number of fish caught. However, while the collection of logbook data commenced in 1979 no blue sharks are recorded in the catch data before 1991. With the expansion of the domestic fleet in the ETBF Japanese longliners were excluded from fishing within the AFZ in 1998 after which time the collection of logbook data from these vessels ceased. As such, the analysis of these data are limited to the years between 1991 and 1998. (Note, Japanese vessels also fished outside the AFZ during this period and the logbook data held by Australia contains information relating to some of these sets – most likely for those vessels which fished both inside and outside the AFZ).

On closer examination it was found the no effort data was recorded for 2309 of the 34,661 sets between 1991and 1998 whilst the number of hooks was recorded as between 1 and 999 for a further 49 sets. As Japanese longliners usually deploy more than 1000 hooks it was not known whether the effort associated with these latter records was in error and as such, together with the sets with no recorded effort, they were not included in the following analysis (note, these records contained a catch of

Table 4. Annual summary of logbook data pertaining to deployed effort and the catch of blue sharks by Japanese longliners operating off eastern Australia. Note: CPUE = number of fish per 10,000 hooks.

YEAR	NSETS	HOOKS	CATCH	DISCARD	TOTAL	CPUE
1991	5346	15684442	5632	0	5632	
1992	6196	18701572	74618	0	74618	39.90
1993	6699	20517567	86936	0	86936	42.37
1994	5839	18464715	85558	0	85558	46.34
1995	4107	13069038	42529	0	42529	32.54
1996	1748	5918376	5557	4557	10114	17.09
1997	2305	7320689	0	0	0	
1998	27	78340	0	0	0	
Avg 92-96	4918	15334254	59040		59951	35.65

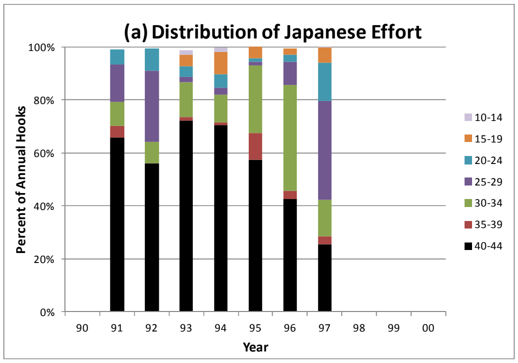
Figure 6. Annual longline effort recorded in logbooks for Japanese longline vessels operating off eastern Australia and percentage of effort observed by Australian observers.

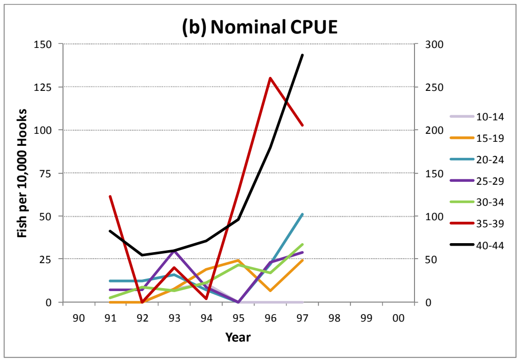


10 blue sharks). A summary of the total annual effort and catch of blue sharks recorded on the remaining 32,267 sets between 1991 and 1998 is shown in Table 4 and Figure 6.

Noting that the catch data for 1991 is obviously incomplete, and the catch for 1997 and 1998 not recorded, the following description is limited to the five years between 1992 and 1996. During this period, the number of blue sharks caught by Japanese longliners fishing within the AFZ (and partially outside) varied between 10114 and 86936 fish, averaging 59040 fish. Whether or not the catch recorded in these logbooks also includes fish discarded remains uncertain. Furthermore, although the database from which the data was extracted contains a field for recording discards there are no catches recorded in this field except for 1996 when 4557 blue sharks were recorded as being discarded. The average annual nominal catch rate during the period 1992-96 was 35.6 fish per 10,000 hooks, which is more than double the catch rate for ETBF vessels around the same period. Again this difference is likely to be due to differences between these fleets in the spatial distribution of effort in relation to the distribution of blue sharks, with the majority of the Japanese effort between 1991 and 1995 (average of 68%) being south of 40°S where blue shark catch rates are highest (c.f. Figure 7).

Figure 7. (a) The annual distribution of Japanese longline effort within each 5-degree latitudinal band off eastern Australia, and (b) the corresponding nominal CPUE within each latitudinal band (Note, the CPUE for the band 40-44°S is shown by the right-hand side axis).





5. Observer data pertaining to Japanese longline operations

Observer data pertaining to Japanese longline operations off eastern Australia exists for the years 1980 to 1997. However, information on the number of observed hooks and the catch of blue sharks only exists for the years 1991 to 1997 so the analysis of these data are limited to these years alone. Of the 3801 observed fishing sets for these years, no effort is recorded for 136 sets (with an associated catch of 112 blue sharks) and the effort is between 1 and 999 hooks for a further 81 sets (with an associated catch of 25 blue sharks). As with the logbook data, it remains unknown whether the observed effort recorded for these sets is in error and so the analysis of these data is limited to the 3584 sets for which the observed effort is 1000 hooks or more. A summary of the total annual effort and catch of blue sharks for these sets is shown in Table 5 and Figure 6. The proportion of blue sharks observed retained over

Table 5. Annual summary of logbook data pertaining to deployed effort and the catch of blue sharks by Japanese longliners operating off eastern Australia. Note: CPUE = number of fish per 10,000 hooks

YEAR	NSETS	HOOKS	RETAIN	DISCARD	UNK	TOTAL	%RET	%DIS	%UNK	
1991	638	1360337	8	27	8068	8103	0.1%	0.3%	99.6%	59.57
1992	657	1475928	610	4407	50	5067	12.0%	87.0%	1.0%	34.33
1993	866	1967335	929	8451	59	9439	9.8%	89.5%	0.6%	47.98
1994	577	1359011	703	6507	109	7319	9.6%	88.9%	1.5%	53.86
1995	237	528857	624	3305	1	3930	15.9%	84.1%	0.0%	74.31
1996	331	821779	719	6580	85	7384	9.7%	89.1%	1.2%	89.85
1997	300	736922	1666	5629	119	7414	22.5%	75.9%	1.6%	100.61
1998	0	0								
Avg 92-97	495	1148305	875	5813	71	6759	13.3%	85.8%	1.0%	66.82

the six years between 1992 and 1997 averaged 13.4%, which is similar to that observed in the ETBF (11.5%), whilst the mean catch rate during this period of 66.8 fish per 10,000 hooks is again significantly higher than that observed in the ETBF after 2000.

The information recorded by observers on the life-status, fate and sex of fish caught by Japanese longliners is provided in Table 6. Of the 49142 sharks where the retrieved life-status is known, most (around 87%) were retrieved alive, which is similar to that observed in the ETBF (89%). However, a smaller proportion were

Table 6. Summary of information recorded by observers on the life-status, fate and sex of fish of blue sharks caught by Japanese longline vessels operating off eastern Australia.

LIFE-STATUS	NFISH	%	NFISH-k	%-k
Alive & vigorous	21469	43.7%	21469	43.7%
Alive & sluggish	8638	17.6%	8638	17.6%
Alive, just	4033	8.2%	4033	8.2%
Alive, no details	8791	17.9%	8791	17.9%
Dead & flexible	3767	7.7%	3767	7.7%
Dead & in rigour	916	1.9%	916	1.9%
Dead & damaged	344	0.7%	344	0.7%
Dead, no details	1184	2.4%	1184	2.4%
	49142	100%	49142	100%

FATE	NFISH	%	NFISH-k	%-k
Cut or flicked free without landing	8634	20.9%	8634	20.9%
Landed and returned to sea dead	15731	38.1%	15731	38.1%
Landed and returned to sea just alive	1650	4.0%	1650	4.0%
Landed and returned to sea alive	9702	23.5%	9702	23.5%
Discarded - no reason given	20	0.0%	20	0.0%
Tagged and returned to sea alive	1	0.0%	1	0.0%
Retained	5532	13.4%	5532	13.4%
Unknown	12	0.0%		
	41282	100%	41270	100%

SEX	NFISH	%	NFISH-k	%-k
Male	12050	25.6%	12050	32.2%
Female	24486	52.0%	24486	65.5%
Indeterminate	859	1.8%	859	2.3%
Unknown or Unexamined	9667	20.5%		
	47062	100%	37395	100%

observed to be in a live and vigorous state (44% compared to 66% in the ETBF) most likely due to the longer deployment times of the Japanese longlines. Of the 41282 sharks with a known fate most were landed and then discarded (66%) whilst a further 21% were cut or flicked free before being landed; 13% were retained. Finally, of the 47062 sharks for which a sex was recorded, about twice as many females were observed than males (66% and 32% respectively) while 2.3% were indeterminate.

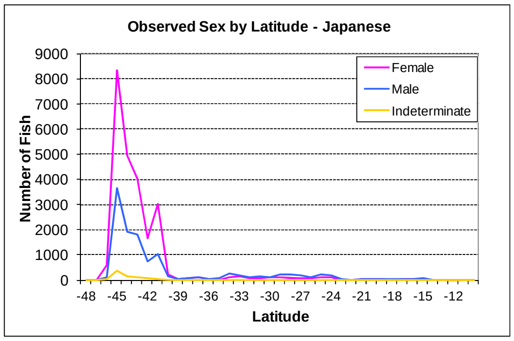
6. Observed Sex by Latitude

A listing of the observed number of blue shark by latitude and identified sex is provided for both the ETBF and Japanese longliners in Table 7 and Figure 8 while the proportion of blue sharks identified as female in each sample is shown by latitude in Figure 9.

Table 7. Listing of the observed number of blue shark by latitude and identified sex by fleet. (Indeter = Indeterminate)

	Japanese Longline			ETBF Longline		
Latitude	Female	Male	Indeter	Female	Male	Indeter
-10	0	0	0	0	0	0
-11	0	0	0	0	0	0
-12	1	1	0	0	0	0
-13	0	0	0	0	0	0
-14	2	6	3	0	0	0
-15	43	83	7	0	0	0
-16	41	35	13	0	0	0
-17	23	19	3	0	0	0
-18	12	37	0	0	0	0
-19	37	31	0	8	4	24
-20	49	33	1	12	0	2
-21	52	49	0	0	0	2
-22	17	15	0	0	0	0
-23	18	39	1	3	0	0
-24	93	167	10	34	21	2
-25	98	228	4	70	137	91
-26	64	119	4	32	97	103
-27	67	167	1	36	52	70
-28	90	204	2	81	47	92
-29	122	234	6	18	60	4
-30	105	129	2	2	51	0
-31	87	158	2	146	101	0
-32	61	120	4	17	248	3
-33	144	200	5	34	322	5
-34	106	254	1	59	162	0
-35	18	76	0	68	138	11
-36	22	38	0	233	188	21
-37	121	108	0	857	653	0
-38	90	58	0	146	85	0
-39	46	35	0	0	0	0
-40	223	134	0	0	0	0
-41	3042	1049	36	0	0	0
-42	1669	740	83	0	0	0
-43	4032	1813	107	0	0	0
-44	4958	1913	136	0	1	0
-45	8352	3634	382	0	0	0
-46	581	123	46	0	0	0
-47	0	0	0	0	0	0
-48	0	0	0	0	0	0
Total	24486	12049	859	1856	2367	430

Figure 8. Number of observed blue sharks by sex and latitude for each fleet.



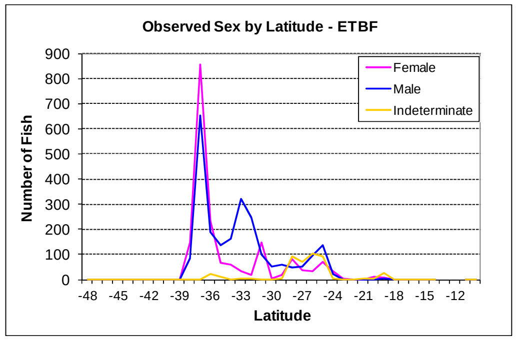
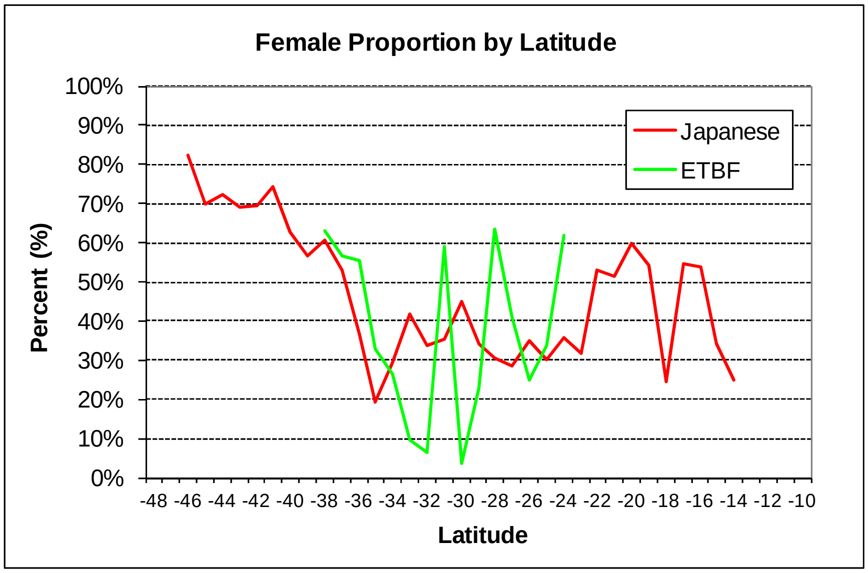


Figure 9. Proportion of blue sharks identified as females in each sample by latitude for each observed fleet.



7. Observed Weights and Lengths

The observer data also contains records of the individual weights and lengths of blue sharks caught by both ETBF vessels and Japanese longliners off eastern Australia. A summary of the length data collected for blue sharks is provided in Table 8 whilst a summary of weight data collected is provided in Table 9. In total there 1686 length measurements from the ETBF and 33068 length and 11115 weight measurements from Japanese longliners. However, the length data contains several records which are not standard as they usually relate to billfish (designated by BF).

A histogram of these size data where there is sufficient data is shown in Figure 10. The average length of blue sharks caught by the Japanese fleet (Lower-jaw to caudal fork, LCF=131cm and Total-Length=148cm) was smaller than the average length of blue sharks caught by the Australian fleet (LCF=177cm and Total-Length=188cm) and is likely due to differences in the spatial distribution of fishing effort.

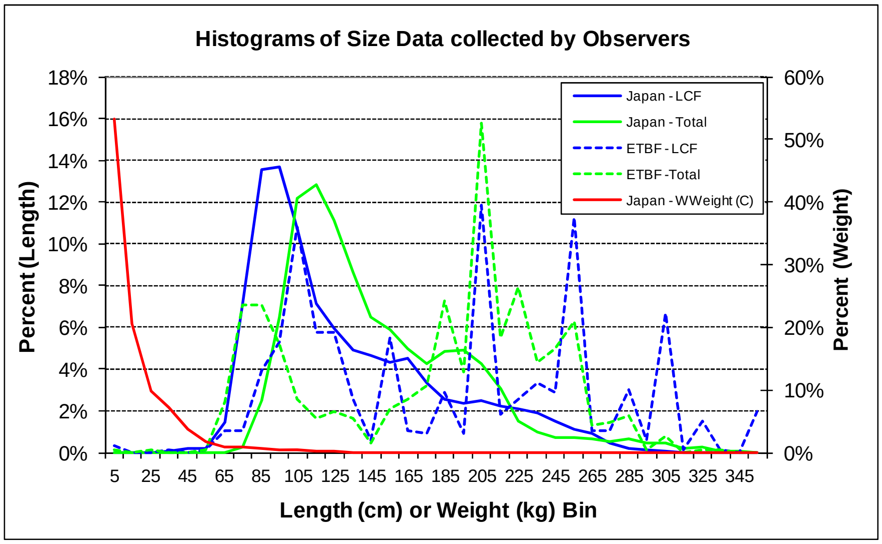
Table 8. Summary of length data for blue sharks collected by observers on ETBF vessels and Japanese longliners off eastern Australia.

FLEET	LENGTH TYPE	NFISH	AVG_LEN
ETBF	Length-to-caudal fork	621	176.6
	Lower jaw to caudal fork (BF)	60	164.8
	Standard Length	22	187.5
	Total	660	187.5
	Partial length	313	58.4
	Unknown	10	232.6
Japanese	Length-to-caudal fork	23326	130.7
	Lower jaw to caudal fork (BF)	1	256
	Orbit to caudal fork (BF)	3	109.7
	Standard Length	26	103.6
	Total	9691	147.9
	Unknown	21	141.2

Table 9. Summary of whole (WWT) and dressed (DWT) weight data for blue sharks collected by observers on ETBF vessels and Japanese longliners off eastern Australia.

FLEET	TYPE	WEIGHT TYPE	NFISH	AVG_WWT	AVG_DWT
JAPAN	WHOLE	Composite measurement	176	66.8	
	ONLY	Measured whole weight	1180	15.1	
		Measured whole weight	103	10.3	
		Not recorded	4209	14.9	
	DRESSED	Fins and fillets retained	2127		29.8
	ONLY	Filleted	409		29.4
		Fins only	174		9.8
		Fins kept and trunked	2176		21.6
		Gilled and gutted	21		42.8
		Whole - tail	8		16.0
		Trunked	500		21.4
		Not recorded	32		20.6

Figure 10. Size histograms of blue sharks caught by ETBF vessels and Japanese longliners operating off eastern Australia. (Note, LCF = Length-to-caudal fork length, Total = Total length and WWeight (C) = Composite Whole Weight).



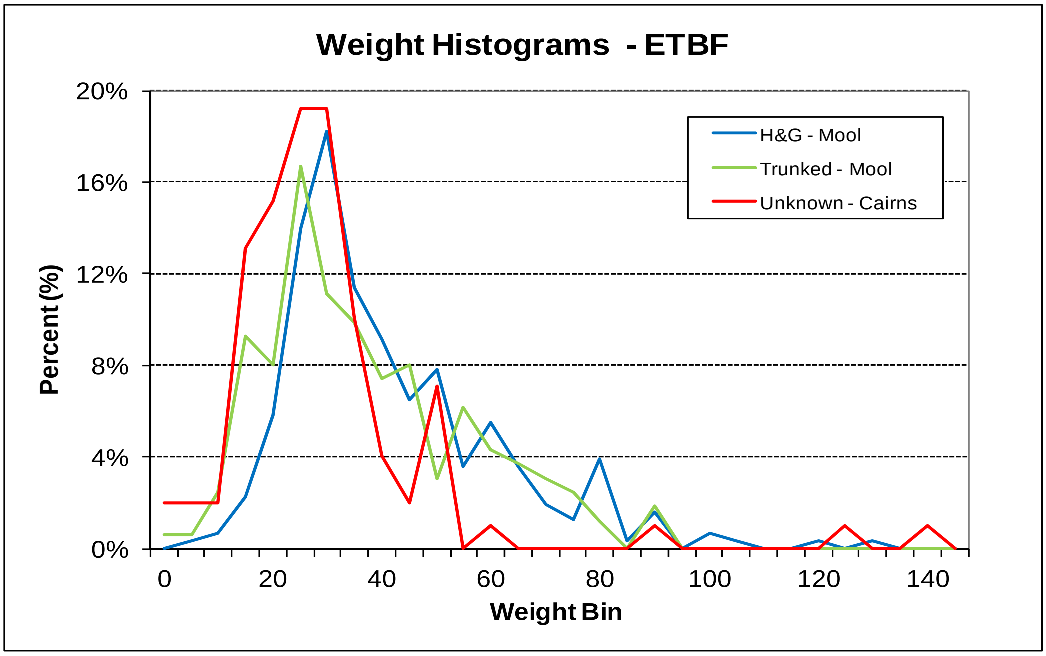
8. ETBF Size Sampling

A large-scale size monitoring program to collect the individual weights of fish landed and weighed at processors in the ETBF has been undertaken since mid-1997. Whilst primarily aimed at the principal catch species, size data has also been collected for a range of non-target species including blue sharks. The number of blue sharks sampled by sampling area and weight-category is shown in Table 10. Histograms of sampled weights (binned within 5kg weight classes) for those areas and weight-categories where 99 or more fish have been sampled are also shown in Figure 11.

Table 10. Number of blue sharks sampled in the ETBF by sampling area and weight-category.

AREA	H-G	Trunked	Whole	Unknown	Total
Cairns				99	99
Mooloolaba	307	162	31		500
Brisbane				2	2
NSW North Coast	6				6
Total	313	162	31	101	607

Figure 11. Histograms of individual weights of blue sharks sampled in the ETBF (binned within 5kg weight classes) for those areas and weight-categories where more than 100 fish have been sampled.



9. Comparison of Logbook and Observer data

As noted earlier, the nominal catch rates of blue-sharks based on observer reports are higher than those reported in logbooks. If the observed sets can be considered a random sample across the fishery then this would indicate that the catch of blue-sharks is under-reported in the logbooks. However, for a number of reasons the ETBF observer program has not been random across the fishery. This can be seen in Table

11 which lists the total number of sets reported in logbooks within each 5x5-degree region of the fishery over the years 2003-11 and the corresponding number of observed sets. If the observed sets where random across the fishery then the percent of total sets observed (i.e. the coverage rate) within each five-degree region over this period would be similar. However this is seen not to be the case with the observer coverage rate within each area ranging from less than 1% to as high as 16.7%. If the catch of blue-sharks were higher in those regions with a high observed coverage rate then that may explain the higher nominal catch rate across all observed sets. As such a more detailed analysis of the two datasets is required to see if the observer reported catch rates are similar or different to those reported on the logbooks.

The distribution of the total number of observed sets within each five-degree area between 2003 and 2011 is shown in Figure 12a while the distribution of the nominal catch rate of blue-sharks based on logbooks over the same period is shown in Figure 12b. The eight 5x5-degree areas where the number of observed sets was greater than 100 were chosen for further analysis. Referring to Table 10 for their locations, the eight selected 5x5-degree areas were (2903, 3003, 3004, 3005, 3105, 3205, 3006 and 3007). However, as the observed CPUE in area 2903 was always zero this area was subsequently excluded from further analysis. Time-series of quarterly logbook-

Table 11. Number of logbook reported and observed sets (N-Sets) within each 5x5-degree region of the ETBF. The column N-Ones provides the number of 1x1-degree areas over which the data were collected.

			LOGBOOK		OBSERVED		Percent
FIVE	Latitude	Longitude	N-Ones	N-Sets	N-Ones	N-Sets	Observed
2802	-12.5	142.5	4	154			0.00%
2902	-12.5	147.5	16	1,295	3	12	0.93%
3002	-12.5	152.5	5	8			0.00%
3102	-12.5	157.5	3	8			0.00%
2903	-17.5	147.5	18	7,799	10	265	3.40%
3003	-17.5	152.5	23	2,544	9	119	4.68%
3103	-17.5	157.5	15	766	5	27	3.52%
3004	-22.5	152.5	12	5,564	9	251	4.51%
3104	-22.5	157.5	18	2,468	10	99	4.01%
3005	-27.5	152.5	11	14,172	12	578	4.08%
3105	-27.5	157.5	25	14,002	25	450	3.21%
3205	-27.5	162.5	23	3,056	14	135	4.42%
3305	-27.5	167.5	19	493	4	16	3.25%
3405	-27.5	172.5	2	8			0.00%
3006	-32.5	152.5	16	9,647	16	976	10.12%
3106	-32.5	157.5	25	1,747	16	60	3.43%
3206	-32.5	162.5	25	1,014	14	31	3.06%
3306	-32.5	167.5	19	577	6	47	8.15%
3406	-32.5	172.5	3	13			0.00%
2907	-37.5	147.5	4	26			0.00%
3007	-37.5	152.5	18	5,819	18	729	12.53%
3107	-37.5	157.5	9	12	2	2	16.67%
3207	-37.5	162.5	3	8			0.00%
3307	-37.5	167.5	1	1			0.00%
2909	-47.5	147.5	1	3			0.00%
2908	-42.5	147.5	11	108			0.00%
3008	-42.5	152.5	1	1			0.00%
				71,313		3,797	5.32%

Figure 12a. Total number of ETBF sets observed within each 5x5-degree area between 2001 and 2011.

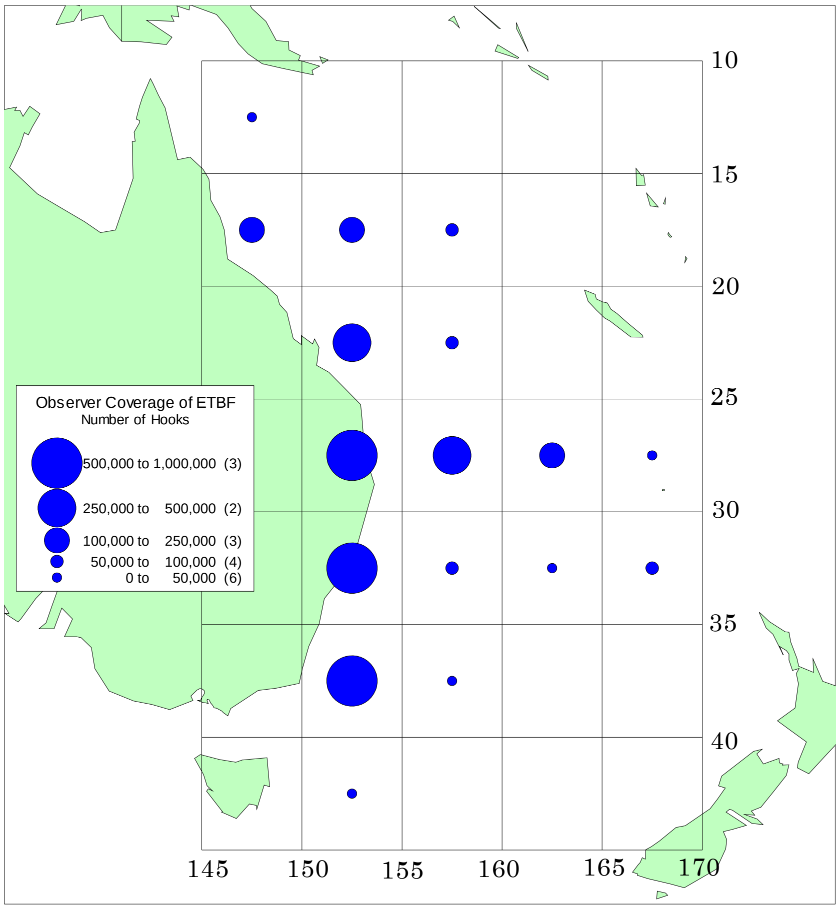
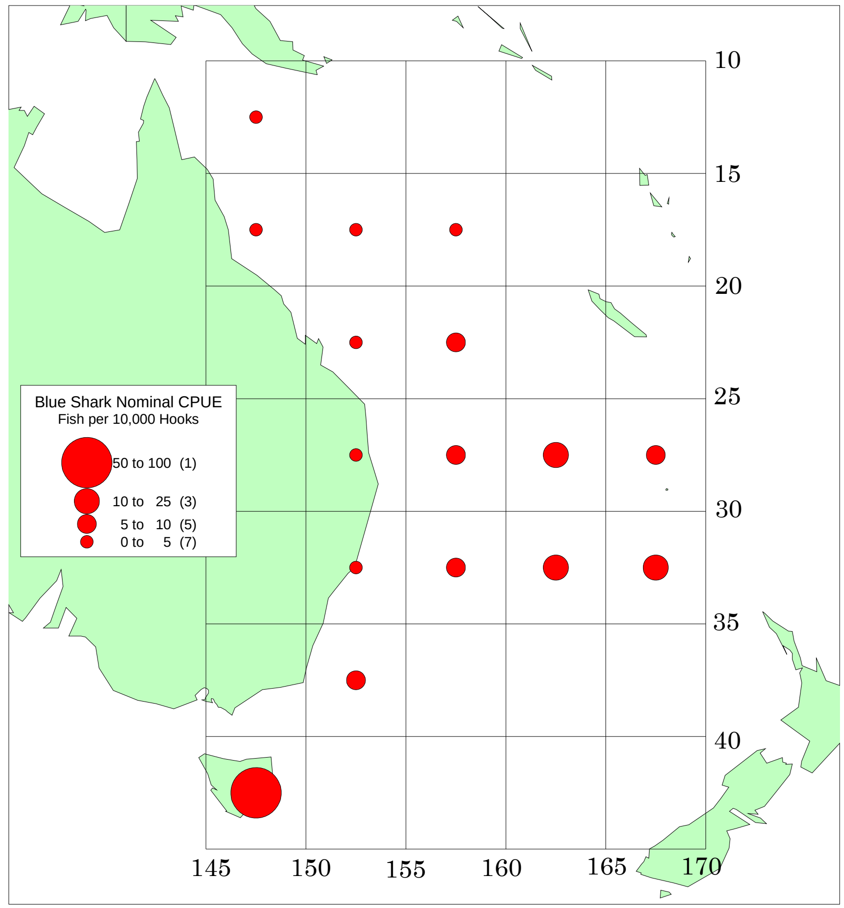


Figure 12b. Nominal CPUE of blue sharks within each 5x5-degree area based on ETBF logbooks between 1995 and 2010.



reported CPUE and observer-reported CPUE within the three areas having the highest observer coverage are shown in Figure 13a. Two features are of note. First, the observed CPUE in some quarters is anomalously high. For example, for area 3007 and quarter 3 in 2010 the observed CPUE is 226 fish per 10,000 hooks. Second, there are a number of quarters where the observed CPUE is zero while the logbook CPUE is non-zero (as seen for the first two quarters shown for area 3005). In both instances these outliners are most likely due to the small sample (i.e. number of observed hooks). For example, in areas 3007 and 3006 during quarter 4 in 2008 only 700 and 2108 hooks were observed. When comparing logbook and observer reported catch rates one needs to be aware of how anomalously high or low values in the observer data due to a low coverage rate may influence the results. One can filter out quarters

Figure 13. Time-series of quarterly logbook-reported CPUE and observer-reported CPUE for three 5x5-degree areas of the ETBF. The plots on the left are for those quarters where the observed effort was greater than 1 hook while the plots on the right are for those quarters where the minimum observed effort was greater than, or equal to, 10,000 hooks.

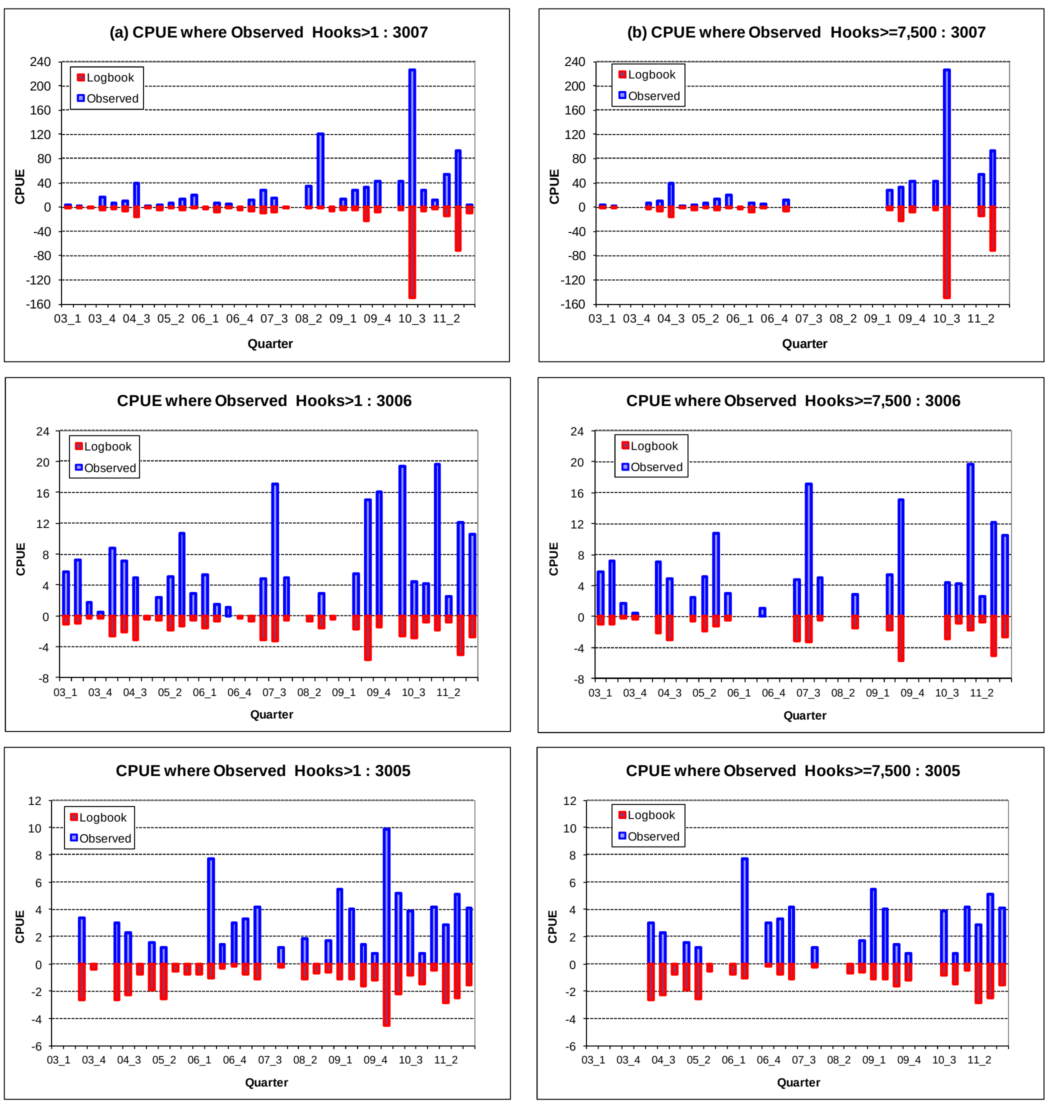
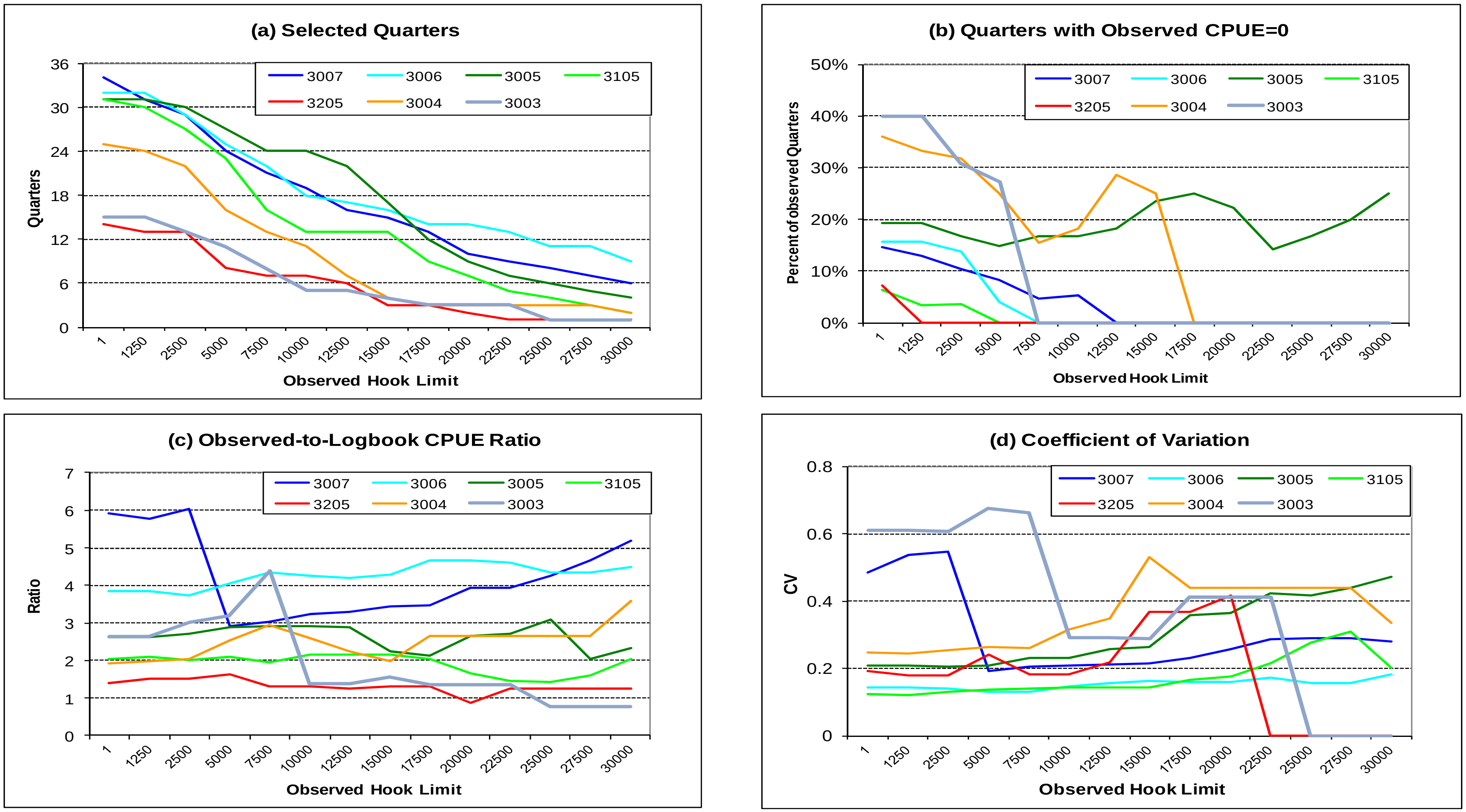


Figure 14. For each 5x5-degree area, (a) the number of quarters selected given a minimum observed effort, (b) the percent of quarters where the observed CPUE is zero, (c) the mean ratio of observed-to-logbook CPUE across the selected quarters, and (d) the associated coefficient of variation.



where the observed number of hooks is small by only including those quarters where the observed number of hooks is greater than some pre-determined minimum. However, there is obviously some balance required between selecting this minimum value and retaining a representative number of quarters within each area.

In order to explore this issue further, within each of the seven 5x5-degree areas selected above the following analyses were conducted:

1. The total logbook reported catch of blue sharks and effort (number of hooks deployed) together with the total observed reported catch and effort, both aggregated by quarter, were listed for each area over the years 2003-2011.
2. The nominal blue-shark catch rate was calculated for each quarter for which there was both logbook and observer data.
3. The ratio *R*=(Observed-CPUE)/(Logbook-CPUE) was calculated for those quarters for which there was both logbook and observer coverage. Note, three year-qtr-area strata were excluded where the Logbook-CPUE was zero.
4. The mean, standard-error and coefficient of variation of *R* was calculated over all quarters for which there was both logbook and observer coverage.
5. Steps 2-4 were repeated selecting only those quarters where the observed (and logbook) effort was greater than a minimum number of hooks between 1 and 30,000.

Plots of the number of quarters selected within each 5x5-degree area given a minimum observed effort, together with the percent of quarters where the observed CPUE is zero, the mean ratio of observed-to-logbook CPUE, and the coefficient of variation (CV) is shown in Figure 14.

As expected, the number of quarters selected shows a steady decrease as the minimum number of observed hooks in any quarter increases (c.f. Figure 14a). Across the seven areas effort was observed in 182 of the 308 year-qtr-area strata between 2003 and 2011, though only 25 strata exceed a minimum of 30,000 observed hooks. The number and percent of strata where the observed CPUE is zero (c.f. Figure 14b) also generally decreases with an increase in the minimum number of observed hooks: from 34 (19%) across all observed strata to 7 (7.2%) of the 97 strata where the minimum observed effort was 10,000 hooks and only 1 (2.4%) of the 41 strata where the minimum observed effort was 22,500 hooks.

As shown in Figure 14c, the ratio of the observed-to-logbook CPUE, *R*, is generally greater than 1 (indicating an under-reporting of the catch of blue-sharks on logbooks) for all areas and observed hook limits. This ratio also displays a degree of variation as the minimum number of observed hooks changes. For example, for the southern most area (3007) this ratio has its highest value of 6 when all quarters are selected and has its lowest value of 3 when the minimum number of observed hooks in each quarter is equal to 5000. The initial high value is influenced by the anomalously high catch rate of 226 identified previously. Over the range of values shown for the minimum observed effort the ratio of the maximum and minimum values of *R* for each area is generally small, being between 1.25 and 1.87 for all areas except areas 3007 and 3003 where this ratio is 2.06 and 5.72 respectively. The highest degree of variability is displayed by the northern area (3003) due to the small number of selected quarters as the observed hook limit increases (e.g. less than 5 quarters when hooks>12500) and the associated changes in the CV across these quarters (as shown in Figure 14d).

Given the variation in the value of *R* shown in Figure 14c one needs to ask which value provides the best estimate of the true ratio of the observed-to-logbook CPUE within each area. If one assumes that the level of under-reporting of the catch of blue-sharks on logbooks is similar across all areas of the fishery then the ratio *R* would be expected to be similar across the different areas. However, this does not seem to be the situation, and given that a different selection of fishers with possibly different reporting habits are likely to fish within different areas of the fishery then perhaps this assumption is not valid anyway.

Refining this assumption, one may assume that the reporting habits within an area may be similar over time so that the ratio of the observed-to-logbook CPUE will be similar across the different quarters within each area. If this assumption is valid, then one method of trying to identify the most appropriate estimate of *R* would be to look for the associated hook limit where the CV of the ratio across the different quarters within each area is a minimum. The associated minimum observed hooks where this occurs varies from 1250 for areas 3105 and 3004, 2500 for areas 3005 and 3205, 5000 for area 3007, 7500 for area 3006 and 15,000 for each 3003 (and 10,000 based on the weighted average, using the number of selected quarters. across these seven areas). Alternatively, one could use the minimum number of hooks in each area where the observed CPUE is always non-zero. This occurs for 1250 hooks for area 3025, 5000 for each 3015, 7500 for areas 3006, 3004 and 3003, and 12,500 for area 3007 (and the percentage of quarters over all areas where the zero CPUE has a minimum when the minimum number of observed hooks is 7500 hooks).

Table 12. Estimated ratio of the observed-to-logbook reported CPUE of blue sharks across six 5x5-degree areas of the ETBF under a range of hook-limit scenarios.

Scenario	3007	3006	3005	3105	3205	3004	3003
all quarters	5.92	3.84	2.63	2.04	1.41	1.92	2.63
min-CV	2.93	4.34	2.72	2.11	1.52	1.20	1.57
all CPUE>0	3.3	4.34	2.72	2.09	1.52	2.64	4.39
limit=5,500	2.93	4.04	2.89	2.09	1.64	2.54	3.20
limit=7,500	3.04	4.34	2.92	1.96	1.30	2.96	4.39
limit=10,000	3.24	4.25	2.92	2.15	1.30	2.59	1.37

The estimated ratio of the observed-to-logbook reported CPUE of blue sharks within each of the seven areas under a range of hook limits scenarios is given in Table 12: All scenarios indicate a heterogeneous level of reporting across of the fishery, with the level of under-reporting appearing to be highest in the southern part of the fishery where the catch-rates of blue shark are generally highest, and lowest in the northern part of the fishery where the catch-rates of blue shark are generally lowest. Given the results across the four areas for which the largest amount of data was available, a balance between eliminating anomalous values (achieved by minimising the CV) and eliminating zero CPUE observations appears to be achieved in adopting the scenario of using the value of 7500 for the minimum number of observer hooks (which corresponds to minimising the weighted average of the CV, using the number of selected quarters. across these four areas). A comparison of the time-series of logbook-reported CPUE and observer-reported CPUE for three of the six areas using this scenario is shown in Figure 13b.

10. Estimation of Total ETBF Catch

Given the apparent under-reporting on logbooks of the catch (including retained and returned to the seas) of blue sharks based on the analysis of the previous section, and if one accepts that the observer data provides a more accurate level of reporting, then the observer data will need to be used to estimate the catch of blue sharks in the ETBF. An estimate of the catch within any area can be found by multiplying the observed CPUE in that area by the logbook reported effort in that area. Summing these estimates across all areas of the ETBF will then provide an estimate of the total catch across the ETBF.

Due to the possibility of seasonal changes in the catch rates within the areas chosen, the above analysis was undertaken on a quarterly basis. The estimate of the total catch of blue sharks in the ETBF in year Y was then calculated as follows:

$$EstimatedCatch = \sum_{Q=1}^{4}\sum_{A=1}^{N} CPUE_{YQA}(observed) * Effort_{YQA}(\log book)$$

where Q denote quarter of the year and A denotes the N areas chosen across the ETBF.

Given the spatial-heterogeneity in the distribution (and associated catch rates) of blue sharks, ideally the areas should be chosen at a scale where the catch rates within each area are reasonably uniform. While 5x5-degree areas may have been useful for this purpose, the temporal coverage of observer data across such areas (cf. Figure 12a) is not adequate for these areas to be used. Instead, 5-degree bands of latitude off eastern Australia were chosen. Given the availability of observer data, the period between 2003 and 2011 was chosen for analysis. Due to a lack of observer data in the two 5-degree bands between 10-15^{o}S and 40-45^{o}S these areas were excluded from the analysis. However, based on the catches reported in logbooks, over the period defined above the catch in these two bands represented only 1.2% and 2.1% respectively of the total catch in the ETBF. Excluding these bands left five latitudinal bands between 15-40^{o}S.

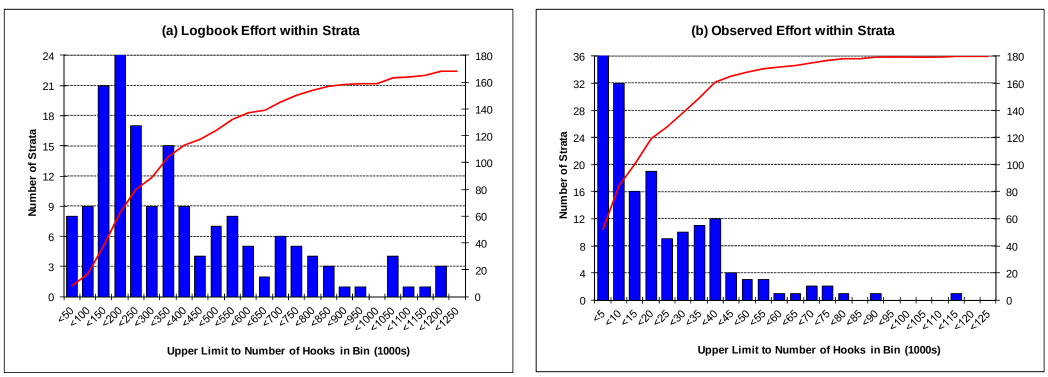
The more limited spatial-temporal distribution of observer data (in comparison to logbook data) does not allow the calculation of $CPUE_{QA}(observed)$ in all quarters within each 5-degree band. Of the 180 year/quarter/5-degree strata included in the analysis, logbook data was available for all strata while observer data was available for only 151 strata. For those strata where observer data was not available, a proxy for the $CPUE_{QA}(observed)$ is required. Two proxies were developed for these missing strata as follows:

1. $CPUE_{QA}(observed)$ was set equal to the nominal observer catch rate for the corresponding 5-degree band aggregated over the period: a) 2003-2006 or b) 2007-2010 in which the corresponding quarter was included. Two periods were chosen to allow for any possible trend over time.
2. $CPUE_{QA}(observed)$ was set equal to $CPUE_{QA}(logbook)*R$ where R is the corresponding mean ratio of CPUE(Observed)/CPUE(logbook) over all quarters for the corresponding 5-degree area where the observed number of hooks is 7500 or greater and the observed catch is non-zero.

Finally, as in the previous section, in order to eliminate possible outliers in the observer data, *$CPUE_{QA}$(observed)* was calculated only for those strata where a minimum level of effort (number of hooks) was observed. The analysis was repeated for various minimum effort levels and for each separate analysis the estimated catch in each year was calculated together with the ratio of the estimated-to-logbook catch for each year.

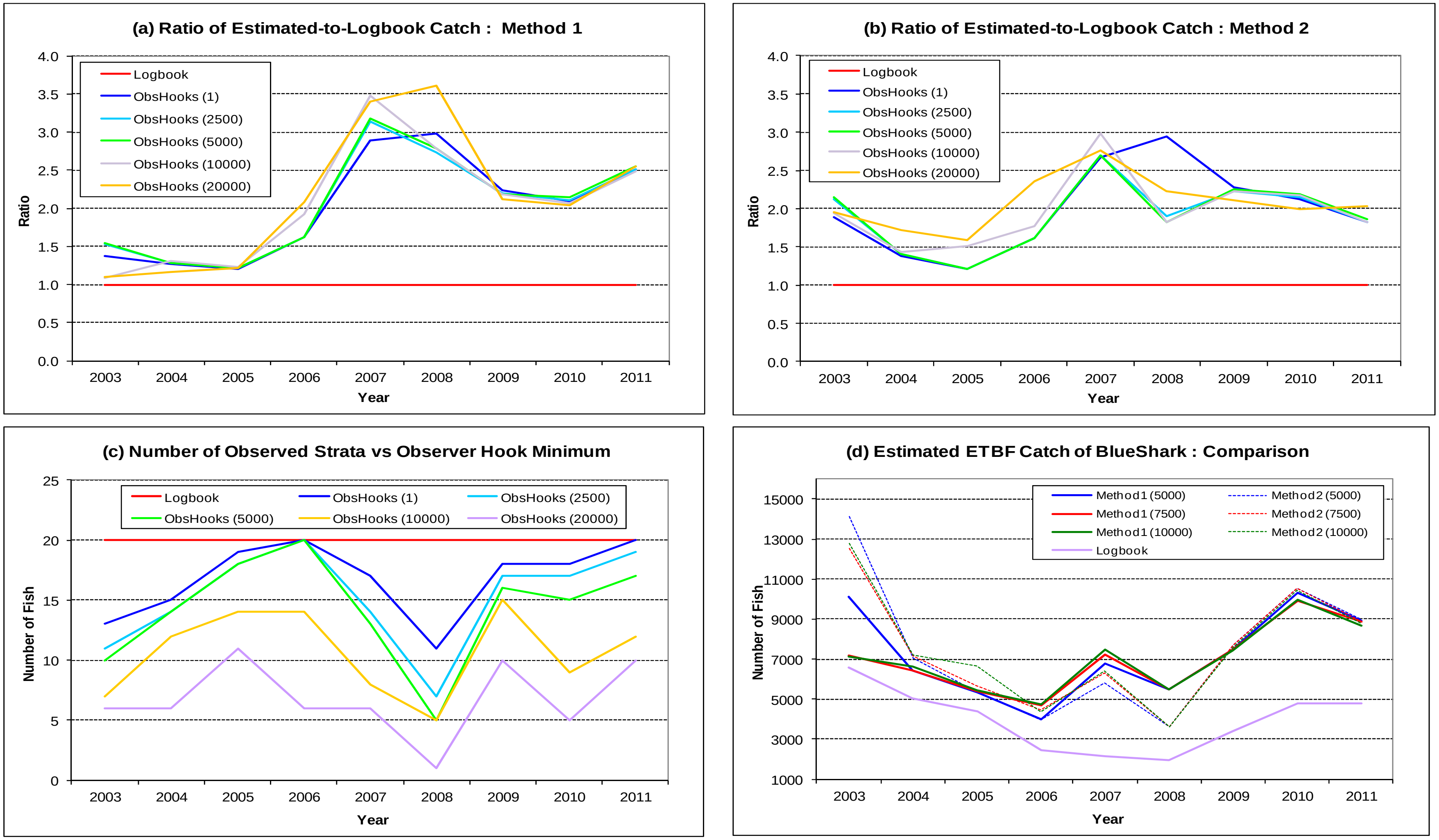
The distribution of the number of hooks deployed in each of the 180 spatial-temporal strata (year/quarter/5-degree band) included in the analysis, together with the corresponding number of hooks observed in each strata, is shown in Figure 15. Only two strata (having 1000 and 13750 hooks) had less than 20,000 hooks deployed and only 7 (4.4%) strata had less than 50,000 hooks deployed. On the other hand, 63% and 91% of all strata had less than 20,000 and 50,000 hooks observed respectively. For the analyses undertaken, minimum observed hook limits of 1, 2500, 5000, 10000 and 20000 hooks were used in the first instance, resulting in *$CPUE_{QA}$(observed)* having to be estimated by either of the two methods described above for 29, 43, 52, 84 and 119 of the 180 strata. The number of strata for which observer data was used to calculate *$CPUE_{QA}$(observed)* is shown for each year in Figure 16c.

Figure 15. Histograms of the number of hooks deployed in each of the 180 spatial-temporal strata (year/quarter/5-degree band) included in the analysis, together with the corresponding number of hooks observed in each strata. The red lines show the corresponding cumulative distribution.



Plots of the ratio of the estimated-to-logbook catch for each year using the two methods for estimating *$CPUE_{QA}$(observed)* are shown in Figures 16a and 16b. In each case the results indicate large (up to 3-fold) differences between the estimated catch and the logbook catch for most years. Furthermore, the results are reasonably consistent across the range of minimum observed hooks used in the analysis. This is despite the possibility noted in the previous section of anomalous observed catches when the number of observed hooks is low though aggregating the observer data across large 5-degree bands of latitude would help to minimise this possibility. However, as the minimum number of observed hooks is set higher the proportion of strata for which *$CPUE_{QA}$(observed)* is estimated by one of the methods above increases. Indeed, when the limit is set at 20000 hooks the number of estimated strata is already 119 (66%) of the 180 strata. As such, the ratio for each method asymptotes to the result based on the proxies used to estimate *$CPUE_{QA}$(observed)*.

Figure 16. (a&b) Plots of the ratio of the estimated-to-logbook catch for each year using the two methods for estimating *$CPUE_{QA}$(observed).(c)* number of strata where *$CPUE_{QA}$* is based on observer data, and (d) estimates of total annual catch in the ETBF between 15-40^{o}S .



In order to explore the sensitivity of these estimates to changes in the observed hook limit, the estimated catch in each year based on analyses using either 5000, 7500 and 10000 hooks as the minimum limit are shown in Table 12 and Figure 14d. For each method the estimated catch is seen to be similar for most years, with the greatest difference seen in 2003. There are, however, some significant differences in the estimated annual catch between the two methods, with the most significant differences occurring in 2003 and 2008. Despite these differences the estimated total catch over all years (2003-11) based on the two methods are reasonably similar, with method 1 indicating a total catch 176-182% higher than the logbook catch and method 2 indicating a total catch 188-190% higher than the logbook catch.

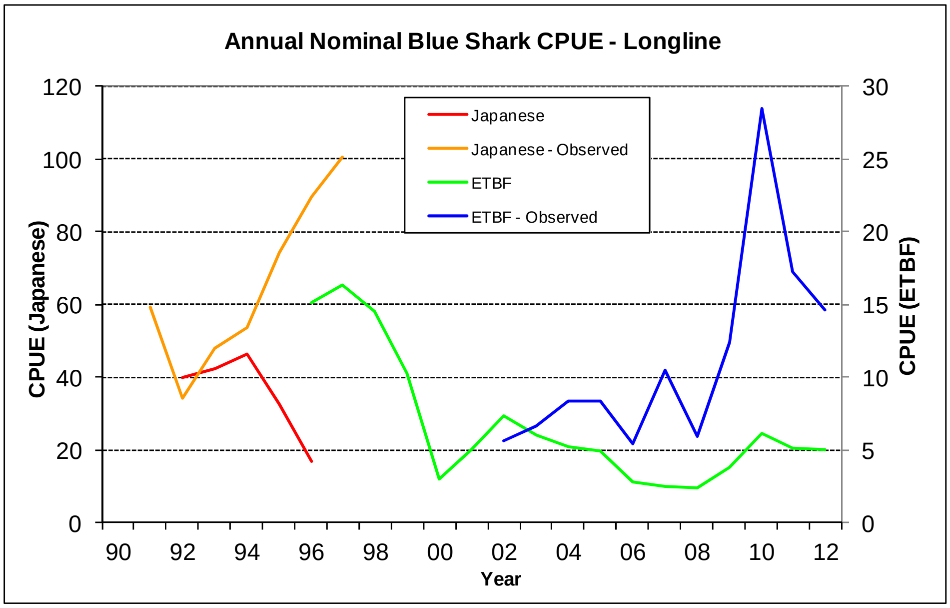
Table 12. The logbook reported catch (number of fish) of blue shark in each year together with the estimated catches based on the methods described in the text.

	Logbook	Method 1			Method 2		
Year	Catch	5000	7500	10000	5000	7500	10000
2003	6585	10143	7166	7107	14117	12516	12801
2004	5044	6433	6433	6614	7066	7135	7208
2005	4412	5335	5401	5448	5373	5638	6666
2006	2465	3984	4690	4721	3984	4483	4362
2007	2146	6804	7249	7460	5795	6326	6402
2008	1977	5496	5496	5496	3612	3612	3612
2009	3419	7482	7482	7453	7728	7728	7622
2010	4815	10323	9943	9969	10518	10526	10467
2011	4815	8938	8852	8690	8993	8874	8794
Avg	3964	7215	6968	6995	7465	7426	7548
Percent of Logbook		182%	176%	176%	188%	187%	190%

11. Index of Availability

Time-series of catch rates are often used to provide some index of possible trends of abundance or availability of a resource to a fishery. The annual time-series of nominal blue shark catch rates based on the logbook and observer data from each of the ETBF and Japanese longline fleets is shown in Figure 17. While the time-series for the ETBF fishery shows a sharp decline in nominal CPUE over the period 1996 to 2000, after this period there is no apparent trend despite a reasonably large degree of inter-annual variability. The nominal CPUE for the observer data in the ETBF between 2002 and 2008 also displays no apparent trend (averaging around 7.3 fish per 10000 hooks) but then displays a 3-fold increase during 2010 before decreasing to around 15 fish per 10000 hooks in 2011 and 2012. For the period 1992-1994 the values and temporal pattern of the two time-series relating to the Japanese fleet are similar but after this period the two indices diverge greatly. Whist differences in the raw values between the different nominal CPUE indices are likely to be related to differences in the operational practices of the respective fleets and the under-reporting of blue sharks on logbooks, the reasons for the differences in temporal pattern remain uncertain. However, the temporal coverage of the observer data in some years may explain some of these differences.

Figure 15. Annual time-series of nominal blue shark catch rates based on the logbook and observer data from each of the ETBF and Japanese longline fleets.



In order to provide a better metric of the available abundance for blue shark in the ETBF, the following two standardised indices were was calculated:

1) A spatially-weighted index based on the following calculation:

$$Index(year_Y) = \sum_{A=1}^{NA} Area_A \cdot \left[\frac{1}{NQ} \sum_{Q=1}^{NQ} CPUE_{YQA} \right]$$

where *NQ* is the number of quarters in the year, *NA* is the number of spatial areas, and $Area_A$ is the size of each spatial area (taken to be the number of unique 1x1-degree areas fished in that area over all years). The index was calculated for the years 1996-2012 though as in the previous section in order to provide an adequate coverage across each area the areas used in calculating the above index corresponded to the five 5-degree bands of latitude down the east coast of Australia from 15-40^{o}S. It should be noted that this index is similar to standardising the CPUE across quarters and areas, but obviously does not standardise for other aspects such as changes in gear configurations.

2) A standardised index based on fitting a two-step delta/negative-binomial Generalised Linear Model (GLM) to the data where in each step the fitted model included the following factors:

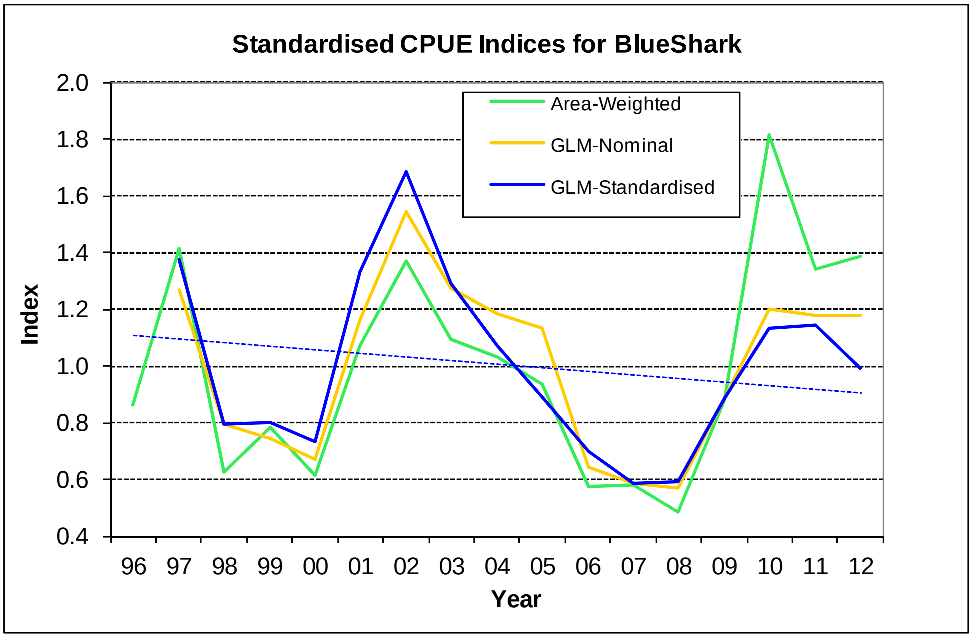
MODEL = *intercept* + *year*qtr* + *quarter*area*

+ *hook-per-basket* + *lightstick-usage* + *bait_type* +*start_time*

+*soi*area* + *sst*area* + *moon_phase*

where soi = southern-oscillation-index and sst=sea-surface-temperature. A full description of these models is provided in Campbell (2012). The index was calculated using the logbook data for the period 1997 to 2012.

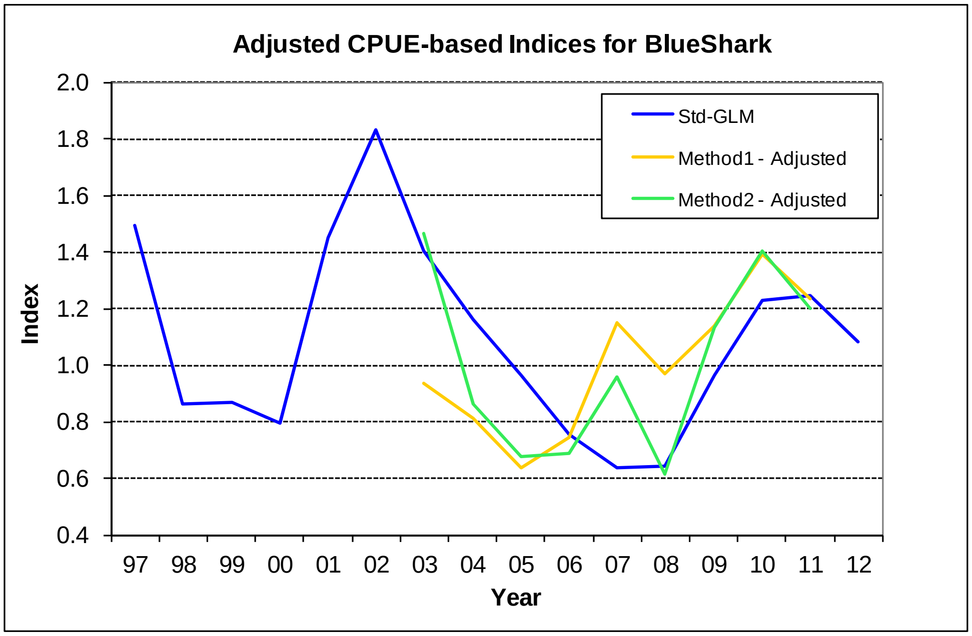
Figure 16. Standardised CPUE indices for blue shark within the ETBF based on i) spatial-temporal stratified logbook data, ii) the nominal CPUE of data fitted to a GLM model, and iii) the standardised CPUE after fitting to a GLM. A linear trend line is fitted the GLM-standardised index.



A comparison of these two indices together with the nominal CPUE (total catch/total effort) for the data used in the GLM is shown in Figure 16. Note, to assist in the comparison each index has been scaled so that the mean of the index over the common period 1997-2012 is equal to one. All indices display a similar temporal pattern over the years shown, though the standardised GLM index is higher during the first half of the previous decade and lower since 2010 in comparison with the Area-Weighted index. The linear trend line fitted to the standardised GLM index suggests a small declining trend over the period shown despite the high inter-annual variation between years. If these indices approximate an index of abundance or availability of this species then it would appear that the availability of blue sharks off eastern Australia has been relatively variable since the mid-1990s but with a suggestion that the successive peaks and troughs in the cycle of availability having declined over this period.

Finally, as noted in previous sections the logbook data used to calculate the above indices is likely to under-report the true catch of blue sharks. If the rate of under-reporting was the same for all sets then this would not be a major problem as the scaling-factor needed to correct for any level of under-reporting in the logbook data would be the same for sets and hence for all years when adjusting the annual index. However, previous results appear to suggest that the level of under-reporting is not constant across the fishery and across years. Unfortunately it is not possible to estimate the scaling factor that would need to be applied to each set used in the above analyses in order to adjust for the under-reporting on logbooks. As such, given the limited information available we can only assume that the level of under-reporting each year provided by the ratio *R* of the observed-corrected catch to the logbook reported catch (c.f. Table 12) is an appropriate proxy for the measure of under-

Figure 17. Comparison of the GLM-based standardised CPUE index for blue shark within the and two other indices which attempt to correct for any under-reporting on logbooks.



reporting across all sets. For each of the two methods described in the previous section for calculating the total annual catch, a single value of *R* for the years 2003-11 was obtained by taking the average value of *R* across the three sets of minimum observed hook limits shown in Table 12 (i.e. 5000, 7500, 10000). The standardised-GLM based annual index was then multiplied by each value of *R* for each year over the period 2003-11 and then scaled so that the mean value of the index over this period was equal to 1. A comparison of the resulting indices together with the original unadjusted GLM-based index is shown in Figure 17. If the final indices are reflective of 'local' blue shark density then it seems to reflect substantial changes in the available of blue sharks off eastern Australia. These changes could be related to movements of fish in and out of the AFZ or alternatively changes in the size of the resource in response to trends in annual recruitment. Alternatively the index may be an unreliable measure of blue shark availability off eastern Australia and greater effort needs to be placed on reporting and understanding the factors which influence both catch rates and inter-annual changes in the availability of this species off eastern Australia (e.g. inter-annual variability in oceanographic conditions).

Reference

Campbell, R. (2012) *Aggregate and size-based standardised CPUE indicators for longline target species caught in the south-west Pacific*. Information paper SA-IP-13 provided to the 8th meeting of the Scientific Committee held 7-15 August 2012, Busan, Korea.