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Blue shark catch and effort data collected by Japanese research and training vessels[1]

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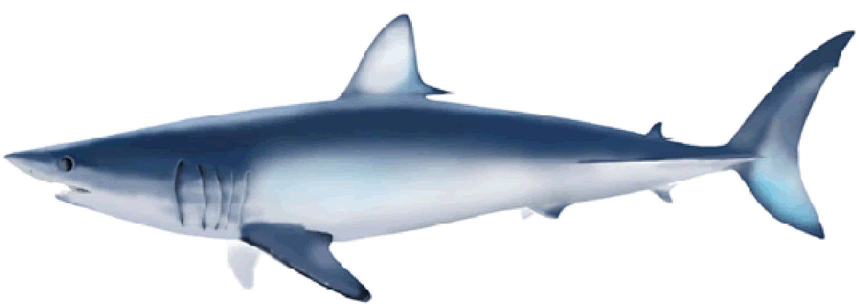

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Abstract

In the spring of 2010, limited information from the secretariat of the research and training association bring information that at least part of Japanese research and training vessels do not report all of their shark catches. Questionnaire survey to each vessel conducted right after that supported this information though only less than half of vessels answered to this survey. The nominal CPUE trend of blue shark of each vessel in their main fishing grounds shows that apparently unnatural large up and down or unnatural low CPUE value observed in part of vessels since early 2000. The CPUE of blue shark standardized with the effect of vessels started to decline and its CV in the 2000s. The increase of CV occurred in the 2000s supposed to be caused by the fact that Japanese research and training vessels underreported the catch of blue shark in the 2000s and the degree of underreporting are different among vessels which cause the increase of CV. The results of analysis of catch and effort data of blue shark indicates the fact that the under reporting activity start with small scale in the early 2000s and it gradually expanded in terms of the number of vessels and/or areas, and in the mid 2000s, the under reporting activity becomes more apparent.

In Japan, there are two types of research vessels; one is operated by prefectural fishery laboratories. They are conducting research to offer the information about fishing and sea conditions to fishers, and they are member of part of the research and training association and subject of this study. Other research vessels are one operated by the national research institutes. In the 2000s, the information by research vessels operated by national research institutes could only be used for the CPUE analysis of blue shark in the north Pacific.

Introduction

ISC Shark working group recognized there are some problems in the report of blue shark catch in the data of Japanese research and training vessel (ISC, 2013). In this document, we checked these data by merging its log-book data and bio-sampling data which containing information about fate of caught fish.

Materials and methods

Log book and bio-sampling data of Japanese research and training vessel in 1992 - 2013 was digitized, compiled and error checked in National Research Institute of Far Seas Fisheries (NRIFSF). The bio-sampling data contains information about treatment (retain, discard, release) of each fish caught. The data in 2013 is preliminary and did not use part of analysis.

CPUE of blue shark in the core area and high fishing season in their south and north fishing ground around Hawaii islands were standardized by GLM model with negative binominal error. The formula of the model is as follows;

North fishing ground (20N – 30N, 160W - 140W) in 3rd and 4th quarters

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glm.nb(formula = blueshark ~ as.factor(year) + as.factor(qt) +
       poly(lat5, 2) + poly(lon5, 2) + as.factor(shipname) + offset(log(hook)),
       data = datHI2, init.theta = 4.049357509, link = log)
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South fishing ground (10N – 20N, 180W - 150W) in 1st and 2nd quarters

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glm.nb(formula = blueshark ~ as.factor(year) + as.factor(qt) +
       poly(lat5, 2) + poly(lon5, 2) + as.factor(shipname) + offset(log(hook)),
       data = datHI1, init.theta = 2.640568777, link = log)
```

where qt is quarter of year, lat5 is 5 degree of latitude, lon5 is 5 degree of longitude, shipname is name of vessel.

Results and Discussions

In the spring of 2010, limited information from the secretariat of the research and training association bring information that at least part of Japanese research and training vessels do not report all of their shark catches. Questionnaire survey to each vessel conducted right after that supported this information though only less than half of vessels answered to this survey. Based on this, NRIFSF officially requested the association to improve the reports of catch of sharks by the research and training vessels. The main fishing grounds of Japanese research and training vessels are in the northern and southern areas of Hawaiian Islands (Fig. 1). The nominal CPUE trend of blue shark of each vessel in their main fishing grounds shows that apparently unnatural large up and down or unnatural low CPUE value observed in part of vessels since early 2000 (Tables 1 and 2). This seems to support the information from the association.

The catch number of major shark species shows continuous decreasing trends since 1993 (Fig. 3) which follows the declining trend of the amount of effort (Fig. 2). Among the major shark species, catch of thresher sharks shows rather strange trend. Sudden decrease observed in the early 1990s and after that, it stays in nearly zero level. Because their annual operational pattern do not change largely, which is decided by the office of fishery high school or prefectural office, sudden decrease of the catch to the negligible level means the collapse of the stock within couple of years. Because thresher sharks mostly caught as by catch and distribution areas of thresher sharks are relatively large, some large quantity of change should be occurred in the fishery to destroy the stocks of thresher sharks, but such kind of notable change do not occurred in the pelagic area of the Pacific.

In around 2000, treatments of catch of blue and shortfin mako sharks changed drastically (Fig. 3). Before 2000, both of them were mostly discarded, but after 2000, shortfin mako shark mostly retained but blue shark released. The nominal CPUE trend of blue shark shows sharp declining trend since the mid 2000s, and it partially recovered in 2010. The timing of partial stock recovery coincides with the time when NRIFSF officially requested to improve of shark statistics to the research and training vessels.

Figure 4 shows the annual trend of CV of the average of the nominal CPUE of blue shark caught by each vessel shown in Tables 1 and 2. In both north and south fishing ground of the research and training vessels, value of CV increased in the 2000s. The timing of the start of the increase of CV coincides with the timing of the nominal CPUE of blue shark starting to decrease. This would indicate the fact that the way of underreporting the blue shark catch becomes different among vessels since the mid 2000s. Decrease of the number of vessels in the 2000s would also contribute to the increase of CV, but observed large increase of CV could not be attained only this reason.

The CPUE of blue shark standardized with the effect of vessels in addition to other popular effects shows that the standardized CPUE started to decline and its CV in the 2000s in the core area of the both of their northern and southern fishing grounds, though the timing of start to increase and increasing trend are different between areas (Figs. 6 and 7). The way of increase of CV and decease of standardized CPUE is more prominent in the core area of the northern fishing ground, but increase of CV and decreased of CPUE start earlier in the southern fishing ground. Larger magnitude of the increase CV observed in the northern fishing ground than the south would be due to the fact that CPUE of blue shark is generally higher in the northern area. One of the main reasons of the underreporting of shark catches is the fact that collecting data of shark catches is laborious and dangerous thing. Thus the higher catch rate means larger number of underreporting for the vessels with lack of seriousness.

When these facts written above and the fact that at least part of training vessels starts not fully report their catch of sharks in the early 2000s are considered together, increase of CV occurred in the 2000s supposed to be caused by the fact that Japanese research and training vessels underreported the catch of blue shark in the 2000s and the degree of underreporting are different among vessels which cause the increase of CV. It seems to difficult to evidence the underreporting activities perfectly in the stochastic way without information from the vessels. The increase of CV could be caused by other reasons such as the change of environmental factors, decrease of the number of vessels, influences by commercial boats. In this point, the results of analysis in this study can only provide circumstantial evidence for the underreporting activities. At the same time, the results of the analysis in this study coincide with the information by Japanese research and training vessels. At now, only part of vessels answered to our questionnaire, and thus, further collection about real situation of underreporting.

The results of analysis of catch and effort data of blue shark also indicates the fact that the under reporting activity start with small scale in the early 2000s (means, start with limited number of vessels and/or areas) and it gradually expanded in terms of the number of vessels and/or areas, and in the mid 2000s, the under reporting activity becomes more apparent. The degrees of underreporting were different among vessels and this cause the increase of CV of CPUE. The degrees of underreporting also seem to be different by shark spices, and thresher sharks seem more frequently underreported than blue shark. The way of report of shark catches by Japanese research and training vessels should be corrected to the reliable one as soon as possible. In Japan, there are two types of research vessels; one is operated by prefectural fishery laboratories. They are conducting research to offer the information about fishing and sea conditions to fishers, and they are member of part of the research and training association and subject of this study. Other research vessels are one operated by the national research institutes. Though the number of their cruise is limited and is not conducted regular based, their shark report is reliable. In the 2000s, the information by research vessels operated by national research institutes could only be used for the CPUE analysis of blue shark in the north Pacific.

References

ISC Shark Working Group. 2013. Stock assessment and future projections of blue shark in the North Pacific Ocean. International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, 17-22 July 2013, Busan, Korea. 83p.

Table 1. Annual nominal CPUE of blue shark caught of each training and research vessels in the area of 0N - 20N and 175E – 130W in 1992 – 2013. The data with less than 10,000 hooks deleted. The number in the first row shows the code number of each vessel. The values highlighted by yellow indicate the examples of unnatural large up and down or unnatural low CPUE values.

	831	832	1331	1443	1434	1511	1531	1631	1731	1881	1831	1932	2011	2031	2032	2231	2431
1992			3.8	0.7			6.5	3.1	1.9		3.9	5.2	6.7	5.6	6.7	5.5	4.7
1993	15.4	5.9	2.7	4.2	11.3	11.3	5.0	5.3	3.0	8.9	4.7	3.1	2.2	3.4	6.7	5.4	5.6
1994	16.4	7.4	1.6	2.7	7.1	7.1	4.6	3.1	3.3	7.8	5.2	3.0	3.3	7.3	4.4	6.7	6.6
1995	7.2	7.4	1.9	3.0	8.4	8.4	5.1	4.4	2.5	6.8	3.6	4.0	3.6	6.0	4.7	2.5	5.3
1996	10.9	11.7	1.8	2.9	15.9	15.9	6.3	4.3	3.8	5.6	5.1	5.4	1.6		5.5	5.2	5.5
1997	13.8		1.8	3.9	11.1	11.1	3.8	6.5	4.3		5.1	5.8	3.1		9.8	4.0	6.6
1998	15.9		1.7	3.6	8.1	8.1	3.3	4.6	3.1		4.3	5.2	2.0		12.8	4.6	4.9
1999	11.2	8.3	2.0	3.1	10.9	10.9	4.0	4.2	3.8		3.7	6.4	3.4		4.8	5.9	6.5
2000	12.9	8.2	3.1	2.7	4.7	4.7	3.9	4.6	4.5		5.0	5.0	1.5		10.8	2.6	6.5
2001	10.7	6.8	3.0	3.5	5.8	5.8	3.7	3.9	5.2		4.5	4.9	1.9		8.5	3.5	6.6
2002	14.5		1.5	4.2	1.9	1.9	3.7	4.3	4.0		4.5	2.6	2.6		7.9		10.8
2003	9.1	8.4	1.5	6.6	3.5	3.5	4.9	7.0	5.2		6.1	4.2			7.4	3.6	8.8
2004	7.7	7.8	1.9	2.9	4.5	4.5	3.6	3.2	2.6		3.8	3.6			4.7	4.5	5.7
2005	9.3	7.7	1.9	3.6	3.6	3.6	3.6	3.3	2.1		3.2	3.0			4.2	2.3	5.6
2006	11.8	3.8	1.1	1.9	3.6	3.6	2.1	2.4	1.8		3.0	3.2			1.6	4.5	2.2
2007	9.0	2.5	1.3	1.7	9.4	9.4	1.8	1.4	1.9		3.5	0.3			0.5	3.7	2.9
2008	4.6	4.3	0.9	1.2			1.4	0.9	1.3		2.6	0.0			0.0	2.6	1.0
2009	9.4	4.6	0.9	3.4			2.5	0.9	1.0		2.6	0.1				0.0	0.7
2010	13.9	5.8	0.9	1.6			4.3		0.2		3.8	0.0			7.0	6.3	1.0
2011	10.3	4.6	0.9	1.5				0.2	3.2		3.2	1.7			5.3	8.1	
2012	21.7	2.6	0.7	1.3			6.2		0.0		2.8	1.0			3.6	10.7	
2013		4.3	1.9												2.4		

	2531	2631	2831	3331	3430	3532	3931	4031	4131	4231	4331	4332	4531	4731	4831	4931	9503
1992	4.4	9.6	5.1		4.8	9.4	3.9	3.7	6.5		5.6		5.2	5.7	5.7	5.2	0.3
1993	4.8	7.0	6.4	8.1	14.8	7.5	4.9	4.2	3.7	0.3	4.6		5.2	6.0	3.9	4.8	1.4
1994	1.8	6.2	6.2	8.8	14.4	4.2	3.6	4.7	5.2	3.4	3.9		6.0	3.7	2.2	4.7	2.9
1995	1.6	6.0	5.5	4.4	9.6	5.9	3.8	4.5	3.6	2.6	5.8		6.6	3.1	5.9	2.6	17.7
1996	2.7	4.5	2.9	4.2	9.6	5.4	5.0	3.6	2.6	4.8	4.9		5.1	3.5	4.6	3.5	22.9
1997	1.1	7.4	6.7	19.1	20.5	3.2	8.1	6.5	4.1	4.1	5.8		6.6	2.5	6.7	2.7	3.0
1998	0.7	7.4	7.6	13.5	13.8	4.2	5.0	2.3	4.7		4.8		11.2	3.6	7.8	2.8	
1999	2.7	5.2	7.0	3.0	11.4	4.5	4.7	4.0	3.9	1.8	4.0		10.0	3.2	5.3	4.3	
2000	3.1	5.5	3.3	4.0		5.4	6.2	4.4	5.7	3.0	3.0		6.6	1.4	6.1	1.9	
2001	0.3	4.1	2.1			5.7	4.3	3.8		5.7	5.4		5.2	2.4	4.1	2.3	
2002	2.6	4.6	2.3	2.9		5.5	4.9	4.4		2.7	4.7		5.3	1.8	3.8	1.3	
2003	8.9	4.3	3.4	2.9		3.5	6.4	5.3	7.6	2.7	7.5		11.8	3.6	4.3	2.6	
2004	3.5	4.0	2.7			3.3	5.4	4.0	4.6	1.9	6.3		9.9	4.5	4.2	2.2	
2005	2.1	4.1	2.7			2.8	2.1	3.5	0.1	1.1	4.0		7.4	3.4	3.0	1.6	
2006	0.4	2.2	1.6			1.6	7.3	2.9	1.1	0.5	1.6		8.1	4.2	2.2	2.0	
2007	1.3	2.4				2.2	3.4	2.4		0.2	1.9		4.3	3.8	2.0	0.6	
2008	1.8	2.0				1.1	2.3	3.0		0.1	3.2		3.3	0.0	1.3	0.0	
2009	1.9	0.3				0.8		2.6		0.1	3.2		3.3	1.1	2.6	0.0	
2010	1.2	0.1				2.1		1.9		0.8		7.0			2.9	0.0	
2011		4.0		7.7		1.5		2.1		5.7		3.9			2.3	0.6	
2012				1.8		1.3		1.7	0.0	1.7		3.4			1.9	0.6	
2013						2.4		2.8		2.8		3.1			1.9	0.8	

Table 2. Annual nominal CPUE of blue shark caught of each training and research vessels in the area of 20N - 40N and 175E – 130W in 1992 – 2013. The data with less than 10,000 hooks deleted. The number in the first row shows the code number of each vessel. The values highlighted by yellow indicate the examples of unnatural large up and down or unnatural low CPUE values.

	831	832	1331	1433	1434	1511	1531	1631	1731	1811	1831	1932	2031	2032	2131	2231	2431	2531	2631
1992		9.4	6.8	7.1	0.3		8.3	3.6	4.7	8.3	6.1	9.2	8.8	6.7	5.9	8.5	6.3	5.2	9.6
1993	12.4	6.5	3.1	5.7	4.3	10.9	5.7	6.4	3.9	7.5	5.3	4.2	4.0	7.5	1.9	7.0	6.5	4.9	8.5
1994	16.5	4.5	2.7		3.5	7.2	5.9	3.6	4.9	5.9	6.1	2.3	9.8	6.6	4.6	8.1	7.2	3.1	6.7
1995	6.8	7.4	2.0		3.1	8.4	5.5	4.8	2.8	4.3	4.0	4.8	6.3	4.8	2.5	2.3	5.3	1.7	7.5
1996	11.4	11.5	1.8		2.9	9.5	6.4	4.4	3.8		5.1	5.5		5.5	1.7	5.7	5.4	2.3	5.7
1997	14.2	7.2	1.8		4.4	9.3	3.8	6.5	4.5		5.1	7.2		9.8	3.5	4.8	9.1	1.0	8.3
1998	15.7	5.8	1.8		5.0	13.0	3.3	5.3	4.5		5.5	7.8		12.8	5.8	6.5	4.5	0.9	9.7
1999	11.1	6.9	2.2		3.8	2.6	4.0	4.4	4.4		4.3	9.1		5.6	6.4	7.8	7.1	2.3	6.3
2000	12.9	8.0	3.8		3.5	4.5	4.0	5.9	4.7		6.3	6.4		10.6	5.3	3.1	6.5	3.4	6.4
2001	8.9	7.8	3.0		3.5	2.7	3.9	3.2	5.2		4.6	6.3		7.3	4.3	3.5	6.3	0.3	4.1
2002	24.3	7.7	1.6		5.0	2.1	3.7	5.7	4.9		5.0	4.0		6.5	0.8	6.1	3.5	0.7	6.0
2003	11.4	3.8	1.0		6.6	4.6	5.1	7.9	5.6		7.1	4.0		7.2	9.2	4.1	3.3	11.7	4.4
2004	7.9	2.4	1.9		2.9	3.8	3.6	3.3	2.5		3.9	3.8		3.6	2.0	2.2	2.4	0.7	3.8
2005	5.5	4.3	1.9		3.8	3.3	3.5	2.6	2.0		3.2	3.2		4.5	5.4	4.6	3.1	0.6	4.2
2006	10.0	4.6	1.1		1.9	5.1	2.1	1.7	1.9		3.0	0.1		1.7	5.1	5.1	1.0	0.4	2.2
2007	5.3	5.8	1.3		1.7	8.3	1.8	1.6	2.1		3.5	0.2		0.6	8.5	3.4	1.6	0.1	2.8
2008	3.9	4.6	0.9		0.8		1.2	0.8	1.7		2.6	0.0		0.0		2.7	0.8	0.9	2.3
2009	6.0	2.6	0.9		3.4		2.4	0.9	1.2		2.6	0.1				6.3	0.6	0.5	0.5
2010	9.6	4.3	0.9		1.6		4.3	0.2	0.2		3.8	1.1		7.0		7.9		1.2	0.1
2011	8.7	7.1	0.9		1.5		6.2	4.7	8.3		3.3	8.8		5.3		9.9			4.3
2012	15.5	4.8	0.7		1.3		3.6	3.9	7.5		2.9	4.0		3.6		11.8			
2013														2.4					

	2831	3331	3430	3532	3931	4031	4131	4231	4331	4332	4531	4731	4831	4931	5011	5031	5032	9503
1992	5.9		2.5	8.6	6.6	3.9	6.5	6.9	6.1		8.3	6.9	6.6	6.9	2.5			
1993	6.4	8.0	12.8	7.7	5.8	5.1	4.4	3.6	5.7		5.6	7.3	4.5	6.0	2.7	1.9		0.3
1994	6.5	8.9	14.4	7.0	3.8	5.0	6.6	6.7	5.6		6.5	4.5	3.5	5.2		0.1		4.7
1995	5.5	11.4	9.6	6.6	4.5	5.6	3.6	4.9	7.1		7.9	3.5	5.9	2.8		0.6		3.3
1996	3.2	4.2	10.9	5.9	5.3	3.9	2.8	5.5	5.3		5.1	4.0	4.7	3.9		1.0		12.7
1997	6.7	19.1	20.5	4.0	8.1	6.5	4.4	9.7	5.8		7.9	3.1	7.0	2.9				3.4
1998	7.6	13.5	13.8	5.3	5.4	2.5	5.3	0.9	4.8		11.2	4.4	8.5	3.3		9.1		6.9
1999	7.0	3.0	11.4	5.1	4.8	4.0	3.9	1.7	4.0		10.0	3.8	6.5	4.5		4.9		2.7
2000	3.3	4.0	7.1	7.6	7.1	5.4	7.3	4.3	4.9		6.6	1.2	9.6	1.9		3.8		
2001	2.1			6.2	4.3	3.8		5.7	5.9		6.0	2.6	4.4	2.1		2.6		
2002	2.3	2.9		8.4	5.6	5.5		1.7	6.4		5.3	1.7	4.9	0.9		5.3	9.6	
2003	3.4	3.4		4.5	6.4	6.0	9.7	2.6	8.0		9.9	4.5	4.8	3.0			4.9	
2004	2.7	2.8		3.7	5.7	4.1	5.6	1.4	6.2		10.1	4.0	5.1	1.7			7.1	
2005	2.7			3.3	2.3	3.2	0.1	1.3	3.5		7.9	4.1	3.4	1.9			3.6	
2006	1.5			1.6	7.0	2.8	0.3	0.5	2.1		8.1	3.9	2.3	1.7			3.1	
2007				2.9	3.9	2.7		0.0	2.1		4.6	4.9	2.0	0.7			6.0	
2008		5.7		1.3	2.3	3.7		0.1	4.5		5.0	0.0	1.2	0.0			2.4	
2009		2.9		1.0		2.8		0.1	3.2		3.7	1.1	2.8	0.0			6.3	
2010		10.3		2.1		1.8		0.6		7.0			3.0	0.0			1.9	
2011				2.0		2.1		0.9		4.0			2.3	0.7			1.6	
2012				1.6		1.7		2.1		3.7			1.9	0.8			2.4	
2013				2.4		2.8	0.0	2.8		3.1			2.4	0.8			2.4	

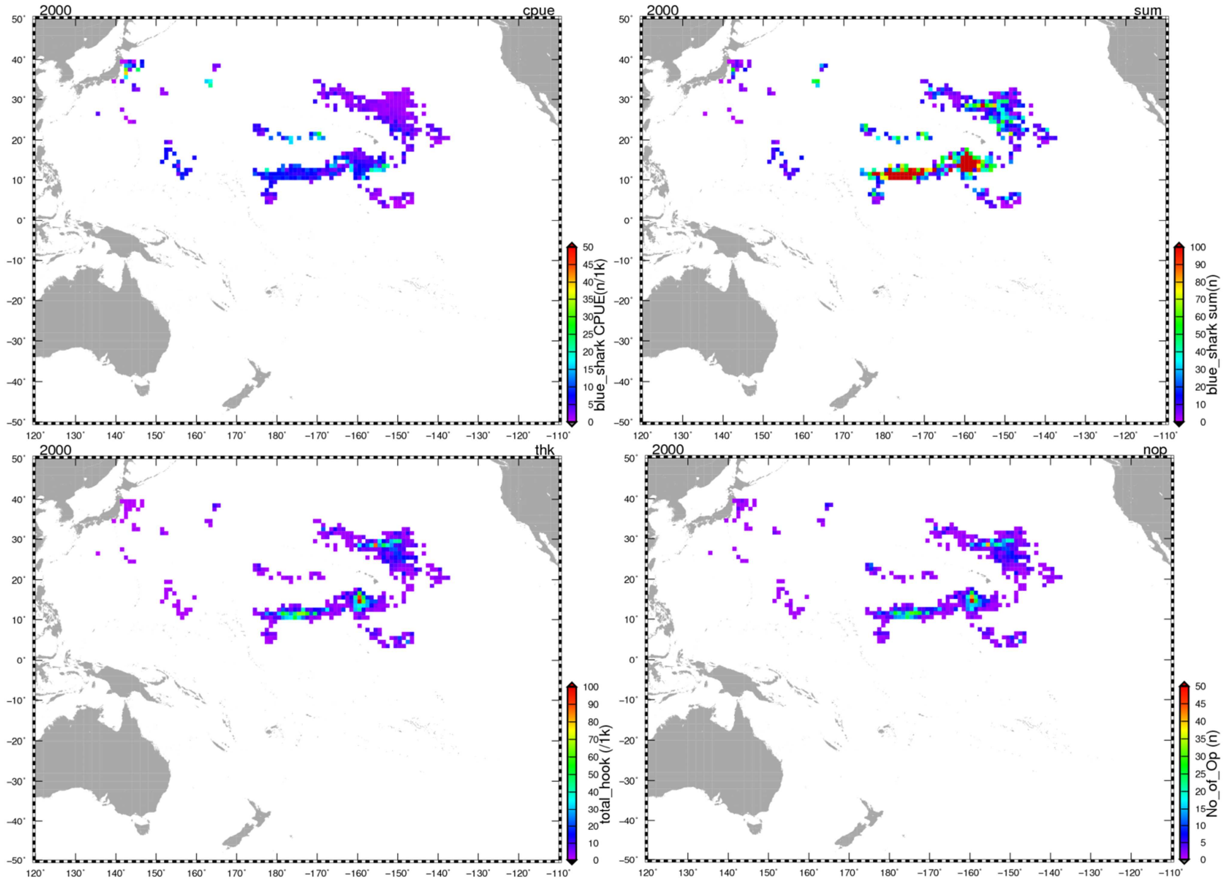

Fig. 1. Distribution of CPUE (left top), catch number (right top), hook number (left bottom) and number of operation of blue shark caught by Japanese research and training vessels in 2000.

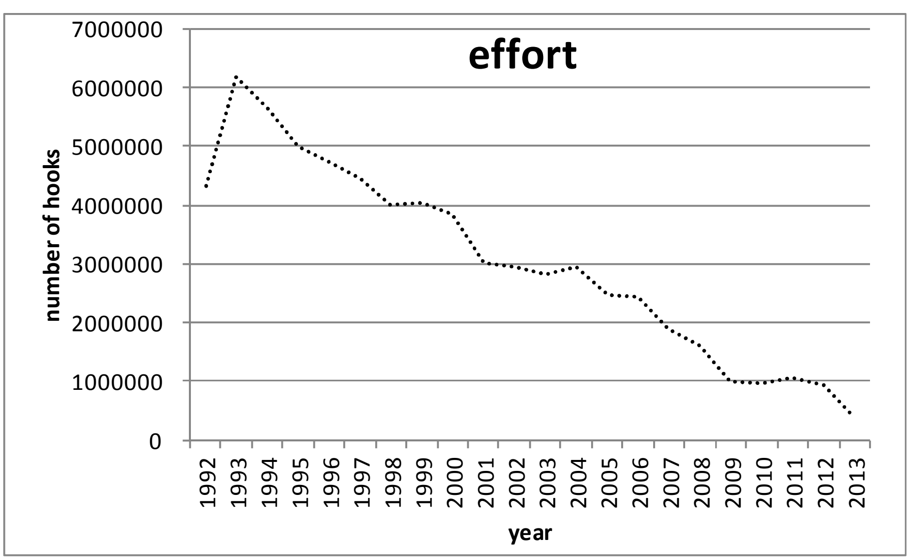

Fig. 2. Trend of amount of effort (number of hooks) of Japanese research and training vessel in 1992 – 2013. Value of 2013 is preliminary.

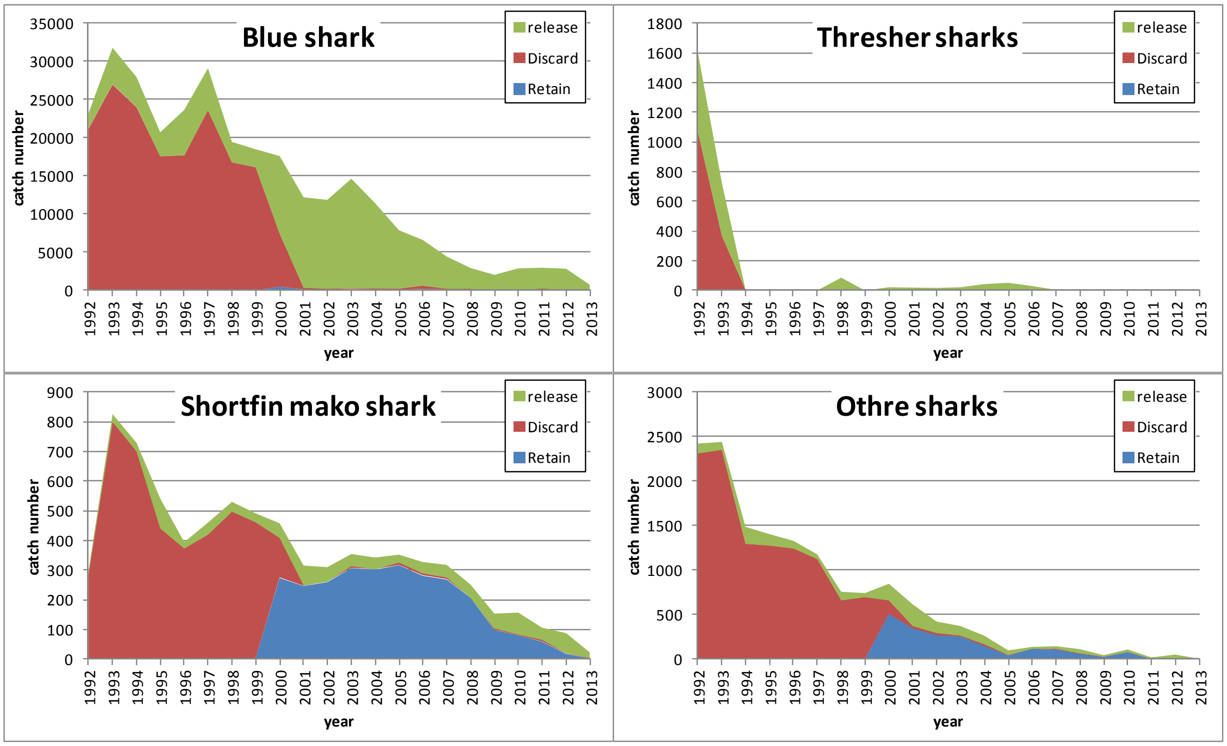

Fig. 3. Annual catch number of blue shark (left top), thresher sharks (right top), shortfin mako sharks (left bottom) and other sharks (right bottom) by the treatment.

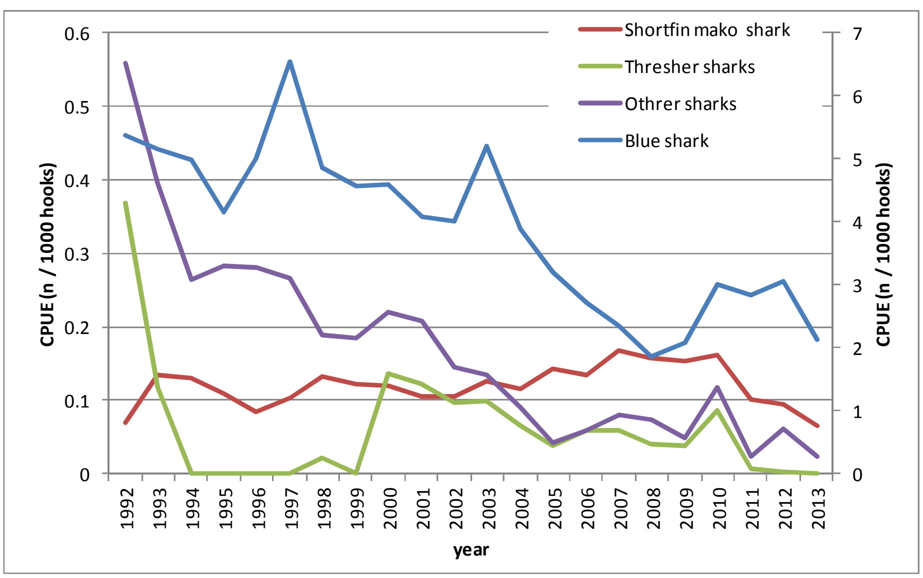

Fig. 4. Nominal CPUE (n / 1000 hooks) of blue shark, shortfin mako shark, thresher sharks, and other sharks caught by Japanese research and training vessel in 1992 – 2013.

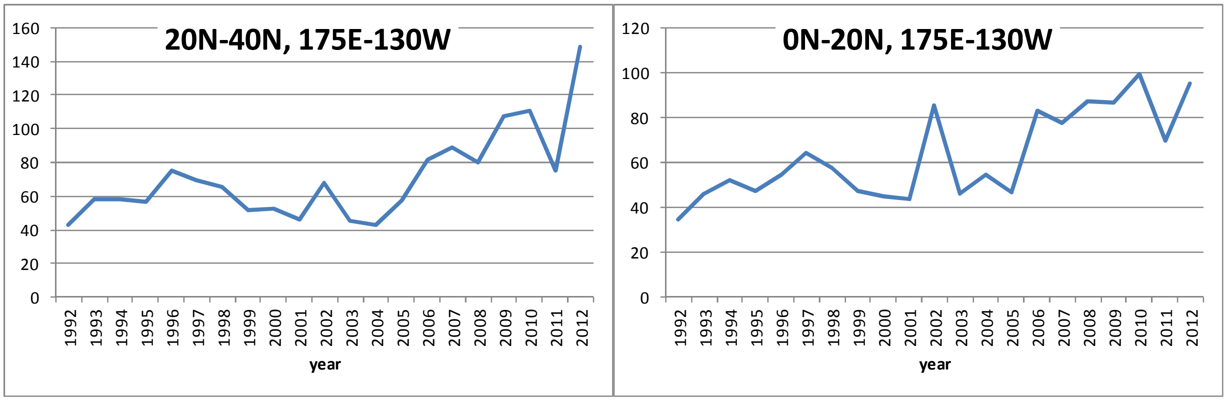

Fig. 5. Annual trend of CV of annual CPUE of blue shark caught by Japanese research and training vessel in their south fishing ground (left) and in their north fishing ground (right). CV calculated from the annual nominal CPUE of each vessel shown in Tables 1 and 2.

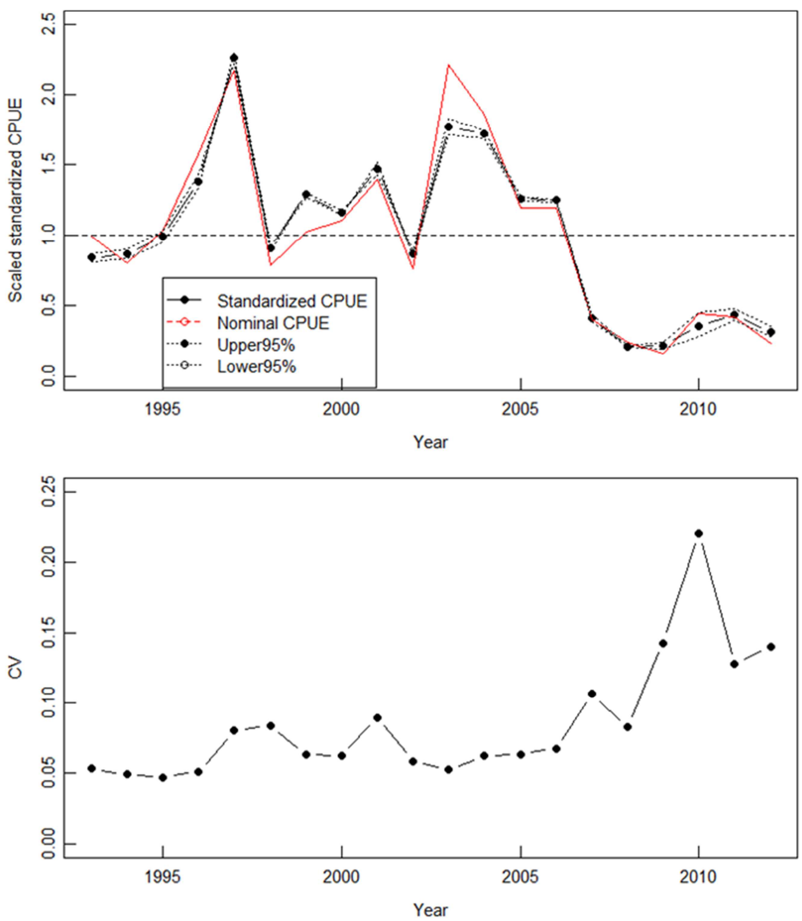

Fig. 6. Standardized and nominal CPUE of blue shark in the core area in the north fishing ground (20N – 30N, 160W - 140W) and high fishing season (quarters 3 and 4) of Japanese research and training vessel (top), and CV of CPUE (bottom).

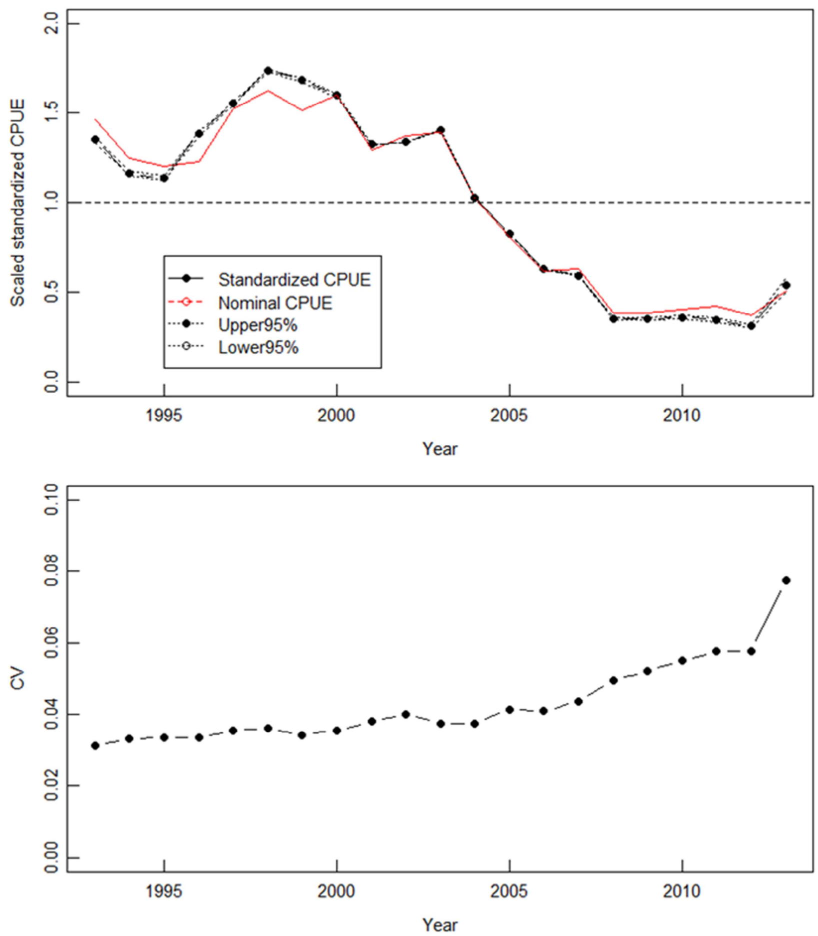

Fig.7. Standardized and nominal CPUE of blue shark in the core area in the south fishing ground (10N – 20N, 180W - 150W) and high fishing season (quarters 1 and 2) of Japanese research and training vessel (top), and CV of CPUE (bottom).

APPENDIX

CPUE analysis results in the north fishing ground

```
Call:
glm.nb(formula = blueshark ~ as.factor(year) + as.factor(qt) +
    poly(lat5, 2) + poly(lon5, 2) + as.factor(shipname) + offset(log(hook)),
    data = datHI2, init.theta = 4.049357509, link = log)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.4325  -0.9564  -0.2135   0.4726   4.7991

Coefficients:
                         Estimate Std. Error z value Pr(>|z|)
(Intercept)             -5.981769   0.110346 -54.209  < 2e-16 ***
as.factor(year)1994      0.030016   0.055864   0.537 0.591050
as.factor(year)1995      0.165556   0.056756   2.917 0.003535 **
as.factor(year)1996      0.500694   0.056378   8.881  < 2e-16 ***
as.factor(year)1997      0.990211   0.077155  12.834  < 2e-16 ***
as.factor(year)1998      0.076763   0.081686   0.940 0.347356
as.factor(year)1999      0.428168   0.065148   6.572 4.96e-11 ***
as.factor(year)2000      0.324445   0.066440   4.883 1.04e-06 ***
as.factor(year)2001      0.563563   0.086348   6.527 6.73e-11 ***
as.factor(year)2002      0.036975   0.062723   0.589 0.555526
as.factor(year)2003      0.747812   0.057375  13.034  < 2e-16 ***
as.factor(year)2004      0.718065   0.065701  10.929  < 2e-16 ***
as.factor(year)2005      0.407437   0.065133   6.256 3.96e-10 ***
as.factor(year)2006      0.396480   0.069942   5.669 1.44e-08 ***
as.factor(year)2007     -0.707739   0.100874  -7.016 2.28e-12 ***
as.factor(year)2008     -1.383912   0.081911 -16.895  < 2e-16 ***
as.factor(year)2009     -1.359090   0.128020 -10.616  < 2e-16 ***
as.factor(year)2010     -0.853187   0.181754  -4.694 2.68e-06 ***
as.factor(year)2011     -0.654474   0.117716  -5.560 2.70e-08 ***
as.factor(year)2012     -0.978864   0.126368  -7.746 9.47e-15 ***
as.factor(qt)4          -0.298041   0.055353  -5.384 7.27e-08 ***
poly(lat5, 2)1         -16.970053   0.725773 -23.382  < 2e-16 ***
poly(lat5, 2)2           1.197410   0.692585   1.729 0.083827 .
poly(lon5, 2)1         -11.430852   0.823694 -13.878  < 2e-16 ***
```

```
poly(lon5, 2)2                    -5.448315    0.754898  -7.217 5.30e-13 ***
as.factor(shipname)りあす丸        0.341551    0.181045   1.887 0.059220 .
as.factor(shipname)阿州丸         -0.005329    0.116360  -0.046 0.963469
as.factor(shipname)愛知丸         -0.201971    0.213942  -0.944 0.345145
as.factor(shipname)雲龍丸          0.209759    0.104884   2.000 0.045509 *
as.factor(shipname)越山丸          0.450164    0.152790   2.946 0.003216 **
as.factor(shipname)加能丸          0.442730    0.102026   4.339 1.43e-05 ***
as.factor(shipname)海友丸          1.245870    0.306364   4.067 4.77e-05 ***
as.factor(shipname)開発丸         -0.363886    0.158152  -2.301 0.021399 *
as.factor(shipname)宮城丸          0.420039    0.112657   3.728 0.000193 ***
as.factor(shipname)玄洋丸          0.255938    0.104628   2.446 0.014439 *
as.factor(shipname)香川丸          0.328625    0.105129   3.126 0.001773 **
as.factor(shipname)薩摩青雲丸     -0.234520    0.103360  -2.269 0.023271 *
as.factor(shipname)鹿島丸          0.188930    0.099926   1.891 0.058664 .
as.factor(shipname)湘南丸          0.263280    0.102162   2.577 0.009964 **
as.factor(shipname)新りあす丸     -0.440185    0.118288  -3.721 0.000198 ***
as.factor(shipname)新大分丸        0.117551    0.107806   1.090 0.275538
as.factor(shipname)神海丸          0.396657    0.109494   3.623 0.000292 ***
as.factor(shipname)進洋丸          0.411754    0.115276   3.572 0.000354 ***
as.factor(shipname)青森丸         -0.816831    0.117004  -6.981 2.93e-12 ***
as.factor(shipname)千潮丸          0.101724    0.112553   0.904 0.366110
as.factor(shipname)船川丸          0.388988    0.102453   3.797 0.000147 ***
as.factor(shipname)大分丸         -0.239148    0.115520  -2.070 0.038436 *
as.factor(shipname)但州丸          0.380000    0.199627   1.904 0.056969 .
as.factor(shipname)鳥海丸         -0.020774    0.104135  -0.199 0.841882
as.factor(shipname)土佐海援丸      0.005102    0.133677   0.038 0.969556
as.factor(shipname)福島丸          0.223153    0.106592   2.094 0.036302 *
as.factor(shipname)雄山            0.516857    0.121372   4.258 2.06e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(4.0494) family taken to be 1)

    Null deviance: 8161.6  on 3599  degrees of freedom
Residual deviance: 4086.3  on 3548  degrees of freedom
AIC: 18702

Number of Fisher Scoring iterations: 1
```

Theta: 4.049
Std. Err.: 0.173

2 x log-likelihood: -18596.335

CPUE analysis results in the south fishing ground

Call:

```
glm.nb(formula = blueshark ~ as.factor(year) + as.factor(qt) +
    poly(lat5, 2) + poly(lon5, 2) + as.factor(shipname) + offset(log(hook)),
    data = datHI1, init.theta = 2.640568777, link = log)
```

Deviance Residuals:

Min	1Q	Median	3Q	Max
-3.4532	-0.9227	-0.2295	0.4245	5.8925

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.254869	0.036389	-144.409	< 2e-16	***
as.factor(year)1994	-0.149895	0.031068	-4.825	1.40e-06	***
as.factor(year)1995	-0.171717	0.032298	-5.317	1.06e-07	***
as.factor(year)1996	0.026844	0.032920	0.815	0.414822	
as.factor(year)1997	0.140700	0.033282	4.228	2.36e-05	***
as.factor(year)1998	0.253392	0.034124	7.426	1.12e-13	***
as.factor(year)1999	0.222456	0.032897	6.762	1.36e-11	***
as.factor(year)2000	0.170028	0.033417	5.088	3.62e-07	***
as.factor(year)2001	-0.019359	0.035714	-0.542	0.587785	
as.factor(year)2002	-0.009223	0.037926	-0.243	0.807860	
as.factor(year)2003	0.040110	0.035952	1.116	0.264567	
as.factor(year)2004	-0.272142	0.035794	-7.603	2.89e-14	***
as.factor(year)2005	-0.495010	0.039478	-12.539	< 2e-16	***
as.factor(year)2006	-0.766754	0.039532	-19.396	< 2e-16	***
as.factor(year)2007	-0.823497	0.041469	-19.858	< 2e-16	***
as.factor(year)2008	-1.349842	0.047378	-28.491	< 2e-16	***
as.factor(year)2009	-1.350301	0.049194	-27.448	< 2e-16	***
as.factor(year)2010	-1.329722	0.052238	-25.455	< 2e-16	***

as.factor(year)2011	-1.368249	0.054284	-25.205	< 2e-16 ***
as.factor(year)2012	-1.476662	0.054631	-27.030	< 2e-16 ***
as.factor(year)2013	-0.922500	0.072011	-12.811	< 2e-16 ***
as.factor(qt)2	0.033674	0.015492	2.174	0.029735 *
poly(lat5, 2)1	-2.100721	0.968353	-2.169	0.030054 *
poly(lat5, 2)2	3.487953	1.100543	3.169	0.001528 **
poly(lon5, 2)1	-22.324470	0.944804	-23.629	< 2e-16 ***
poly(lon5, 2)2	2.978008	0.746218	3.991	6.59e-05 ***
as.factor(shipname)りあす丸	0.136571	0.053013	2.576	0.009989 **
as.factor(shipname)阿州丸	0.091374	0.038172	2.394	0.016679 *
as.factor(shipname)愛知丸	0.002665	0.045703	0.058	0.953502
as.factor(shipname)雲龍丸	0.173587	0.039919	4.349	1.37e-05 ***
as.factor(shipname)越山丸	0.354601	0.096850	3.661	0.000251 ***
as.factor(shipname)加能丸	-0.130657	0.102129	-1.279	0.200779
as.factor(shipname)海友丸	0.721208	0.136009	5.303	1.14e-07 ***
as.factor(shipname)開発丸	0.375946	0.163235	2.303	0.021274 *
as.factor(shipname)宮城丸	0.009496	0.038173	0.249	0.803538
as.factor(shipname)玄洋丸	0.177109	0.047147	3.757	0.000172 ***
as.factor(shipname)香川丸	0.178927	0.037017	4.834	1.34e-06 ***
as.factor(shipname)薩摩青雲丸	-0.582977	0.036452	-15.993	< 2e-16 ***
as.factor(shipname)鹿島丸	-0.031433	0.047224	-0.666	0.505665
as.factor(shipname)若千葉丸	-0.126109	0.092114	-1.369	0.170983
as.factor(shipname)若竹丸	0.444073	0.119567	3.714	0.000204 ***
as.factor(shipname)若鳥丸	0.421578	0.131286	3.211	0.001322 **
as.factor(shipname)湘南丸	0.263575	0.048969	5.382	7.35e-08 ***
as.factor(shipname)新りあす丸	-0.358324	0.047925	-7.477	7.61e-14 ***
as.factor(shipname)新宮城丸	-0.062584	0.128704	-0.486	0.626782
as.factor(shipname)新大分丸	-0.267975	0.053211	-5.036	4.75e-07 ***
as.factor(shipname)神海丸	0.385619	0.041444	9.305	< 2e-16 ***
as.factor(shipname)進洋丸	0.346862	0.044526	7.790	6.69e-15 ***
as.factor(shipname)青森丸	-0.697193	0.040909	-17.043	< 2e-16 ***
as.factor(shipname)千潮丸	0.074773	0.042678	1.752	0.079765 .
as.factor(shipname)船川丸	0.089931	0.042659	2.108	0.035017 *
as.factor(shipname)大分丸	-0.183509	0.050697	-3.620	0.000295 ***
as.factor(shipname)第一りあす丸	-0.128553	0.134386	-0.957	0.338771
as.factor(shipname)但州丸	0.316540	0.129226	2.450	0.014305 *
as.factor(shipname)長水丸	0.262865	0.055309	4.753	2.01e-06 ***
as.factor(shipname)鳥海丸	-0.020600	0.043551	-0.473	0.636214

```
as.factor(shipname)土佐海援丸       -0.628011     0.078623     -7.988 1.38e-15 ***
as.factor(shipname)福島丸            0.323763     0.036845      8.787   < 2e-16 ***
as.factor(shipname)北鳳丸            0.459832     0.118995      3.864 0.000111 ***
as.factor(shipname)雄山              0.259250     0.045468      5.702 1.19e-08 ***
as.factor(shipname)翔南丸三世       -0.125957     0.104534     -1.205 0.228227
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(2.6406) family taken to be 1)

    Null deviance: 23420  on 13016  degrees of freedom
Residual deviance: 15193  on 12956  degrees of freedom
AIC: 81305

Number of Fisher Scoring iterations: 1


              Theta:  2.6406
          Std. Err.:  0.0453

 2 x log-likelihood:  -81180.7580
```