DESCRIPTION OF US NORTH PACIFIC ALBACORE FISHING EFFORT ESTIMATES REPORTED TO THE WESTERN AND CENTRAL PACIFIC FISHERIES COMMISSION PURSUANT TO CONSERVATION AND MANAGEMENT MEASURE 2005-03

At its September 2018 meeting the Council assigned the HMSMT the following task:

> …analyze fishing effort in the West Coast North Pacific albacore fishery to support discussions at the IATTC [Inter-American Tropical Tuna Commission] about specifying effort limits consistent with Resolution C-05-02. Based on the comparable Western and Central Pacific Fisheries Commission (WCPFC) conservation and management measure, the WCPFC Northern Committee (NC) defined the effort limit as the 2002-2004 average level. A fishing effort analysis could also support a change in the NC effort definition, to harmonize it with any limit adopted by the IATTC.

In 2005 the WCPFC and IATTC adopted parallel measures limiting fishing effort for the North Pacific albacore fishery. These measures state:

- CMM 2005-03
  1. The total level of fishing effort for North Pacific albacore in the Convention Area north of the equator shall not be increased beyond current levels.
  2. The Members, Cooperating Non-Members and participating Territories (hereinafter referred to as CCMs) shall take necessary measures to ensure that the level of fishing effort by their vessels fishing for North Pacific albacore in the WCPF Convention Area is not increased beyond current levels.
- C-05-02
  1. The total level of fishing effort for North Pacific albacore tuna in the Eastern Pacific Ocean not be increased beyond current levels.
  2. The CPCs shall take necessary measures to ensure that the level of fishing effort by their vessels fishing for North Pacific albacore tuna is not increased.

Paragraph 4 in CMM-2005-03 describes reporting requirements: "All CCMs shall report annually to the WCPFC Commission all catches of albacore north of the equator and all fishing effort north of the equator in fisheries directed at albacore. The reports for both catch and fishing effort shall be made by gear type. Catches shall be reported in terms of weight. Fishing effort shall be reported in terms of the most relevant measures for a given gear type, including at a minimum for all gear types, the number of vessel-days fished." (Paragraph 3 states "All CCMs shall report all catches of North Pacific albacore to the WCPFC every six months…")

Regular reporting of catch and effort data for North Pacific albacore pursuant to the measure evolved over several years starting from 2007. Compilation and provision of the data was intermittent up to NC 11 (2015) when the WCPFC Secretariat began regularly providing a working paper to the NC summarizing catch and effort data provided by CCMs.

At least since 2008 the NC discussed using 2002-2004 as a baseline period to represent "current levels" specified in the measure. NC7 (2011) confirmed the decision to use 2002–2004 as the baseline (see paragraph 59 in the Summary Report).

The most recent paper reporting catch and effort data is WCPFC-NC14-2018/WP-01 (Rev.01), presented as Annex 1 to this paper. The US effort estimates in this paper are derived from ISC17/STATWG/WP-1, *Revision of Catch and Effort Estimates in the U.S.A. North Pacific Albacore Troll and Pole-and-Line Fishery*. This paper describes the methods used to estimate fishing effort and presents these estimates for 2000 through 2016, presented as Annex 2 to this paper (with authors' permission).[1]

In 2018 the IATTC adopted C-18-03, *An Amendment to Resolution C-13-03 Supplementing Resolution C-05-02 on North Pacific Albacore*. This measure requires CPCs to report retrospectively, 2013-2017, and annually by June 30 hereafter, those fisheries or fleets that caught North Pacific albacore in the Convention Area, which of those fisheries or fleets were targeting North Pacific albacore, and the annual catch by fishery or fleet. CPCs must also report fishing effort in fishing days and number of vessels. Two reporting templates are included under the measure, which are comparable in format to the tables in the NC working papers.

Figure 1 shows US fishing effort for North Pacific albacore for the entire North Pacific as reported in the STATWG working paper.[2]

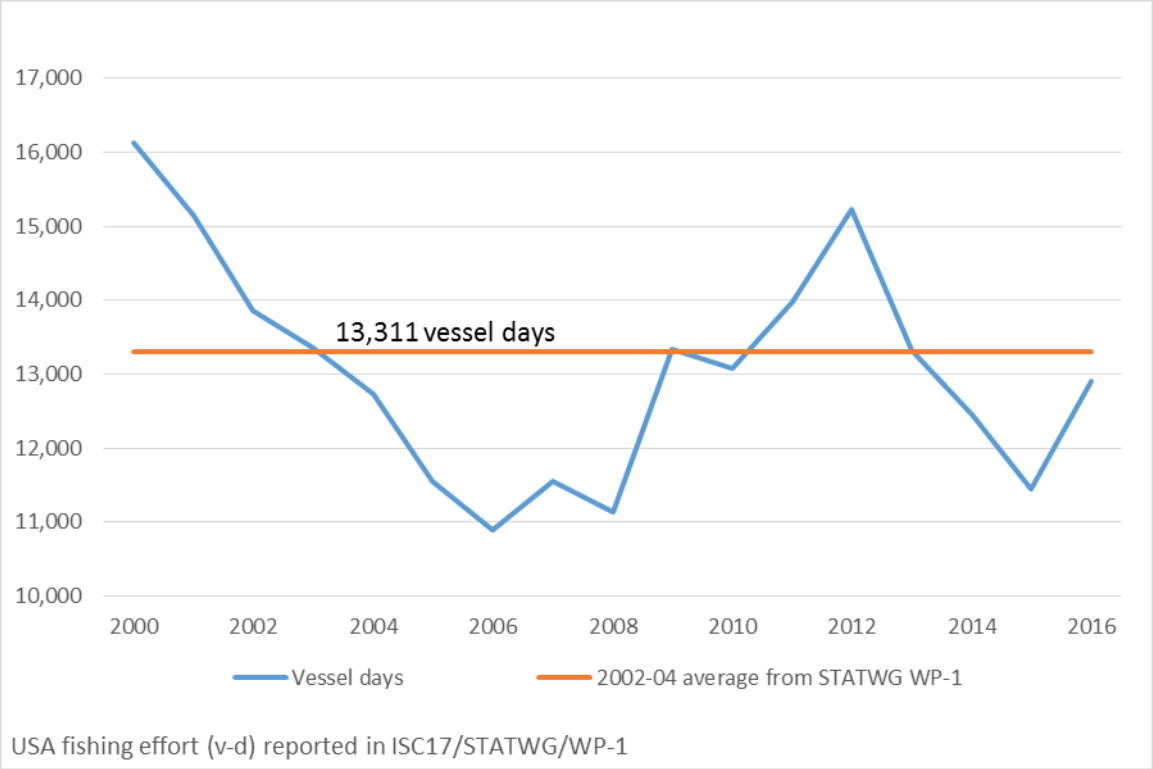

Figure 1. Fishing effort in vessel days, 2000-2016 reported in the ISC STATWG working paper. The same values for 2005-2016 are reported in WCPFC-NC14-2018/WP-01 (Rev.01).

[1] Note that fishing effort, characterized as vessel days in the NC working paper, is calculated based on days fished.
[2] In this time period very little US fishing effort for North Pacific albacore has occurred in the WCPFC Convention Area (in the North Pacific, west of 150°W longitude).

For comparison, Table 1 shows rolling 3-year averages of US fishing effort for the 2000-2016 time period. The average for the entire time period is slightly less than the 2002-2004 average. The averages for the years 2009-2011 to 2012-2014 are higher than the 2002-2004 average.

Table 1. Rolling 3-year averages of fishing effort, 200-2016.

Time Period	Average Effort
2000-2002	15,044
2001-2003	14,118
2002-2004	**13,311**
2003-2005	12,544
2004-2006	11,724
2005-2007	11,332
2006-2008	11,194
2007-2009	12,010
2008-2010	12,518
2009-2011	13,466
2010-2012	14,093
2011-2013	14,177
2012-2014	13,666
2013-2015	12,410
2014-2016	12,268
2000-2016	**13,064**

NORTHERN COMMITTEE
FOURTEENTH REGULAR SESSION
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Updated information on North Pacific albacore fishing effort
(Reference: Attachment C/Annex A in NC7 Summary Report)

WCPFC-NC14-2018/WP-01 (Rev.01)

Note:
1. Rev.01 – US effort data for 2016 and 2017 are fixed in Table 2.

Secretariat

Table 1. Average annual catch of North Pacific albacore (metric tonnes)

CCM	Data pertain to WCPFC Area only or entire N Pacific?	Fisheries with ANY catch of NP albacore	"Fishing for" NP albacore? (Y/N)	2006-2010 average annual catch
Canada	N Pacific total catches	Albacore troll	Y	5,911 ~~5,899~~
			Total catches for Canada:	5,911 ~~5,899~~
			Catches in fisheries "fishing for" NP albacore:	5,911 ~~5,899~~
			% of total catch in fisheries "fishing for" NP albacore:	100
China	N. Pacific	Longline	Y	1,967
	N. Pacific	Longline	N	98
			Total catches for China:	1,967
			Catches in fisheries "fishing for" NP albacore:	1,869
			% of total catch in fisheries "fishing for" NP albacore:	95
Note: Historically, there are 10 longliners seasonally operating in the high seas of Northern Pacific Ocean targeting albacore, which covered the Convention Areas of WCPFC and IATTC				
Cook Islands	N Pacific total catches	Albacore troll	Y	31
	N Pacific total catches	Longline	Y	8
			Total catches for Cook Islands:	39
			Catches in fisheries "fishing for" NP albacore:	39
			% of total catch in fisheries "fishing for" NP albacore:	100
Fiji				1.188mt
			Total catches for ~~Cook~~ Fiji Islands:	1.188mt
			Catches in fisheries "fishing for" NP albacore:	None
			% of total catch in fisheries "fishing for" NP albacore:	None
Japan	CA only	LL Coast	Y	16,817
		LL DW	Y	4,230
		PL Coast	N	89
		PL DW	Y	24,504
		PS Coast	N	14
		PS DW	N	1,841
		GN	N	430
		Troll	N	505
		Set Net	N	52
		Others	N	36
			Total catches for Japan:	48,518
			Catches in fisheries "fishing for" NP albacore:	45,551
			% of total catch in fisheries "fishing for" NP albacore:	94
Korea	CA only	LL DW	Y	18
	CA only	LL DW	N	157
			Total catches for Korea:	175
			Catches in fisheries "fishing for" NP albacore:	18
			% of total catch in fisheries "fishing for" NP albacore:	10
NOTE: Three LL DW participated in fishing for NP Albacore in 2007 and 2008, and the catch was 87 tons.				
Philippines	N Pacific	others	N	75

			Total catches for Philippines (average for 2009-2011):	75
			Catches in fisheries "fishing for" NP albacore:	0
			% of total catch in fisheries "fishing for" NP albacore:	0
NOTE: Catches are mainly from artisanal Hook-and-Line Gear (non-targeting ALB)				
Chinese Taipei	N Pacific	albacore LL	Y	2,548
	N Pacific	LL others	N	552
			Total catches for Chinese Taipei:	3,100
			Catches in fisheries "fishing for" NP albacore:	2,548
			% of total catch in fisheries "fishing for" NP albacore:	82
United States	N Pacific	Albacore troll	Y	12,344
		Longline	N	288
		Gillnet	N	3
		Pole and line	N	0
		Purse seine	N	23
		Other	N	577
			Total catches for United States:	13,236
			Catches in fisheries "fishing for" NP albacore:	12,344
			% of total catch in fisheries "fishing for" NP albacore:	93
NOTE: 1) These USA (2006-2010) data may not be confirmed from figures available to the Secretariat. 2) US response: See all our annual reports under CMM 2005-03, the latest of which is dated 30 April 2012.				
Vanuatu	CA only	LL	Y	2,660 ~~1,794~~
			Total catches for Vanuatu:	2,660 ~~1,794~~
			Catches in fisheries "fishing for" NP albacore:	2,660 ~~1,794~~
			% of total catch in fisheries "fishing for" NP albacore:	100
CA				
Note: Report is derived from Dorado report for CMM 05-03 of Catch of North Albacore North of the Equator				
Belize	CA only	LL	Y	95
			Total catches for Belize:	95
			Catches in fisheries "fishing for" NP albacore:	95
			% of total catch in fisheries "fishing for" NP albacore:	100
NOTE: catch unsegregated by area				
Federated States of Micronesia	CA only	LL	N	18
			Total catches for FSM:	18
			Catches in fisheries "fishing for" NP albacore:	0
			% of total catch in fisheries "fishing for" NP albacore:	0
NOTE: Commenced fishery in 2009				
Marshall Islands	CA only	LL	N	N/A
			Total catches for RMI:	
			Catches in fisheries "fishing for" NP albacore:	
			% of total catch in fisheries "fishing for" NP albacore:	
NOTE: Commenced fishery in 2008				
Vietnam	EEZ only	LL	N	13

Total catches for Vietnam (average of 2000-2011):	13
Catches in fisheries "fishing for" NP albacore:	0
% of total catch in fisheries "fishing for" NP albacore:	0
Note: Catches are mainly from LL only; and there is also possibility of wrongly identify by enumerators to account yellowfin and bigeye as albacore	

Table 1-1. Average annual catch of NP albacore during 2006-2010 (from Table 1)

Country	Target category	CA only	N Pacific
Canada	Target		5,911 ~~5,899~~
	Non-Target		0
China	Target		1,869
	Non-Target		98
Cook Islands	Target		39
	Non-Target		0
Fiji	Target		0
	Non-Target		1.188
Japan	Target	45,551	
	Non-Target	2,967	
Korea	Target	18	
	Non-Target	157	
Philippines	Target		0
	Non-Target		75
Chinese Taipei	Target		2,548
	Non-Target		552
United States of America	Target		12,344
	Non-Target		892
Vanuatu	Target	2,660 ~~1,794~~	3,109
	Non-Target	0	0
Belize	Target	95	
	Non-Target	0	
FSM	Target	0	
	Non-Target	18	
Marshall Islands	Target		
	Non-Target		
Vietnam	Target		0
	Non-Target		13
Total Catch			
		CA only	**N Pacific**
Total catch	Target	47,458	22,699
	Non-T	3,142	1,630
	Total catch	50,600	24,329
Proportion	Target	94%	93%
	Non-T	6%	7%
		100%	100%

Table 2. Fishing effort fishing for North Pacific albacore

CCM	Area[1]	Fishery[2]	2002-04 Average		2005		2006		2007		2008		2009		2010	
			No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days
Canada[3]	N Pacific	ALB troll	215	8,898	213	8,564	174	6,243	207	6,902	137	5,773	138	6,540	161	7,294
	CA[4] only	ALB troll	8	256	1	56	0	0	0	0	0	0	0	0	0	0
China	N Pacific	LL	10	1,250	10	1,230	10	1150	2	260	2	250	2	280	2	240
Cook Islands	N Pacific	ALB troll	4	183	2	240	2	171	1	57	1	0	0	0	0	0
	N Pacific	LL	1	2	1	4	0	0	1	37	1	17	0	0	0	0
Fiji	N Pacific	LL	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Japan[5]	CA only	LL Coast	296	40.988	289	41,197	287	43,366	273	43,480	276	40,030	280	43,536	286	45,877
		LL DW	633	26,851	591	21,548	538	21,186	494	21,712	480	17,823	361	12,060	342	13,084
		PL DW	141	19,839	134	20,442	125	16,059	106	16,931	104	15,667	104	15,248	101	15,541
Korea[6]	CA only	LL DW	13	1,072					3	268	3	107				
Philippines[7]	N Pacific	Handline														
Chinese Taipei[8]	N Pacific	ALB LL	25		23	2,363	24	4,156	21	3,360	18	2,603	13	2,082	20	2,093
USA	N Pacific	ALB troll		13,311		11,552		10,892		11,552		11,138		13,339		13,076
	CA only	ALB troll		789		371		66		42		*		*		*
Vanuatu	N Pacific	LL	26 ~~24~~	1,348 ~~2,496~~	37	4,394	55 ~~31~~	3,196 ~~3,112~~	36 ~~29~~	2,683 ~~3,279~~	41 ~~18~~	2,385 ~~1,483~~	30 ~~18~~	1,530 ~~1,661~~	28 ~~11~~	1,515 ~~313~~
Belize[9]													40		49	

* Data in the WCPO were confidential

[1] Data pertain to WCPFC Area only or entire N Pacific?
[2] Fisheries "fishing for" NP albacore
[3] NOTE: For Canada no fishing inside the CA since 2005
[4] Convention Area
[5] Japanese albacore data indicates the fisheries in north of the equator within CA.
[6] Korea's fishing effort "fishing for" NP albacore occurred in 2007 and 2008, and non-target fishing effort occurred every year in the North Pacific.
[7] Estimates under study
[8] This data just indicates the fishery fishing for NP albacore only
[9] Vessel number and effort was given for all species

Table 2 (continued). Fishing effort fishing for North Pacific albacore

CCM	Area	Fishery	2002-04 Average		2011		2012		2013		2014		2015		2016	
			No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days
Canada	N Pacific	ALB troll	215	8,898	161	8,556	172	5,974	183	6,465	160	4,747	164	5,197	152	5,359
	CA only	ALB troll	8	256	1	3	2	2	1	4	0	0	0	0	0	0
China	N Pacific	LL	10	1,250	10	1240	10	1280	10	1220	10	1290	10	900	10	910
Cook Islands	N Pacific	ALB troll	4	183												
	N Pacific	LL	1	2									2	22	1	68
Fiji	N Pacific	LL	0	0	0	0	9	230	29	920	20	663	10	88	8	170
Japan	CA only	LL Coast	296	40,988	273	42,996	266	38,977 ~~39,135~~	248	37,529 ~~37,522~~	246	35,362 ~~35,400~~	237	37.801 ~~32,771~~	229	37,179 ~~29,774~~
		LL DW	633	26,851	341	12,683	320	13,818	321	13,406 ~~13,367~~	305	13,305	285	11,763 ~~11,801~~	256	10,436 ~~10,761~~
		PL DW	141	19,839	98	13,433	95	14,646	85	12,781	84	12,147	84	12,743	81	13,923
Korea	CA only	LL DW	13	1,072	59	7,407		11,061		1,746		1,224		857		934
Philippines	CA only	Artisanal fishery (non-targeting)														
Chinese Taipei	N Pacific	ALB LL	25		21	1,839	21	1,423	22	2,108	22	2,348	23	2,401	24	2,259
USA	N Pacific	ALB troll		13,311		13,983		15,218 ~~15,520~~		13,509 ~~13,328~~		12,394 ~~12,451~~		11,734 ~~11,451~~		12,581 ~~12,902~~
	CA only	ALB troll		789		155		*		*		6		7		0
Vanuatu	N Pacific	LL	26 ~~24~~	1.348 ~~2,496~~	42 ~~34~~	2,338 ~~2,192~~	46 ~~28~~	1,189 ~~1,234~~	60 ~~41~~	3.337 ~~2,343~~	87 ~~58~~	3,695 ~~3,786~~	88 ~~49~~	3,702 ~~2,906~~	48 ~~45~~	2,183 ~~2022~~
Belize																

Italic = preliminary data

* Data in the WCPO were confidential

CCM	Area	Fishery	2002-04 Average		2017		2018		2019		2020		2021		2022	
			No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days	No. of vessels	Vessel days
Canada	N Pacific	ALB troll	215	8,898	121	4,978										
	CA only	ALB troll	8	256	5	100										
China	N Pacific	LL	10	1,250	10	850										
Cook Islands	N Pacific	ALB troll	4	183	0	0										
	N Pacific	LL	1	2	0	0										
Fiji	N Pacific	LL	0	0	7	147										
Japan	CA only	LL Coast	296	40,988	233	35,207										
		LL DW	633	26,851	253	10,505										
		PL DW	141	19,839	82	13,923										
Korea	CA only	LL DW	13	1,072		1,983										
Philippines																
Chinese Taipei	N Pacific	ALB LL	25		25	2,567 ~~1,211~~										
USA	N Pacific	ALB troll		13,311		12,545 ~~12,815~~										
	CA only	ALB troll		789		0										
Vanuatu	N Pacific	LL	26 ~~24~~	1,348 ~~2,496~~	69	2,615										
Belize																

Table 2-1. As requested by the NC12 (Paragraph 57) related to Paragraph 2 in CMM 2005-03, CCMs are requested to report on how to control their fishing effort fishing for North Pacific albacore by indicating, for example, limiting vessels, fishing days, licenses, or some other measures.

CCM	Area	Fishery	Regulation of fishing effort
Canada	N Pacific	ALB troll	Canada issues domestic "CT" fishing licences for Albacore Tuna. The CT licence is intended to act as a management measure to strengthen management of the domestic tuna fishery, and help ensure Canada is meeting international obligations related to effort. As of 2013, commercial licence holders wanting to harvest tuna are required to hold a primary licence (with Schedule II privileges) and apply for/receive a separate CT (Tuna) licence. The CT licence authorizes fishing of Pacific Albacore tuna in Canada's Exclusive Economic Zone (EEZ) and on the high seas under separate licence conditions. The CT licence is vessel-based and must be renewed annually. Canadian licence holders without a primary licence are able to access tuna in international high seas waters through "Section 68 High Seas" licenses. The Section 68 licence is intended to act as a management measure to strengthen management of the tuna fishery in the high seas, and help ensure Canada is meeting international obligations related to effort. The Section 68 licence must be renewed annually.
	CA only	ALB troll	Canada issues domestic "CT" fishing licences for Albacore Tuna. The CT licence is intended to act as a management measure to strengthen management of the domestic tuna fishery, and help ensure Canada is meeting international obligations related to effort. As of 2013, commercial licence holders wanting to harvest tuna are required to hold a primary licence (with Schedule II privileges) and apply for/receive a separate CT (Tuna) licence. The CT licence authorizes fishing of Pacific Albacore tuna in Canada's Exclusive Economic Zone (EEZ) and on the high seas under separate licence conditions. The CT licence is vessel-based and must be renewed annually. Canadian licence holders without a primary licence are able to access tuna in international high seas waters through "Section 68 High Seas" licenses. The Section 68 licence is intended to act as a management measure to strengthen management of the tuna fishery in the high seas, and help ensure Canada is meeting international obligations related to effort. The Section 68 licence must be renewed annually.
China	N Pacific	LL	
Cook Islands	N Pacific	ALB troll	Not Applicable, CK has no troll vessels in the fishery
	N Pacific	LL	Limited by license~~, numbers, only 2 vessels licensed in the high seas.~~
Fiji	N Pacific	LL	Vessel Size class & capacity, Licenses and other measures specified in Offshore Fisheries Management ~~Decree~~ Act 2012 & Offshore Fisheries Management Regulation 2014 and National Strategy for Fiji Fishing Vessels Operating in Areas Beyond National Jurisdiction.
Japan	CA only	LL Coast	The number of fishing vessels is limited by the license system.
		LL DW	The number of fishing vessels is limited by the license system.
		PL DW	The number of fishing vessels is limited by the license system.

Korea	CA only	LL DW	There has been no Korean flagged fishing vessel targeting for N.ALB. However, all authorized fishing vessels operating in the CA are required to report their catches including non-targeting species daily via the e-reporting system.
Philippines	-	-	Not applicable
Chinese Taipei	N Pacific	ALB LL	1.We have limited the number of our fishing vessels fishing for North Pacific albacore to stay below 25 since CMM 2005-03 was implemented. The vessel number is controlled when we issue the fishing permit every year. 2.For other fishing vessels that are not allowed to fishing for North Pacific albacore, their bycatches of this albacore would be monitored to stay below certain ratio
USA	N Pacific	ALB troll	The United States has a single fleet that fishes for North Pacific albacore in the Convention Area: the albacore troll fleet is based out of the U.S. West Coast. The albacore troll fleet is not currently subject to effort or catch controls, but permitting, VMS, and reporting (through vessel logbooks) requirements enable the United States to monitor the fishery, including levels of participation, fishing effort and catches. The United States will continue to monitor fishing effort and implement any controls needed to comply with paragraph 2 of the CMM, as well as with relevant decisions adopted in other RFMOs (IATTC).
	CA only	ALB troll	The United States has a single fleet that fishes for North Pacific albacore in the Convention Area: the albacore troll fleet is based out of the U.S. West Coast. The albacore troll fleet is not currently subject to effort or catch controls, but permitting, VMS, and reporting (through vessel logbooks) requirements enable the United States to monitor the fishery, including levels of participation, fishing effort and catches. The United States will continue to monitor fishing effort and implement any controls needed to comply with paragraph 2 of the CMM, as well as with relevant decisions adopted in other RFMOs (IATTC).
Vanuatu	N Pacific		~~We are~~Vanuatu currently reviewing its Fisheries~~our~~ ~~r~~Regulation to limit the control of fishing effort fishing for North Pacific albacore
Belize			
FSM			
Kiribati			
Mexico			
Vietnam			

Annex 2

ISC17/STATWG/WP-1

Revision of Catch and Effort Estimates in the U.S.A. North Pacific Albacore Troll and Pole-and-Line Fishery

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ABSTRACT

A reexamination of the calculation method for estimating total annual effort for the U.S.A. north Pacific albacore troll and pole-and-line fishery revealed that the use of a stratified CPUE, as described by Kleiber and Perrin (1991), significantly overestimates effort. Changes in U.S.A. fisheries regulations that now mandate the submission of logbook data from fisherman, has increased coverage rates. The review of the estimation of effort resulted in a change in the methodology from using stratified CPUE to using nominal catch ratios from logbooks along with total annual catch to estimate total annual effort. A comparison of the two time series show that the trends in annual effort remains consistent between the new and old method, however the previous method overestimated effort by a factor of two.

INTRODUCTION

In various fisheries, the summary statistic catch per unit effort (CPUE) serves directly and indirectly as an index of relative abundance. CPUE is commonly used in stock assessment and dynamic population models as an indicator of change (Glaser et al, 2011). Nominal CPUE estimates (catch, expressed as total number of fish caught, divided by total effort, expressed as days fished) from the north Pacific albacore troll fishery reflected an increasing trend between the years 1978 and 1988. Kleiber and Perrin (1991) showed that by stratifying CPUE, the resulting estimates showed a decreasing trend. This approach, in contrast to a nominal approach, was used to more accurately address the overall trend of increasing CPUE by mitigating some bias caused by time and location.

Catch and effort data for U.S.A. north Pacific albacore troll fishery are obtained from logbook information recorded by commercial fishermen of this fishery. These data are a sample of the total catch and effort from the fishery since logbook coverage rates are less than 100%. The High Seas Fisheries Compliance Act of 1995 required the submission of logbook data from U.S.A. vessels that fished on the high seas. In 2005 the Fishery Management Plan for U.S.A. West Coast Fisheries for Highly Migratory Species was established which also required submission of logbook data from all U.S.A. vessels that target Highly Migratory Species (HMS). Prior to 2005, annual logbook coverage rates were highly variable, ranging between 37% and 49% based on trip landing weights from

those vessels that submitted logbooks and those that did not. The changes in regulations increased these coverage rates to 77% to 95% from 2005 to present.

Total annual effort for the U.S.A. north Pacific albacore troll and pole-and-line fishery has previously been estimated using stratified CPUE estimates derived from logbook data and total annual catch (Eq.4). When logbook submissions became mandatory and coverage rates neared 100%, it became possible to ascertain a close approximation of the total annual effort by summing known effort from logbook data and only estimating the unknown effort without having to use an inferential method. A comparison of the effort estimated using stratified CPUEs with the summed nominal effort taken solely from logbook data shows that estimated values using stratified CPUEs are approximately twice the summed values from the logbook. This led to a more thorough investigation of the estimation process and shows that stratified CPUE is inappropriate for estimating total effort.

The previous method used to calculate total annual catch in number of fish converts annual total catches in metric tons (MT) to number of fish using a length-weight equation (Watanabe, 2006)[1] and average lengths obtained from a portside size sampling program. Recent improvements in reconciling data from received logbooks (referred to as “logbook” data) with landings data have resulted in better catch estimates for logbook trips between the years 2000 and 2016. The use of these improved logbook catch data provides a more appropriate average weight estimate to convert total catch weight to total number of fish (assuming that ratio of logbook weight to logbook effort is equal to the ratio of total weight to total effort). Revisions to catch and effort estimates are restricted to the years 2000 through 2016.

This paper presents a reexamination of the CPUE calculation methodologies and describes a revised, more appropriate method for estimating total annual effort, annual catch, and annual CPUE for the U.S.A. north Pacific albacore troll and pole-and-line fishery. Effort values obtained through the nominal method are shown to be more representative of true effort. Decadal changes in this fishery require the review of methods

[1] Following the function: $W = aL^b$, $a = 0.23 \times 10^{-4}$, $b = 2.98$

that calculate total effort, catch and resulting CPUE to determine the most appropriate methods. Effort estimates prior to 2000 are known to be significantly overestimated so those existing estimates will be removed and improved estimates will be provided when more appropriate estimation procedures are developed. This study establishes that the most appropriate method of estimating catch, effort, and CPUE for the years 2000 to 2016 in the north Pacific albacore troll fishery is to use a nominal approach.

METHODS

CPUE for the north Pacific albacore troll and pole-and-line fishery is a rate of catch and effort expressed as the number of albacore caught per fishing day. Both the stratified method and revised nominal method for estimating total annual effort assume that logbook catch and logbook effort are representative of the total catch and effort, respectively. Total annual catch data were taken from the most recent catgory I submission to the ISC.

Stratified CPUE Method

The stratified method for computing total annual effort is based on the stratified CPUE methodology described by Kleiber and Perrin (1991) where annual CPUE is estimated as the average of CPUEs computed from strata of 1° latitude by 1° longitude cells and 10-day periods where there is fishing effort. The stratified CPUE is calculated for each time-area strata ($CPUE_{TAU}$) using number of fish (C_i) and total effort (E_i) in days, at the *i*-th stratum:

$$CPUE_{TAU} = \frac{\sum C_i}{\sum E_i} \quad (1)$$

The overall stratified CPUE is calculated by taking the average of all time-area CPUE values:

$$CPUE_{STRAT} = \frac{1}{n}\sum_{i=0}^{n} CPUE_{TAU} \quad (2)$$

The stratified method used to estimate total annual effort ($E_{T,Strat}$) uses annual average fork lengths (FL_{avg}) obtained by port-sampling in combination with the currently accepted length-weight relationship (Watanabe et. al., 2006) to convert the total catch weight (W_T) into the total number of fish ($C_{T,Strat}$) caught for the year. This total number of fish was then used with the stratified CPUE to estimate total effort($E_{T,Strat}$):

$$C_{T,Strat} = \frac{W_T}{(2.30 * 10^{-8})(FL_{avg} * \ 10^{2.98)}} \quad (3)$$

$$E_{T,Strat} = \frac{C_{T,Strat}}{CPUE_{STRAT}} \quad (4)$$

Nominal CPUE method

Following the revised nominal method, logbook catch and total logbook effort data are summed in units of number of albacore caught and number of days fished, respectively. The conversion of total weight (W_T) to total number of fish (C_T) can now be more accurately estimated directly from logbook data:

$$C_T = \frac{W_T \ * C_S}{W_S} \quad (5)$$

Where C_S is sum of fish and W_S is the sum of landing weights from logbook data. Conversions from pounds to metric tons were performed using a conversion factor of 0.000453592.

The assumptions are made that the logbook catch and effort are proportionate to total catch and effort and that all sources of catch are known (total annual catch has 100% coverage). With these two assumptions the following equations relate the ratio of logbook catch (C_S) and total catch (C_T) in number of fish, to the logbook effort (E_S) and total effort (E_T), in vessel-days:

$$\frac{C_S}{C_T} = \frac{E_S}{E_T} \quad (6)$$

The total effort (E_t) can then be estimated using this equation:

$$E_T = \frac{E_S C_T}{C_S} \quad (7)$$

The nominal CPUE can be expressed as:

$$CPUE_{NOM} = \frac{C_T}{E_T} = \frac{C_S}{E_S} \quad (8)$$

RESULTS AND DISCUSSION

Logbook coverage rates in the albacore troll fisheries are calculated as the percentage of estimated landing weights for trips from which logbooks were received divided by the total estimated annual catch. Logbook coverage was the highest for the years 2006 through 2010, with rates ranging from 88 to 95%. Effort summed from the logbook data ranged from 9,151 to 13,290 vessel-days during these years (Table 1.b). The stratified method produces a range of 20,452 to 36,110 total annual vessel-days. The nominal method produces a range of 10,892 to 16,130 total annual vessel-days. Total catch estimates, in number of fish from the revised conversion process, demonstrated an insignificant variance compared to the stratified method (Table 1.a).

Average weights computed from port sampling data possess inherent bias due to the sporadic nature of sampling and sample availability. The sample sizes of logbook data are greater than that of port sample data by orders of magnitude and not subject to biases that are in port sampling. Thus logbook-based average weights are more appropriate to convert total catch in metric tons to number of fish for the calculation of CPUE.

Interannual trends of stratified and nominal CPUEs were similar, if not identical but with significantly different values. The increased logbook coverage rates did not play any significant role in the observed trends between nominal and stratified CPUEs (Figure 3). The nominal method produced CPUE values on average 192% greater than those produced by the stratified method. The low CPUE estimates from the stratified

method cause an overestimation of total effort. The increased logbook coverage rates, in combination with improved estimation of logbook catch in weight, indicate that stratified CPUE is not appropriate in estimations of effort. Nominal methodology produced a coefficient of variation (0.170), lower than that of the stratified (0.208).

Kleiber and Perrin (1991) stated that the high variability of CPUE within fishing grounds was the need for the stratified approach using strata of 1° latitude by 1° longitude cells and 10-day periods. The catch and effort time series shows that with its progression, the distribution of effort becomes more concentrated and the CPUE more evenly distributed. If the extreme outliers are removed from the data sets, the variability in the strata decreases significantly. Figures 4.a and 4.d demonstrate the decreasing dispersion from 2000 to 2016, with the removal of extreme outlier data. It is clear that outliers are a large factor in determination of CPUE homogeneity.

As dispersion decreases, the impact of low catch low effort time-area units becomes extremely disproportionate. Some of these areas of effort are explained as transit effort – effort made while the ship is running to and from fishing grounds (see region: Hawaii, figure 4.a). There are trips that are made solely for the purpose of transit, where small amounts of effort were made along the way. Some of these transit efforts are very far off shore, in locations where there generally is no effort nor history of recorded catch, mostly because it is not cost efficient. Unfortunately, there is no way in which to distinguish these transit vessel-days from other fishing vessel-days thus making it impossible to eliminate its bias. The elimination of extreme statistical outliers can only account for a portion of these efforts.

CONCLUSION

As indicated by Kleiber and Perrin (1991), periodic reevaluation of methods used to produce fisheries statistics are warranted due to the evolutionary changes in pelagic fisheries. It is particularly necessary to do so when using an inferential statistical method, especially in the far-ranging fisheries as environmental, technological, biological, and industrial and other factors change over time. The tendency to strictly adhere to “current

standard operating procedures" and failure to adequately adjust statistical methods when warranted has produced incorrect statistics that have been used in the past for fisheries management and assessment of commercially important fish stocks. Recent changes in regulatory requirements in the north Pacific albacore troll and pole-and-line fishery have resulted in increased amounts of logbook data becoming available that prompted a reevaluation of the estimation of total annual effort in that fishery.

The amount of effort offshore and the consequent importance of vessel size in the 1980's and 1990's, as investigated by Kleiber and Perrin, warranted the implementation of a stratified CPUE; however, the past twenty-two years have seen changes in fishing practices and overall distribution patterns for North Pacific albacore. The use of increasingly accurate logbook data combined with total annual catch estimates using a nominal method results in a much more robust estimation of total annual effort and CPUE in the current fisheries. This review of statistical methodologies has demonstrated that the use of stratified CPUE estimates to estimate total annual effort is inappropriate and results in inflated effort estimates. As data collections become more complete and accurate, analytical methods, such as CPUE calculation should be reviewed for appropriateness.

Year	Stratified Catch	Nominal Catch
2000	1,444,407	1,477,343
2001	1,692,367	1,739,926
2002	1,687,286	1,775,872
2003	1,623,719	1,657,303
2004	2,060,653	2,112,368
2005	1,142,555	1,169,792
2006	1,905,266	1,938,320
2007	1,676,580	1,709,448
2008	1,749,595	1,776,819
2009	1,843,242	1,871,898
2010	1,556,308	1,581,111
2011	1,374,825	1,396,711
2012	2,022,029	2,053,768
2013	1,554,674	1,579,730
2014	1,686,963	1,714,156
2015	1,692,757	1,717,261
2016	1,547,398	1,480,258

(a)

Year	Stratified Effort	Nominal Effort
2000	36,110	16,130
2001	25,259	15,148
2002	25,565	13,854
2003	21,650	13,351
2004	23,961	12,729
2005	21,972	11,552
2006	21,170	10,892
2007	22,354	11,552
2008	24,994	11,138
2009	24,253	13,339
2010	23,943	13,076
2011	27,496	13,983
2012	34,863	15,520
2013	22,532	13,328
2014	28,116	12,451
2015	27,303	11,451
2016	20,452	12,902

(b)

Year	Stratified CPUE	Nominal CPUE
2000	40	93
2001	67	119
2002	66	128
2003	75	142
2004	86	168
2005	52	106
2006	90	188
2007	75	152
2008	70	158
2009	76	148
2010	65	131
2011	50	108
2012	58	143
2013	69	135
2014	60	154
2015	62	161
2016	72	126

(c)

Table 1. Comparison of catch **(a)** in number of fish effort in vessel-days **(b)** & CPUEs **(c)** produced by the stratified and nominal methods.

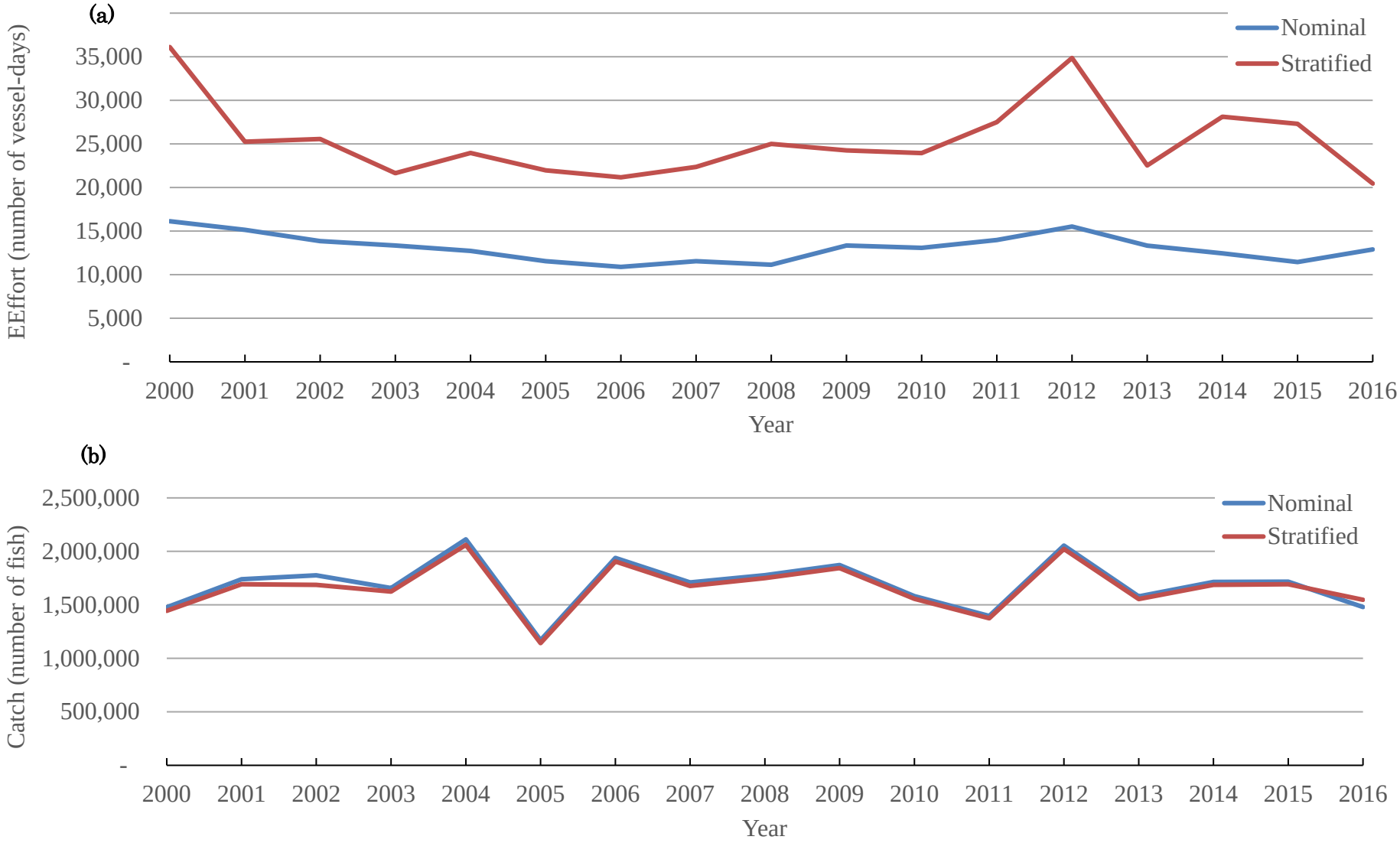

Figure 1. Estimated effort **(a)** and total catch **(b)** produced by the nominal and stratified methodologies.

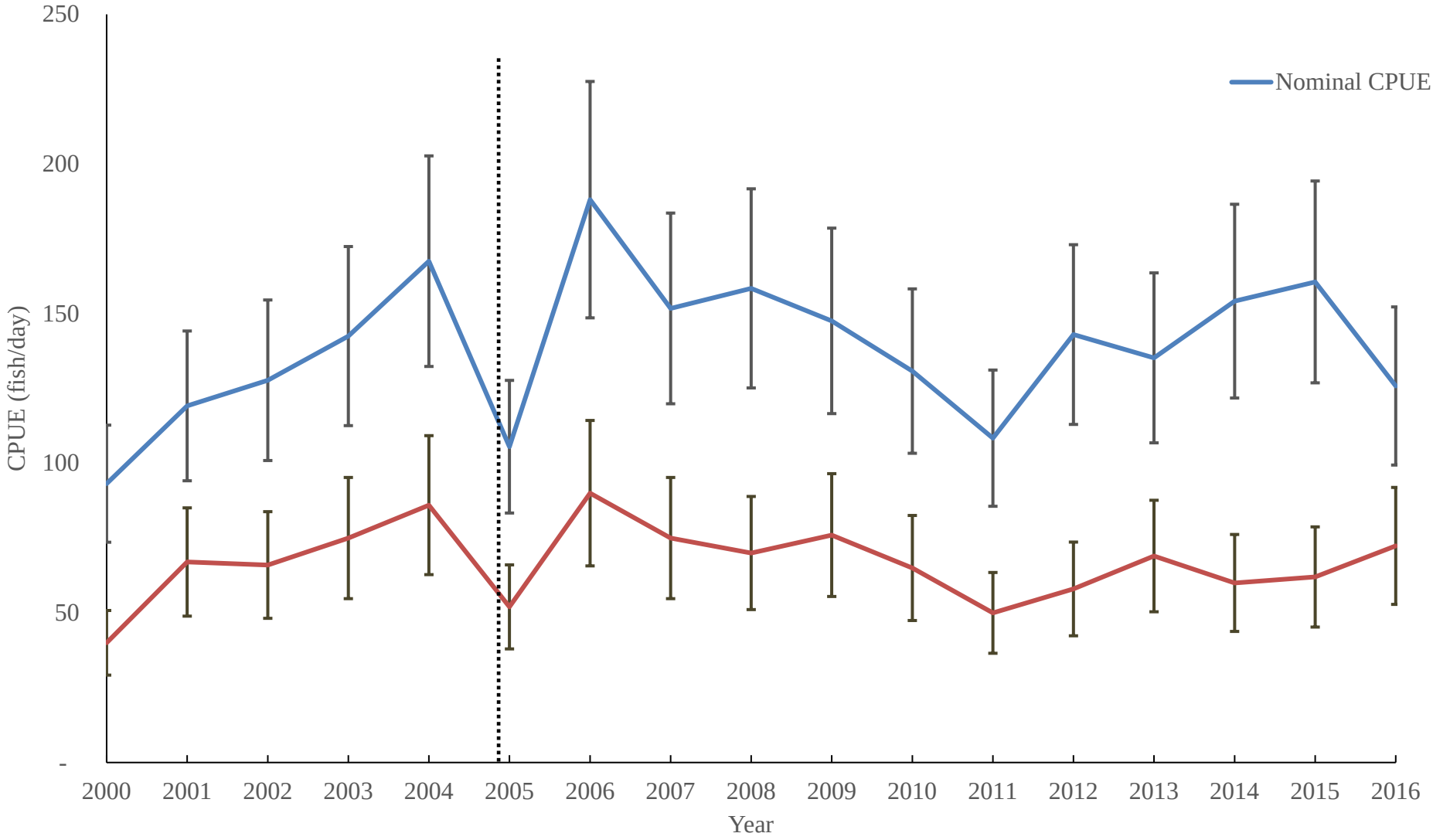

Figure 2. Comparison of Nominal & Stratified CPUE; vertical bar denotes changes in HMS regulations.

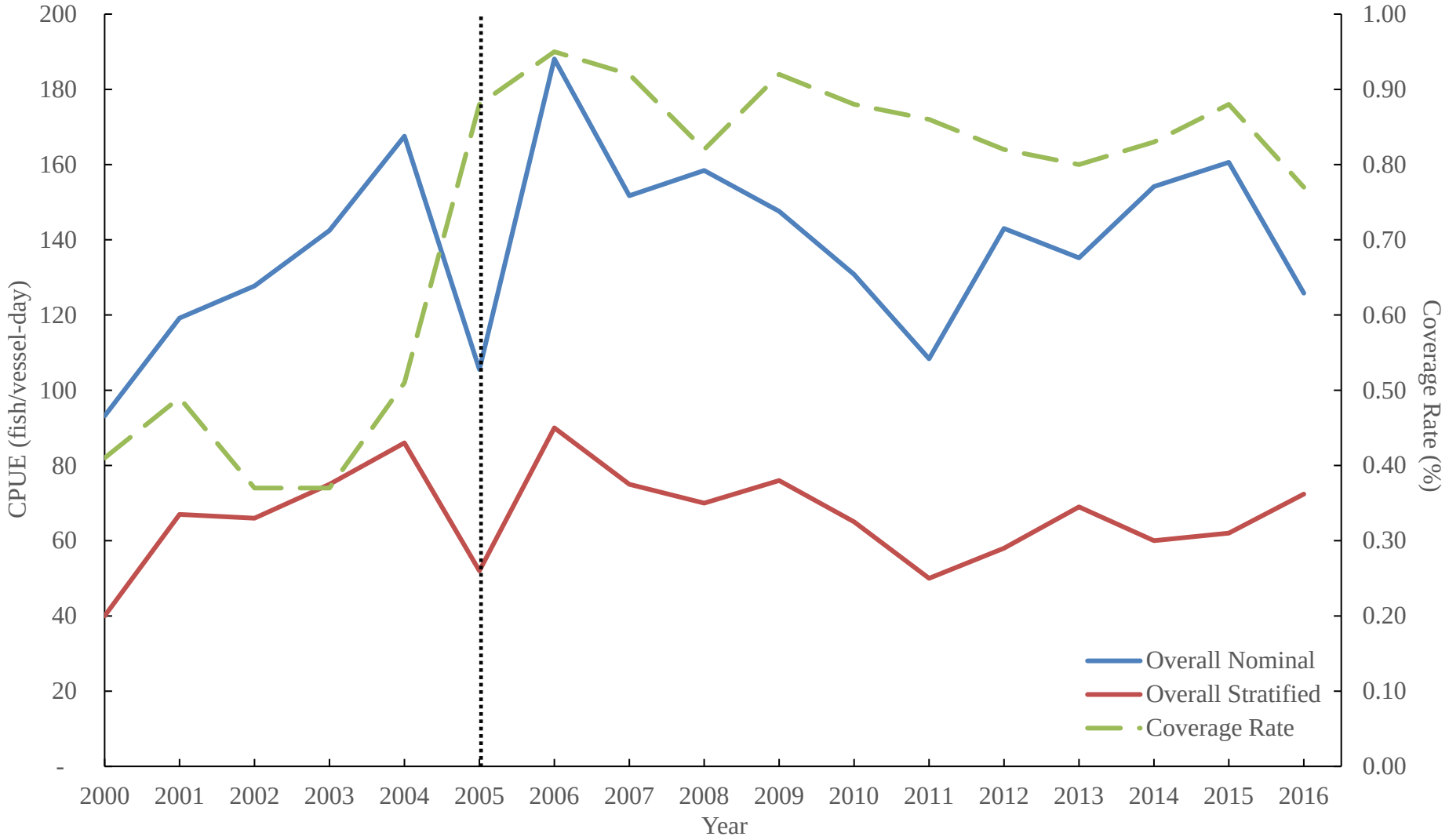

Figure 3. Comparison of Nominal & Stratified CPUE (left axis) & coverage rate (right axis); vertical bar denotes changes in HMS regulations.

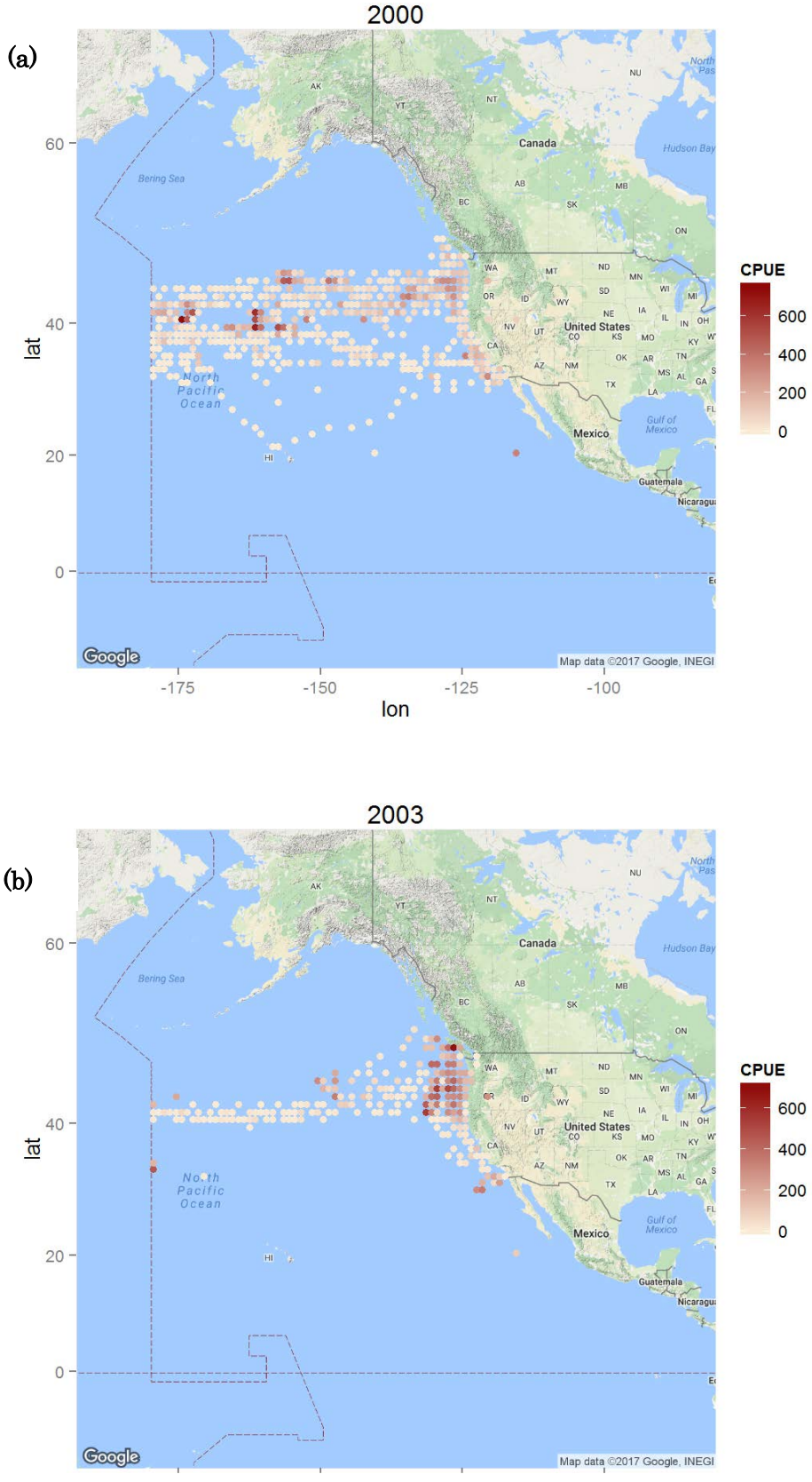

Figure 4. CPUE distribution across the North Pacific in 1° latitude by 1° longitude cells with extreme outliers removed. 2000 **(a)** & 2003 **(b)**

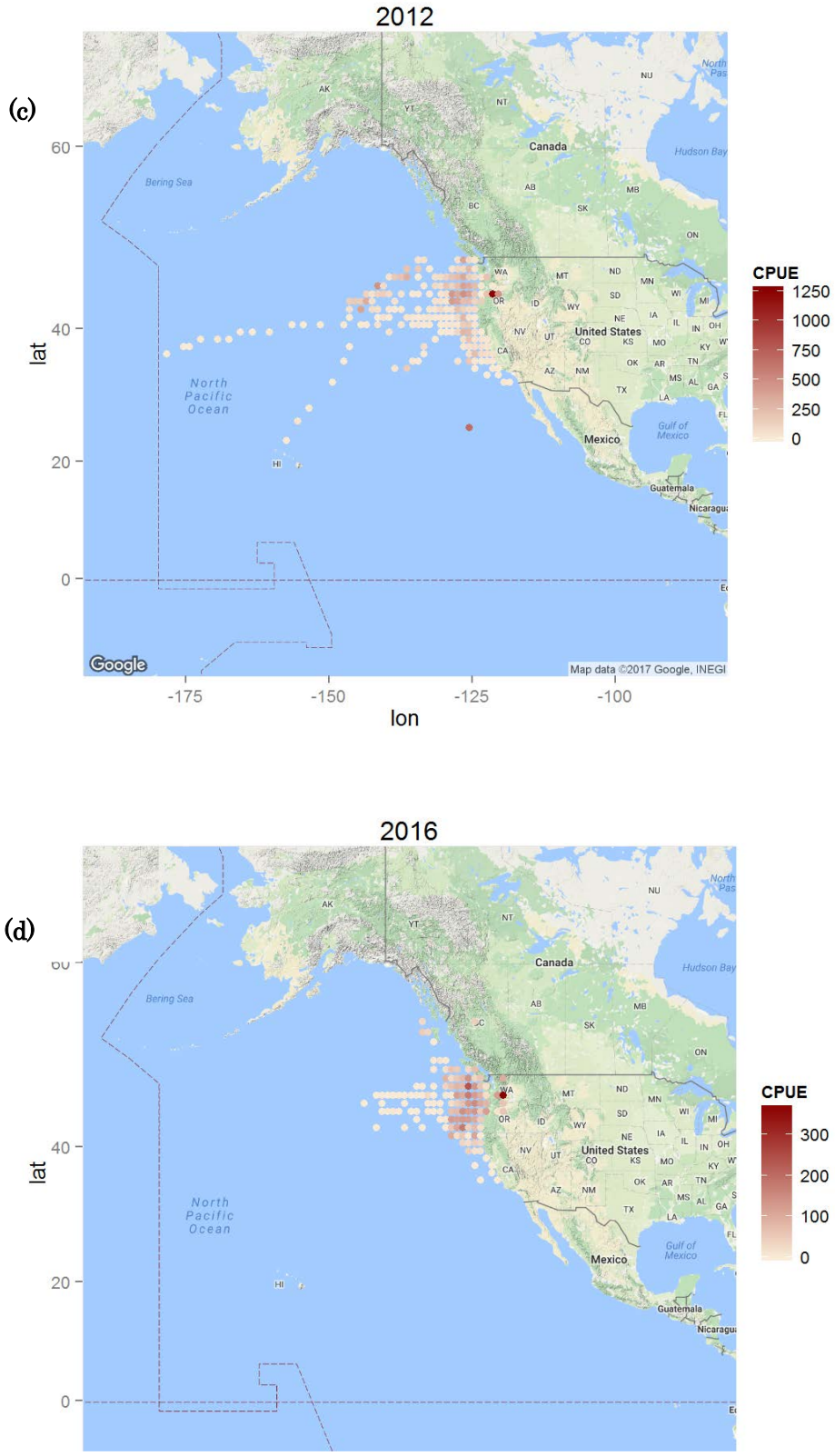

Figure 4. CPUE distribution across the North Pacific in 1° latitude by 1° longitude cells with extreme outliers removed. 2012 **(c)** & 2016 **(d)**

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