PROGRESS REPORT OF THE WORKING GROUP ON MULTI-NATIONAL PELAGIC LONGLINE INDEX FOR WESTERN ATLANTIC BLUEFIN TUNA

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SUMMARY

This document represents a meeting report of a small working group that convened to evaluate the feasibility of combining set by set data from the Japan, Canada, Mexico and United States pelagic longline fishing fleets to obtain a CPUE index for Western Atlantic Bluefin tuna, while maintaining data confidentiality. The group was successful in combining datasets, assigning relevant environmental and gear variables and produced a dataset of 99,054 individual longline sets over the years 1992-2015 from the Gulf of Mexico and the Atlantic Ocean north of 30ºN latitude and west of 45ºW longitude. This represents the most comprehensive collection of set-by-set longline data for Western Atlantic bluefin tuna yet compiled. The recommended next step is to convene another small working group to evaluate alternative statistical modeling approaches and diagnostics for creating a combined index, focusing on whether the statistical models can account for the very different target and non-target fishing strategies of each CPC.

RÉSUMÉ

Ce document représente un rapport de réunion d'un petit groupe de travail qui s'est réuni pour évaluer la faisabilité de combiner des données recueillies opération par opération auprès des flottilles palangrières pélagiques du Japon, du Canada, du Mexique et des Etats-Unis pour obtenir un indice de CPUE pour le thon rouge de l'Ouest, tout en maintenant la confidentialité des données. Le groupe est parvenu à combiner des jeux de données, en attribuant des variables pertinentes liées à l'environnement et à l'engin et a élaboré un jeu de données de 99.054 opérations palangrières individuelles de la période 1992-2015 du golfe du Mexique et de l'océan Atlantique au nord de 30ºN de latitude et à l'ouest de 45ºW de longitude. Ceci représente la collecte la plus exhaustive de données palangrières opération par opération pour le thon rouge de l'Atlantique Ouest ayant été élaborée. La prochaine étape recommandée consiste à convoquer un autre petit groupe de travail afin d'évaluer d'autres approches de modélisation statistique et diagnostics en vue de créer un indice combiné, en se concentrant sur la façon dont les modèles statistiques peuvent tenir compte des stratégies de pêche très différentes, ciblées et non ciblées, de chaque CPC.

RESUMEN

Este documento presenta el informe de la reunión de un pequeño grupo de trabajo que se reunió para evaluar la viabilidad de combinar los datos lance por lance de las flotas pesqueras de palangre pelágico de Japón, Canadá, México y Estados Unidos para obtener un índice de CPUE para el atún rojo del Atlántico occidental, manteniendo a la vez la confidencialidad de los datos. El grupo tuvo éxito a la hora de combinar los conjuntos de datos, asignando variables medioambientales y de arte pertinentes y elaboró un conjunto de datos de 99.054 lances individuales de palangre a lo largo de 1992-2015 procedentes del golfo de México y del océano Atlántico al norte de 30ºN de latitud y al oeste de 45ºW de longitud. Esto representa la recopilación más exhaustiva de datos de palangre lance por lance para el atún rojo del Atlántico occidental que haya sido nunca realizada. El próximo paso recomendado es reunir otro pequeño grupo de trabajo para evaluar diagnósticos y enfoques de modelación estadística alternativos para crear un índice combinado, centrándose en si los modelos estadísticos pueden tener en cuenta las muy diferentes estrategias de pesca dirigida y no dirigida de cada CPC.

KEYWORDS

Bluefin tuna, CPUE standardization, longline

Background

The concept of combing catch and effort data from multiple longline fisheries for western Atlantic bluefin tuna has evolved from the SCRS's concern over existing CPUE indices. Temporal and spatial changes to fisheries, as well as management initiatives, led to recommendations for member countries to examine methods to improve existing indices of abundance and to explore options to develop fishery independent indices for both eastern and western stocks. The "Second meeting of the working group of fisheries and managers and scientists in support of western Bluefin tuna stock assessment" (ICCAT 2014-13), July 10-12, 2014, identified a number of potential new indices and improvements for current ones. Participants included managers and scientists from Canada, Japan and the United States. One conclusion agreed upon by the parties, was to explore the possibility of combining the longline CPUE data from several CPCs to create a new index of abundance and to broaden the spatial and temporal coverage.

Unfortunately, a major challenge on how to combine the data in a non-aggregated (set by set) form developed due to the confidentiality requirements of several CPCs. The problem was not so much with the pooling of the data but the spatial scale at which the data need to be made available to combine the datasets. This delayed the process for several months as the rules and regulations regarding the confidentially differed among CPCs. Several informal discussions among the CPCs were held to look at the options for pooling these data while respecting the confidentiality of each country. This led to the development of a methodology (Lauretta *et al*., 2016a) that permitted the inclusion of set by set information without violating the confidentiality of the data. The approach was successfully implemented when scientists from Canada and the USA met during the summer of 2015 to combine their data (Lauretta *et al*., 2016b). Further discussions on how to make pooling possible occurred at the 2015 SCRS meeting. It was agreed that 1-2 scientists from Canada, Japan, Mexico and the USA would meet during the year to explore mechanisms for utilizing each countries data and to investigate if the longline data can be pooled given the substantial differences in target species, temporal and spatial distribution of fishing, and gear configuration of the fleets. Through the efforts of all CPCs involved, the first meeting of this small working group was held July 20-23, 2016, in Cercedilla, Spain.

Introduction

During the 2015 SCRS species meeting it was agreed that interested CPCs would collaborate to investigate the feasibility of combining pelagic longline data into a non-aggregated database. The specific objective of the working group was to investigate if combining raw catch/effort data was appropriate by first checking 5x5 aggregated data, and to explore approaches for combining the data. To facilitate analytical procedures, each participant agreed to bring their national data in a format that could be evaluated according to predefined specifications. Additional information necessary to evaluate the feasibility of combining CPUE datasets (such as regulatory impacts, fleet changes, etc) was also requested to be made available.

The small working group met in Cercedilla, Spain from July 20 to July 23, 2016, with Dr. Walter from the U.S. in the chair. Logistics for the meeting were coordinated by the Chair. Careful and detailed consideration was given to specific fishery characteristics to avoid misinterpretation that may result from a multi-fleet index. Factors such as spatial and temporal distribution of the fishery, gear configurations, the nominal CPUE (catch per unit effort), and the size of fish caught for each fishery were compared to evaluate if the datasets can be combined into a single index. One of the key outcomes of the meeting was that it illustrated the positive results of collaboration among CPCs and the enhancement of our mutual understandings on the characteristics of fisheries among participants.

Methods

The first day of the meeting was devoted to better understanding the fisheries and their associated data, mainly because of the diversity of fishing strategies and as a part of pelagic longline data from some CPCs has not been fully utilized in the stock assessment for the western Atlantic bluefin tuna. Each CPC provided an overview of their fishery; and potential differences between datasets and challenges in combining datasets were discussed. Where multiple datasets were available (e.g., observer vs logbook) a decision was made on which set was most appropriate. A summary of the data characteristics for each CPC is provided in **Table 1**.

Processing of individual CPC datasets

Initial processing of each dataset was conducted by each CPC. From the raw set-by set data each data set was processed with standard code (Lauretta *et al*., 2016) to assign 5x5 latitude and longitude, sea surface temperature and to remove confidential set information (**Appendix 1**). A listing and brief description of the data columns is provided in **Appendix 2**. Some specific variables require some further clarification and are described below.

Hook_Size and **Hook_Type** were reported exactly as found in CPC dataset and will require some further consideration of the appropriate categories for the combined dataset. This is also the case for **Bait_Type** (recorded as live, dead, artificial or NA) and **Bait_Kind** (recorded as a mixture of categories that have not been harmonized across datasets) For **DAY_NIGHT** sets that started in the a.m. between 2400 and 1200 hours were identified as day sets as the gear fished primarily during the day. For sets that started between 1200 and 2400 were identified as night sets as the gear fished primarily at night. Generally, however, sets were very similar in starting in either the early morning (day) or evening (night) such that day versus night sets were very straightforward to isolate. Linear length of a set from the first bouy to the last bouy was used as the measure of mainline length (**MainLineLength**). This is generally a shorter distance than the total length of mainline paid out from the spool due to sag in the line and meanders in the set. The reduction in linear distance of a section (portion between floats) due to sag is called the shortening ratio which was assumed to be 80% and is used in the calculation of maximum depth of hooks, below. A shortening ratio of 80% is commonly found for the Japan longline fleet so this factor was applied to all other fleets where this variable, or the length of line paid out from the spool, was not reported.

Determination of minimum and maximum depth of hooks on a set

The hooks per basket (HPB) is usually recorded in the longline data and often used in standardization of CPUE as a proxy for gear depth. However, this information is considered confidential for some CPCs and could not be reported in the shared dataset. Instead we have calculated an approximate metric for the depth of the gear based on minimum, maximum and average hook depth. Due to the limitation of the availability of the data for each flag, the calculations for minimum and the maximum hook depths were simplified, although the theoretical catenary curve equation has been commonly used to obtain hook depths for longline (Yoshihara, 1951 and 1954, and Bigelow *et al*., 2006).

The minimum depth (**Min_Depth**) is recorded in the US observer data as the sum of lengths of float (or drop) lines and branch (or gangion + leader) lines (**Figure 1**). While the picture depicts the branch line set just below the float line, which is not the gear configuration for all flags, this assumption provides a minimum hook depth used for easy comparisons. The maximum hook depth (**Max_Depth**) was determined from summing the minimum depth with the estimated sag depth that the deepest hook could reach, assuming that the drop could be characterized by a right triangle facing downward (Figure 1), with the drop equal to the length of *d*. This distance can be determined from the length of side *h* which is ½ the distance between floats and length of the hypotenuse *z* using the Pythagorean Theorem where:

$d = sqrt(z^2 – h^2)$; eq 1

The distance *z* is obtained from the shortening ratio where $z= h/SR$ with an assumed shortening ratio of 80%. The length *h* is obtained from a relationship between the number of hooks between floats and the distance between floats estimated from 11,309 observed values collected by Canadian observers on Canadian (3,316) and Japanese (7,259) longline vessels (**Figure 2**) fishing in the Canadian EEZ (a small number of Faroese and US records were also included). The data spanned 38 years of fishing from 1978 to 2015 and fitting a linear regression to it resulted in estimated linear coefficients of intercept =63 and slope=35.5 with an R^2 of 0.81; producing the following relationship:

Distance_between_floats=63+35.5*HPB; eq 2

h= Distance_between_floats/2; eq 3

The resulting equation for the distance *d* is then:

$d = 0.75*h$; eq 4

Then the maximum depth was obtained by adding the lengths a, b and d in Figure 1. The average depth (**Ave_Depth**) was then approximated by:

(**Min_Depth** + **Max_Depth**) /2;   eq 5

While the average hook depth is unlikely to represent the true depth of the gear, it serves as an approximate proxy in the CPUE standardization to reflect whether fishing gear is set deeper or shallower, in a relative sense.

Spatial partitioning within Gulf of Mexico

The spatial area partitioning for the Gulf of Mexico was loosely based on the areas used in the US index and the areas determined for the joint Mexico-US YFT index (SCRS/2001/67). The Gulf of Mexico was partitioned into 5 areas (**Figure 3**). The first area corresponds to the southwest Gulf of Mexico fishing grounds, adjacent to Veracruz. The second area is the southcentral area. The third area is the Northwestern Gulf of Mexico which overlaps US and Mexican EEZ waters. This area is the primary area of overlap between the US and Mexican fleet. The fourth area is the Eastern Gulf which is primarily fished by the US fleet. The fifth area corresponds to the BFT closure for April and May which was first closed in 2015. These two areas were made a separate area. Previous treatments of area closures have removed all of the data from the time period and area of a closure through the entire time series. However this would have removed a substantial fraction of the BFT catches for the US fleet. Hence it was deemed more appropriate to make this a separate area. All of the sets that occurred in the Desoto closed area were removed from the entire analysis dataset.

Data sources and description of fisheries

Japan

There are two potential sources of BFT data for the Japan longline fleet; logbooks and observer. The group decided to use the logbook data due to low observer coverage in some years. Further support for the logbook dataset came from the fact that since BFT are a target species and not discarded the logbook data would reflect the total catch. The general time frame of fishing operations for WBFT is November-January but after the introduction of individual quotas (IQ) and a limited entry system, voluntarily since August 2007 and by law August 2009 (Japan, 2012) the fishery gradually has started and ended the fishing season earlier, beginning in early September. In recent years there has also been a reduction in the total amount of effort due to the introduced systems.

Sets generally occur only in the morning (set starts at 0600) and no gear is set at night (**Table 1**). The total number of hooks averages ~2700 hooks, the length of line set is ~130 km with a total shortening ratio of about 0.8 yielding a linear distance of a set (called mainline length in **Table 1**) of 104 km, the length of branch line is consistently ~40 m and the fishing gear is very consistent between years (**Figures 6, 7**). The depth of hooks averages around 112 m. To be consistent with the datasets considered in the Japanese longline index (Kimoto *et al*., 2016) only data from north of 30ºN is used. However the temporal timeframe is expanded to the months of August-March, rather than only the main BFT target fishing season of November-February as is used in the current Japan index.

Canada

The Canadian directed fishery for BFT is predominantly a hook and line fishery. However, significant BFT are taken as bycatch in the swordfish longline fishery in summer and early fall which has extensive observer coverage over the years. Observer coverage ranged from 5-20% of trips with a general target of 5%. The longline gear is generally set at night, mainline length is approximately 46 km in length, and with a total number of hooks ~1050 hooks per set. Depth of hooks averages around 47 m based on the average of the minimum and maximum hook depth (Table 1). Float line length is ~8m and the distance between floats about 180 meters. The length of branch line is consistently ~6.5 m with 3-6 hooks per basket (**Table 1, Figures 6, 7**).

United States

The United States pelagic longline fishery operates throughout the Western Atlantic and Gulf of Mexico. Swordfish, yellowfin and bigeye tuna are the predominant target species and BFT are generally not targeted, though they are sometimes retained and sold. Numerous time and area restrictions have applied to the U.S. fleet, many of which represent measures designed to reduce bycatch of BFT. In the Gulf of Mexico, the U.S. fleet sometimes used live bait until it was prohibited. Since August 2004 the U.S. fleet was required to use circle hooks, and since 2011 it is required to use a weak wire circle hook in the Gulf of Mexico during the bluefin spawning season so that large BFT can bend the hook and be released. Observer coverage is approximately 8% of all trips with up to 100% coverage in the Gulf of Mexico during the BFT spawning season in recent years. While both observer and logbook data (which represents a theoretical census of all effort) is available, for this exercise we use the observer recorded catch and effort as it is thought to accurately record discarded fish.

The U.S. fleet shows the greatest diversity of gear characteristics, particularly a mix of number of hooks, wide range in the depth of fishing, the length of the mainline, and time of day of set (**Table 1, Figures 6, 7**). Gear characteristics differ between the Atlantic and the Gulf of Mexico. Longline gear in the Atlantic is set generally at night with 57m average depth in summer-fall, while the gear is set at both day-time and night with 94m depth in spring-early summer in the Gulf of Mexico. The mainline length is approximately 45km in length with a total number of hooks ~739 hooks per set in the Atlantic, while those are 53km and ~628 hooks per set in the Gulf of Mexico. To be consistent with the data used for Japan, all U.S. longline data in the Atlantic south of 30ºN was removed from this analysis.

Mexico

For the Mexican longline fleet, bluefin tuna is also a bycatch species resulting from directed fisheries for yellowfin. Data are available at a set by set level starting in 1993 with 100% observer coverage beginning in 1997. Most sets are in the early morning and soak during the day. Gear retrieval begins about 2000 hours. Mean length of a set is about 64 km and mean depth of fishing is ~106 m with approximately 630 hooks per set (**Table 1, Figures 6, 7**). The Mexican fleet often uses live bait, though a mixture of live and bait types if used. Bait is recorded per trip so it is not possible to assign bait type to a particular set. To determine the maximum depth of fishing it was necessary to assume that the entire Mexican fleet fishes with 4 hooks between floats, which appeared quite consistent with the raw datasheet observations.

Results

The initial exploration of the data involved plotting spatial and temporal maps of longline effort for each fleet to determine if there were spatial and temporal areas of overlap that would permit and evaluation of consistent patterns in nominal catch rates using 5x5 aggregated data (**Figure 4**). From evaluation of the effort a 'core' time/area of overlap was identified (red polygon in Figure 4, continued) over the months of August, September and October where there was substantial effort in number of hooks and in number of sets for Canada and U.S., whereas there was about 10% of total number of hooks or sets for Japan (**Figures 5, 6**). Effort in hooks, number of sets, nominal mean CPUE for all sets and effort, sets and CPUE of just positive sets show some relatively consistent patterns among the fleets (**Figure 5**). Of note, the absolute level of mean CPUE (measured as the number of BFT/1000 hooks) or the mean of the positive CPUE was not dramatically different for the different fleets (**Figure 5**), when viewed in the core time/area. Time series trends show some variability but also some correlation for certain years for different fleets, indicating that they may reflect some similar patterns in abundance, though the nominal trends were not always in agreement. Nonetheless these patterns only reflect nominal CPUE and may not be expected to exactly match. Hence the group felt that some of these differences might be reconciled by gear configuration, month, environmental variables, regulatory impacts or other factors that would be considered in statistical standardization. Hence the group felt that these plots did not rule out the potential that the datasets could be combined in a meaningful manner and that these plots provided justification for proceeding with combining the datasets into a common format.

Set by set data from each CPC was then processed through the R script that removed confidential information and harmonized data fields (**Appendix 1**). The combined dataset then consists of 99,054 individual longline sets over the years 1992-2015 (Table 2), with 3,123 sets (3,092,991 hooks) from Canada, 23,622 sets (64,182,354 hooks) from Japan, 55,720 sets (33,994,741 hooks) from Mexico and 16,589 sets (10,838,307 hooks) from the U.S. (6,577 sets with 4,903,917 hooks in the Atlantic, and 8,723 sets with 5,934,390 hooks in the Gulf of Mexico). An additional dataset from Canadian observers onboard Japanese vessels fishing in Canadian waters between 1982 and 2002 was provided but requires further evaluation before it can be considered part of the combined dataset as there may be some overlap with existing Japan data and it is not clear if the catch rates reflect the entire set.

The combined data set provides a simple way of evaluating the differences between each fleet in fishing characteristics. Japan clearly set both greater numbers of hooks and longer lines while also generally fishing exclusively deep sets (**Figure 6**). U.S. and Canada fished a mix of different numbers of hooks and lengths of lines, while Canada also fished shallowest sets and U.S. in the Atlantic fished shallower than in Gulf of Mexico. The Mexico fleet fished almost as deep as Japan, with a relatively homogenous numbers of hooks and mainline lengths. Furthermore both Canada and Japan show strong seasonality to their fishery while U.S. and Mexico have relatively constant effort over all months (**Figure 6**). U.S. also shows gradual seasonal shift from the Gulf of Mexico to the Atlantic. Each fleet exhibited rather unique spatial and temporal patterns (**Figure 7**) though there was some overlap. Canada and Japan fished primarily the more northerly latitudes (though Japan and U.S. data from south of 30ºN in the Atlantic was not included); Mexico fished only in the Gulf of Mexico where U.S. also overlapped. Furthermore there were clear differences in the predominant SSTs fished by the different fleets, with the US and Mexico fleets fishing more often warm SSTs while the Japan fleet showing many sets below 20ºC (**Figure 7**). Lastly, the fleets also strongly differentiated between whether they were predominantly day or night sets. These clear differences in environmental and gear (area, depth fished, day vs night) - and the overlap that exists- may provide critical links that allow the statistical modeling to differentiate between BFT-targeted and BFT-bycatch fleets.

Conclusions and next steps

The outputs from this working group represent the first big steps in a sequential process to evaluate the potential for combining the catch and effort data from multiple fleets. Major advancements have been made in preparing the data for evaluation through the cooperation of participating members to share their data in a manner that preserves confidentiality. Initial analysis suggests that it may be possible to combine some or all of the datasets into a multi-fleet index with broad temporal and spatial coverage. However, in its present state the data is considered preliminary and will require further exploration by each CPC to fully vet the datasets and identify any data outliers and to harmonize the hook type and bait type categories and to assign the depth of seafloor and other potential environmental variables such as moon illumination.

Overall the meeting was extremely successful and exceeded the expectations of the working group. The meeting allowed a full understanding of each CPC fishing fleet, time to address many issues related to harmonizing the datasets- though several still remain- and allowed CPCs to reach the decision to combine the datasets for the purpose of exploring whether the different fleet data can be statistically modeled to produce CPUE indices in the future.

The group outlined the following conclusions:

- The data could be combined while preserving confidentiality
- Several key gear characteristics and environmental covariates that define targeting were assigned
- When aggregated data was evaluated, spatial and temporal overlap and some consistent patterns amongst fleets were observed.
- This provided encouragement to the group to proceed with combining set by set data
- Further data checking and general data exploration is required before dataset can be used for CPUE modeling.
- Noting that the differences between target and non-target fleets are substantial, the group feels that the process of statistical modeling is necessary to determine whether a combined index can be created.
- The group proposes some criteria to evaluate whether the standardization is appropriate (e.g. year*fleet interaction test, specific hypothesis testing, cross validation: remove one fleet and predict it based on the other fleets)
- Given the sensitivity of the data and the primary purpose to undertake the evaluation for only BFT, access to the combined data will be restricted to the members of this CPUE working group. Use of these data for any other purpose or species is prohibited.

The next step in the process, if the SCRS deems it worthwhile to pursue, is another 3-4 day small working group meeting in early 2017. This meeting will evaluate the feasibility of statistically modeling the combined datasets, primarily noting whether the disparities between target and non-target fleets can be reconciled in the modeling process. If statistical modeling is deemed feasible for 2 or more of the fleet/area combinations, then this meeting will produce appropriate combined indices in advance of the 2017 data workshop for eventual consideration in the 2017 stock assessment. The terms of reference for this proposed meeting are attached as **appendix 4**.

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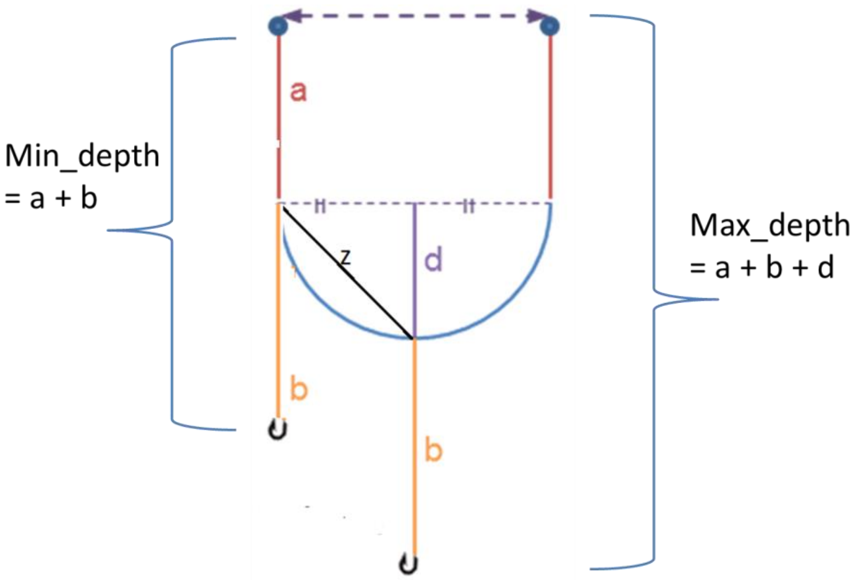
Table 1. Summary characteristics of each longline fishing fleet.

FLAG	**CAN_ATL**		**JPN_ATL**		**USA_ATL**		**USA_GOM**		**MEX_GOM**	
Period	1989-2015		1992-2015		1992-2015		1992-2015		1992-2015	
N	3176		23622		7865		8724		55721	
Gear	LL		LL		LL		LL		LL	
Season	ALL		ALL		ALL		ALL		ALL	
BFT_Area	W_ATL		W_ATL		W_ATL		GOM		CAR-GOM	
Hook_Type	CIRCLE/ J-HOOK/NA		J-HOOK		CIRCLE HOOK/ J-HOOK/MIX/ UNKNOWN		CIRCLE HOOK/ J-HOOK/MIX/ UNKNOWN		TUNA HOOK/ CIRCLE HOOK	
Bait_Type	DEAD		NA		DEAD/LIVE		DEAD/LIVE		DEAD/LIVE	
Bait_Kind	MIXED		MIXED		MIXED		MIXED		MIXED	
GOM_AREA	NA		NA		NA		NA		NA	
DAY_NIGHT	DAY/NIGTH		DAY		DAY/NIGTH		DAY/NIGHT		DAY	
	mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Month	8	2	7	5	8	3	6	3	7	3
Year	2003	6	2001	6	2005	7	2007	6	2006	6
Lat_5x5	42.67	1.60	40.09	4.95	38.62	4.53	27.14	1.29	21.34	2.48
Lon_5x5	-60.08	6.47	-54.57	7.04	-65.58	12.14	-89.34	3.1	-94.79	2.54
SST	17.35	3.69	15.98	4.41	20.64	4.1	25.71	2.55	27.02	2.36
Min_Depth	15.52	4.35	58.28	5.56	23.06	10.2	61.93	18.85	75.23	14.82
Max_Depth	78.88	56.02	165.7	14.59	91.65	17.39	125.7	19.9	136.8	14.82
Ave_Depth	47.20	28.40	111.9	8.88	57.45	12.7	93.77	19.03	106.1	14.81
Effort (hooks)	1050	346.2	2717	334.5	739.0	268.7	680.3	217	628.1	139.4
nBFT	0.61	2.41	3.60	9.46	0.32	1.98	0.21	0.64	0.03	0.22
nYFT	1.16	4.87	2.83	9.04	4.24	9.99	5.96	6.19	9.97	9.77
nSWO	7.61	11.42	0.73	1.61	11.75	13.54	4.42	6.07	0.31	0.93
nBET	2.67	8.58	11.23	17.81	2.31	5.04	0.13	0.62		
MainLineLength	46.48	18.57	104.4	15.23	44.96	15.9	52.76	11.51	64.30	12.53
GOM_Area							3.92	0.9	1.61	0.61

Table 2. Number of sets by fleet and year in combined dataset.

year	CAN_ATL	JPN_ATL	USA_ATL	USA_GOM	MEX_GOM	total
1992		2064	204	35		2303
1993	58	1468	395	223	248	2392
1994	208	1517	335	116	880	3056
1995	137	522	282	212	1505	2658
1996	162	772	82	117	830	1963
1997	127	916	167	155	287	1652
1998	147	1390	124	74	688	2423
1999	83	1486	132	157	2132	3990
2000	100	1669	200	169	2502	4640
2001	329	2139	532	205	2469	5674
2002	405	1617	598	160	2554	5334
2003	132	527	745	269	3053	4726
2004	83	1012	256	335	3400	5086
2005	108	1949	260	459	3366	6142
2006	134	1177	240	272	3584	5407
2007	87	365	219	619	3249	4539
2008	51	223	270	904	3149	4597
2009	125	334	362	1019	3055	4895
2010	110	383	356	502	2947	4298
2011	124	459	373	339	2888	4183
2012	131	470	288	567	3389	4845
2013	58	337	487	835	3135	4852
2014	99	489	461	569	3233	4851
2015	125	337	497	412	3177	4548
totals	3123	23622	7865	8724	55720	99054



- a: length of float/drop line
- b: length of branch/gangion line + leader (if used)
- h: ½ distance between floats (DF)
- d: max depth of the longline curve for maximum hook depth
    - DF= 63+35.5*HPB
    - z=h/0.8 ; where 0.8 is the assumed shortening ratio
    - $d=sqrt(z^2-h^2)$ → $d=sqrt((h/0.8)^2-(h)^2)$ → $d=0.75*h$ → $d=0.375DF$

Figure 1. Graphical depiction of calculations used to obtain proxy for minimum and maximum depth of the gear.

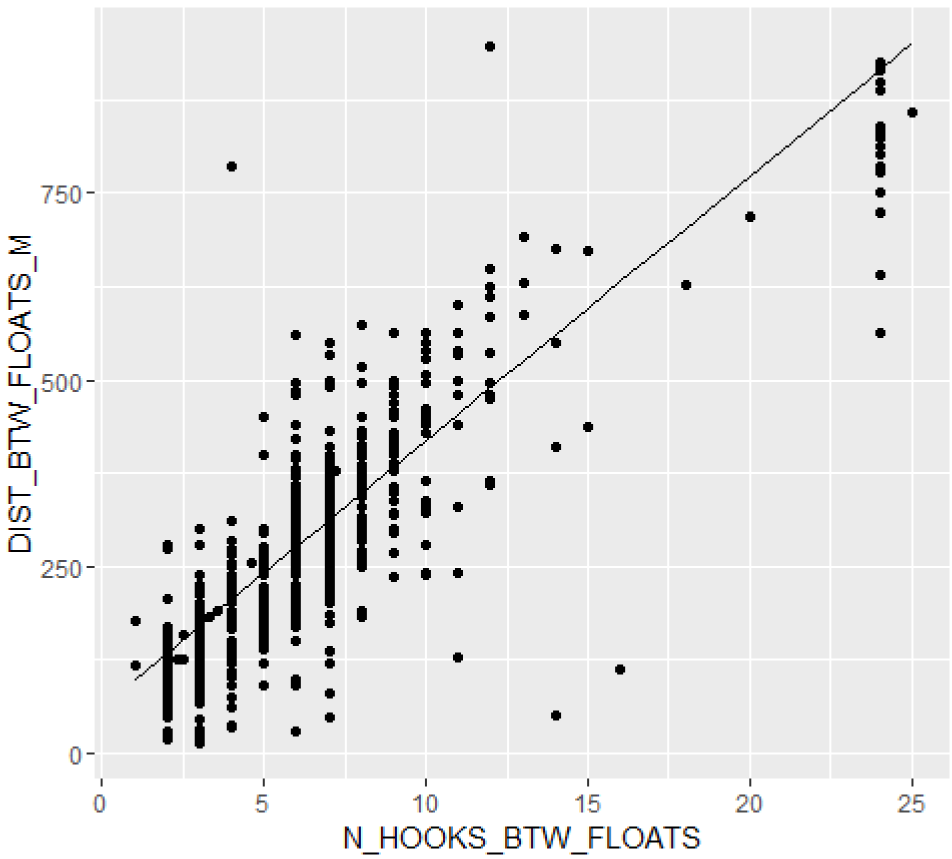


Figure 2. The relationship between the hooks per basket or number of hooks between floats and the distance between floats for data collected by Canadian observers onboard Japanese and Canadian longline vessels (1978 to 2015).

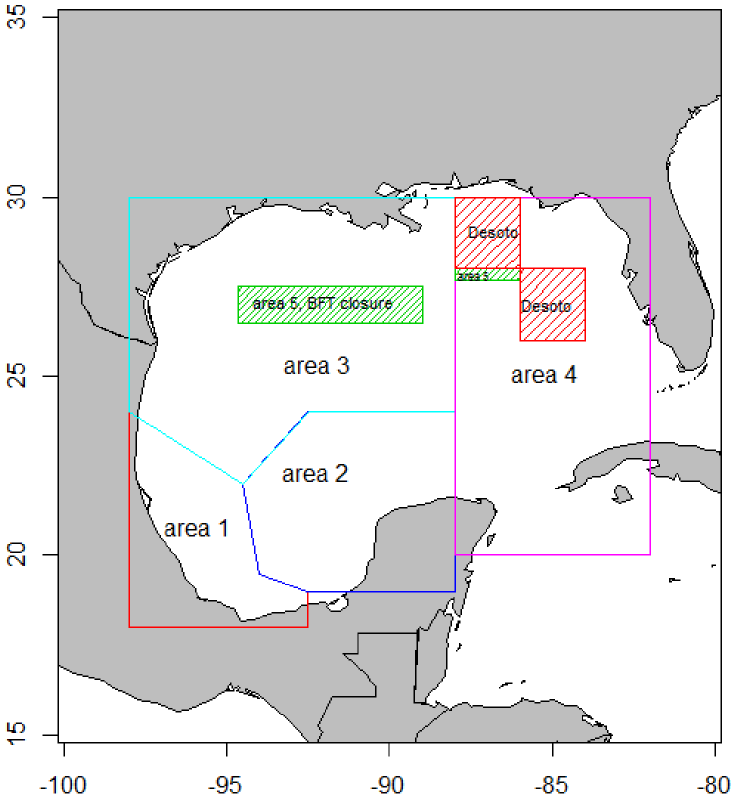


Figure 3. Spatial partitioning for Gulf of Mexico.

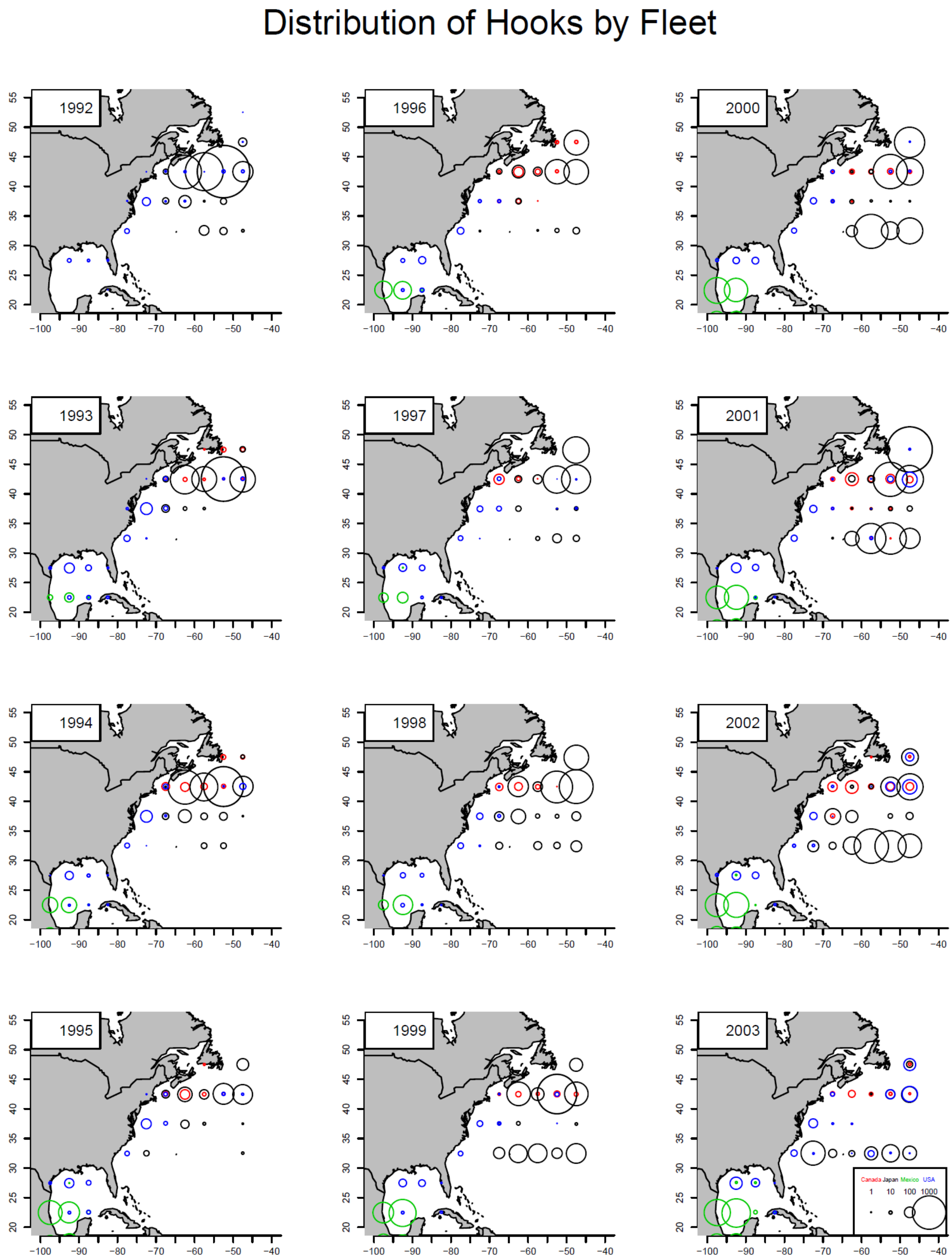


Figure 4. Distribution of Canada, Japan, Mexico and USA longline effort by 5x5 latitude and longitude.

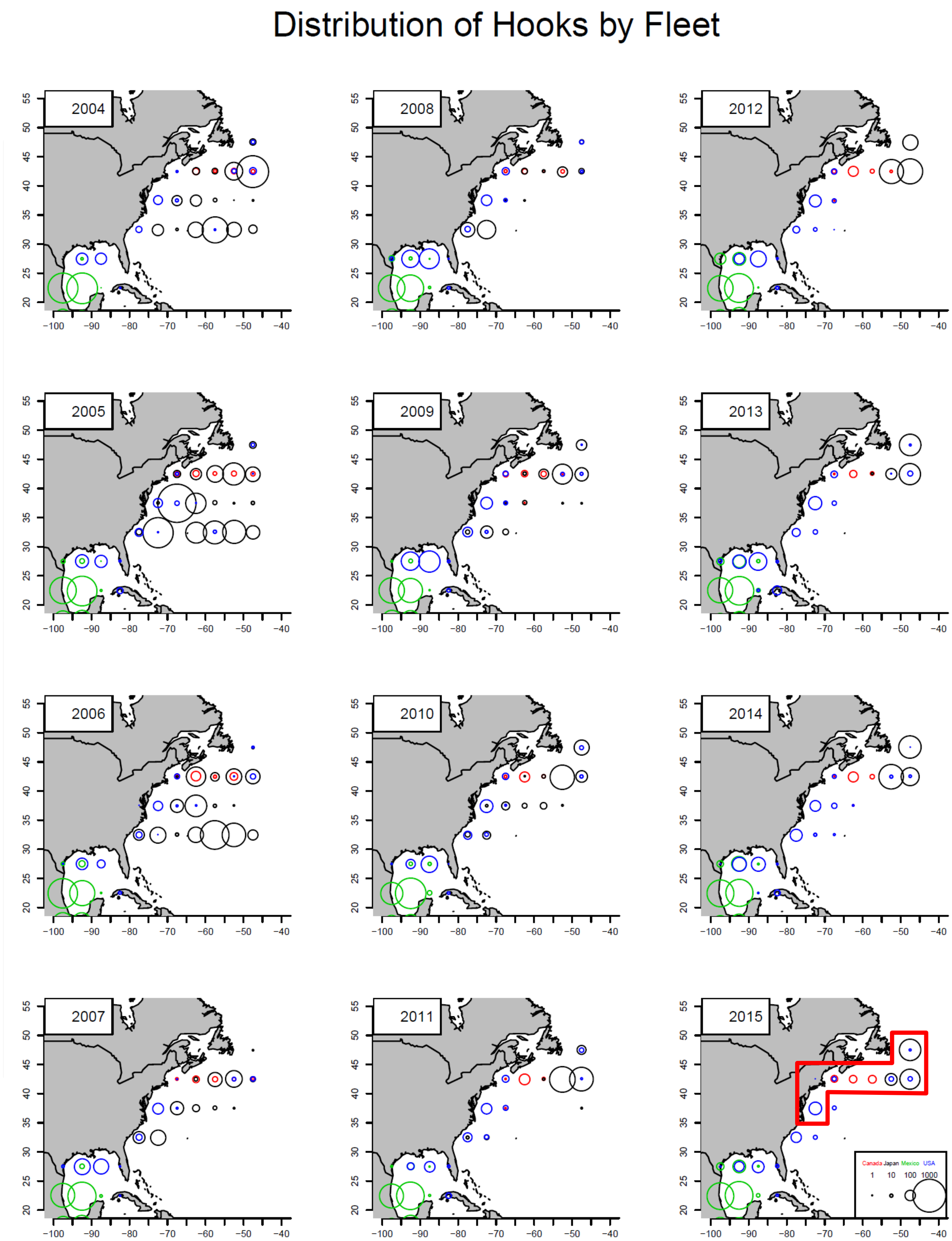


Figure 4, continued. Distribution of Canada, Japan, Mexico and USA longline effort by 5x5 latitude and longitude, red polygon represents core overlap area.

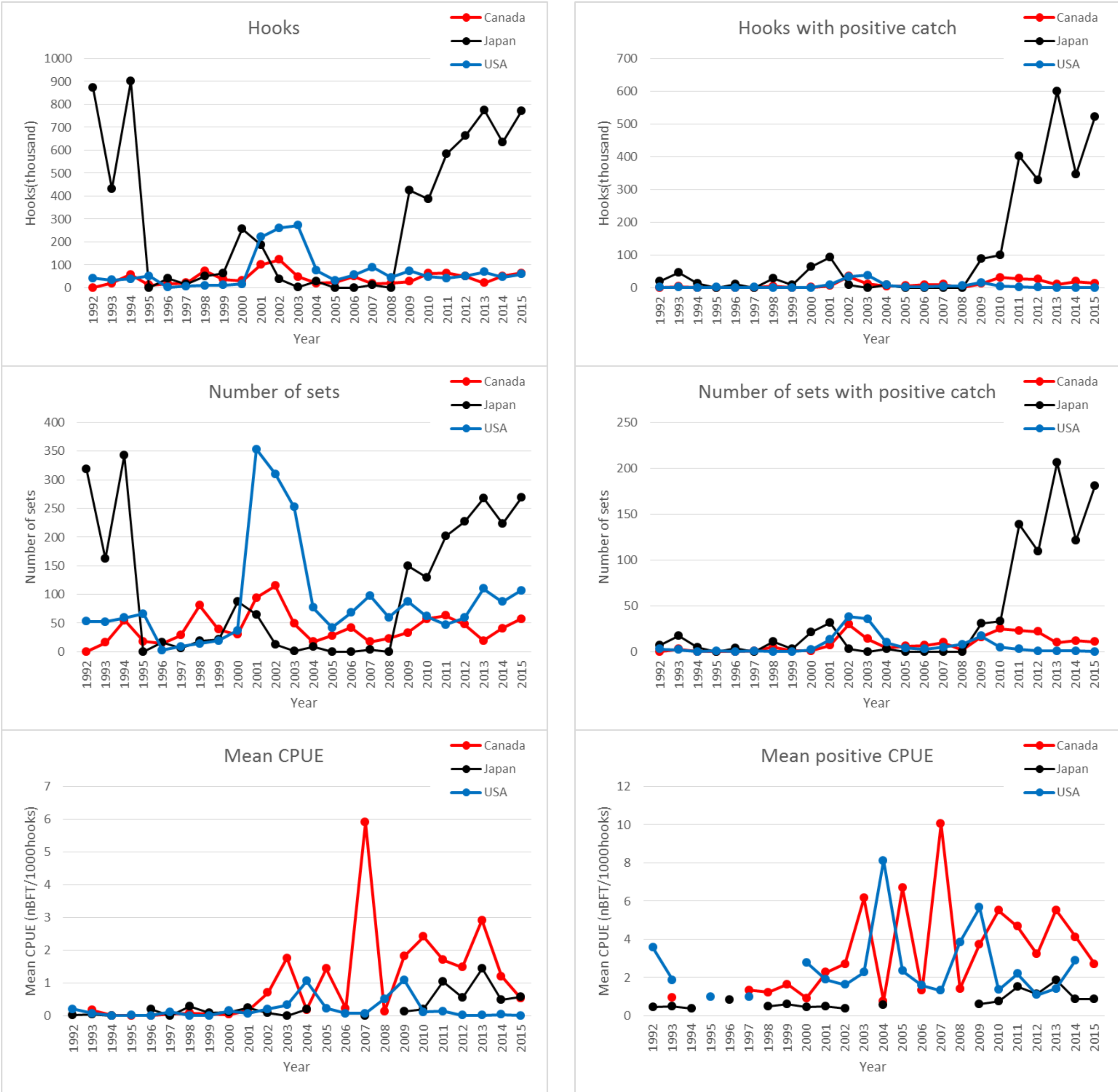


Figure 5. Effort in number of hooks, number of sets, mean CPUE, number of hooks and sets with positive catch and mean of positive CPUE for the core spatial and temporal cells identified in **Figure 1**.

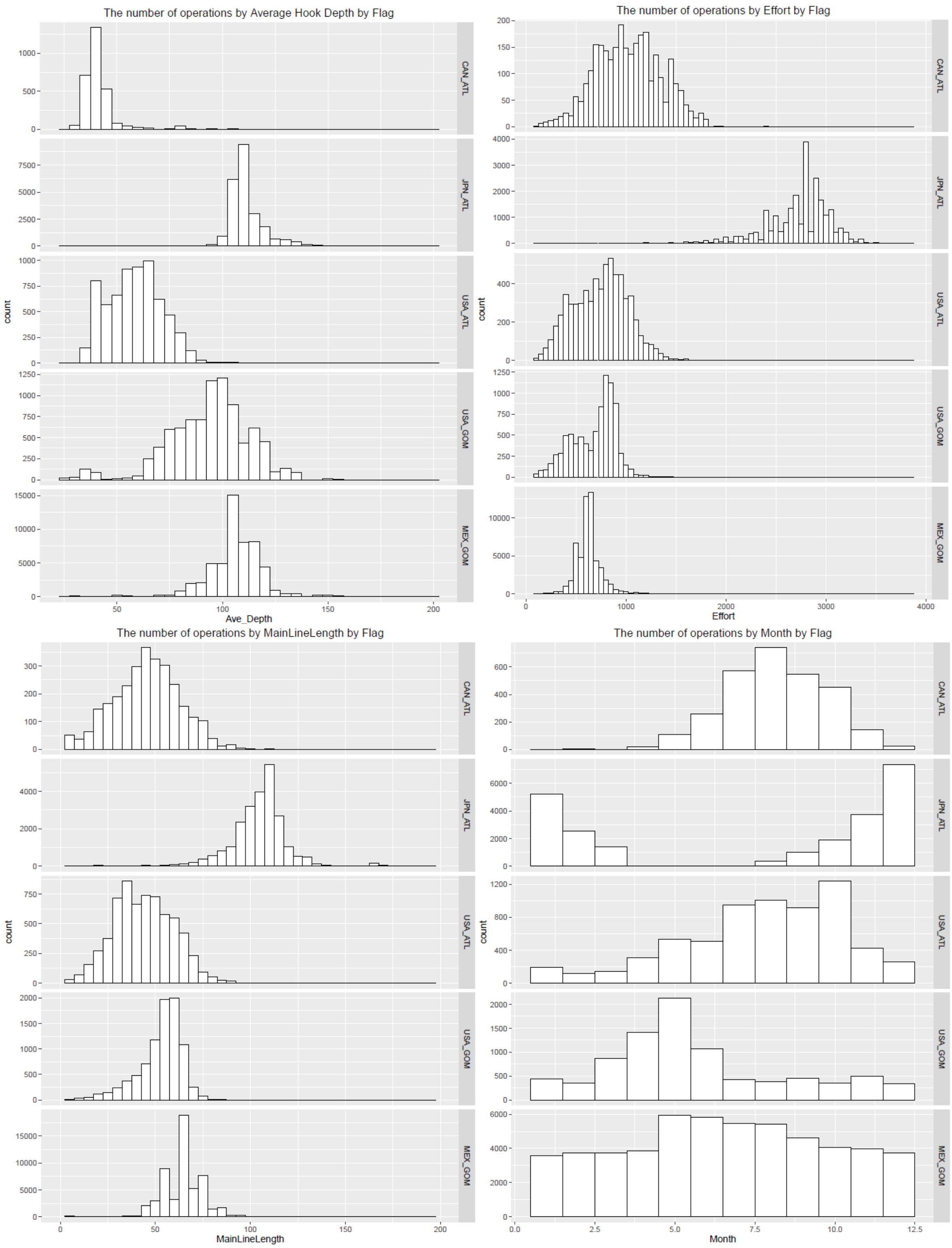


Figure 6. Gear/set characteristics of each fleet.

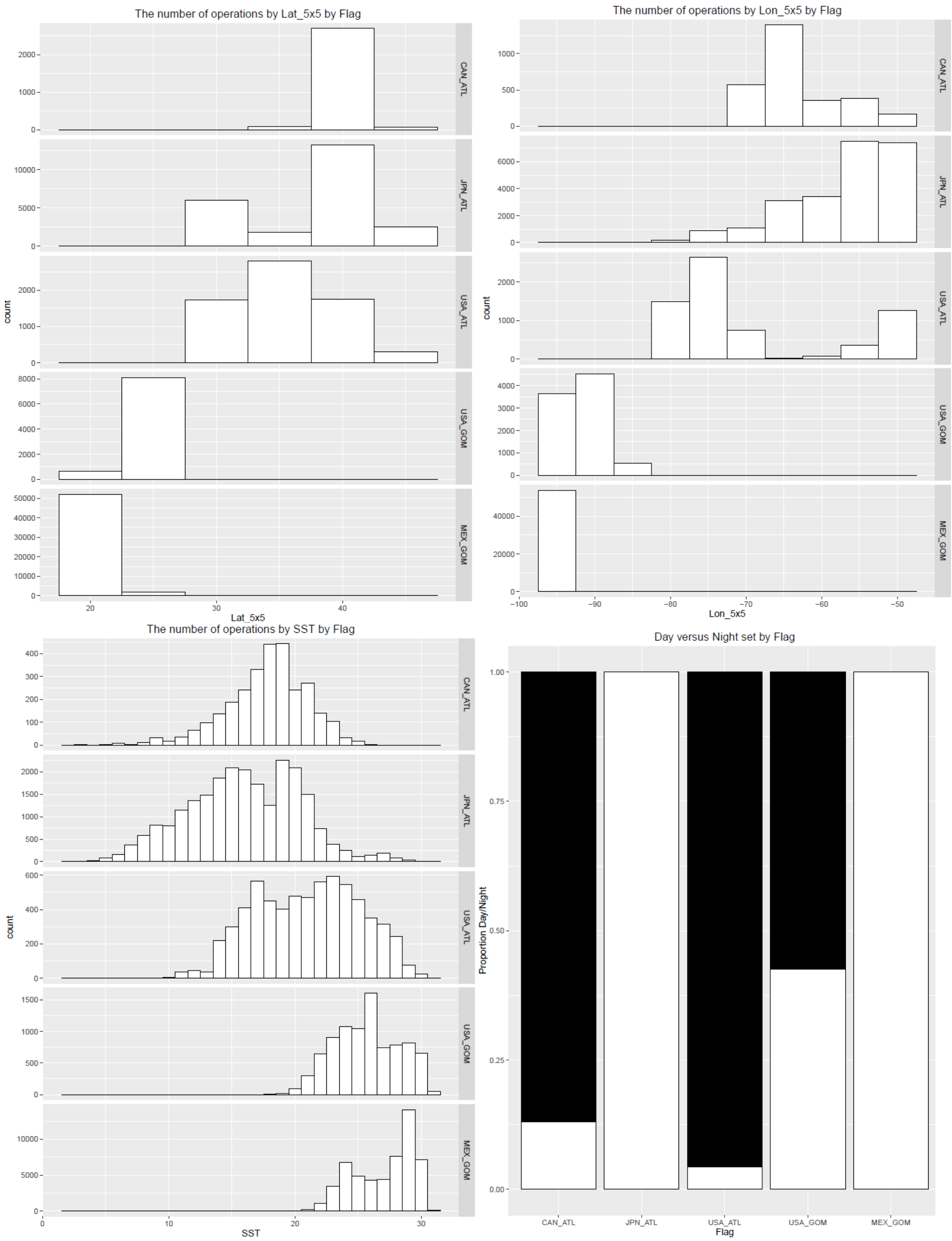


Figure 7. Gear/set characteristics of each fleet, continued (the colors in the right-bottom panel show day (white) or night (black) sets).

Appendix 1

Example R code to format datasets for combined analysis, noting that some slight modifications may be necessary for each CPC.

```
#Code to process a CPC-specific longline dataset, process it and turn it into an analytical dataset
#Cercedilla, Spain
#"Thu Jul 21 13:03:17 2016"
#matt lauretta, alex hanke, john walter, gary melvin, Ai kimoto and karina ramirez

setwd('E:/data')

#Read in each CPC raw datasets
pll=read.csv('observer/PLOPcatch_in_numberJuly16_v2.csv',header=TRUE)
head(pll)
length(pll[,1])

# US PLOP append gear_log to observer data
gear=read.csv('observer/gear_log.csv')
pll2=merge(pll,gear,all.x=TRUE,by="GEAR_LOG_KEY")
head(pll2)
length(pll2[,1])

#specific to US_PLL, removes lost hooks and removes closed areas throughout time series, but not the treatment
#of the Gulf of Mexico closed area that is created as a new GOM_AREA

pll2$Hooks=pll$NUMBER_HOOKS_SET-pll$NUMBER_HOOKS_LOST
pll3=subset(pll2,Hooks>99&AlwaysOpen=='YES'&YEAR<2016)
length(pll3[,1])


#ASSIGN SEA SURFACE TEMPERATURE from satellite data
#Note that ncdf only works with older versions of R and is no longer available. This code might need to be updated to be
#compatable with ncdf4 library which is a current R package that can handle ncdf files.
#modified R code to get SST using ncdf4 as ncdf is no longer available.

#simply we need library(ncdf4)
#use "nc_open" to open files, and "ncvar_get" to get values.
#It works fine, as I checked whether I can get the correct values by comparing what we created in
Cercedilla.

library(ncdf4)
sst1=nc_open(paste(dir3,'sst.wkmean.1981-1989.nc',sep="")) #Data accessed here:
#http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html
sst2=nc_open(paste(dir3,'sst.wkmean.1990-present.nc',sep="")) #downloaded on July 12, 2014
x1=ncvar_get(sst1,"lon")
y1=ncvar_get(sst1,"lat")
z1=ncvar_get(sst1,"time")
temp1=ncvar_get(sst1,"sst")
x2=ncvar_get(sst2,"lon")
y2=ncvar_get(sst2,"lat")
z2=ncvar_get(sst2,"time")
temp2=ncvar_get(sst2,"sst")

assign_sst=function(lon,lat,date)
        {
        if(date<'1981-10-29')
                {
                'Data Not Available'
                }
        else
                {
                if(date<'1990-01-01')
                        {
                        week=which(z1>julian(as.Date(date),origin=-62091)[1])[1]-1
                        temp1[which(trunc(x1,0)==trunc(lon,0)),which(trunc(y1,0)==trunc(lat,0)),week]
                        }
                else
                        {
                        week=which(z2>julian(as.Date(date),origin=-62091)[1])[1]-1
                        temp2[which(trunc(x2,0)==trunc(lon,0)),which(trunc(y2,0)==trunc(lat,0)),week]
```

```
                    }
            }
    }

pll3$date=as.Date(paste(pll3$YEAR,'-',pll3$MONTH,'-',pll3$day,sep=''))
pll3$SSTemp=sapply(1:length(pll3[,1]),function(i)assign_sst(360+pll3$lon[i],pll3$lat[i],pll3$date[i])[1])
write.csv(pll3,'pll_observer_SST.csv')\


#Assign OCEAN DEPTH
#requires R package “marmap”
library(marmap)
NATL <- getNOAA.bathy(lon1 = -100, lon2 = -20, lat1 = 5, lat2 = 60, resolution = 1)
dim(NATL)
write.csv(NATL,'N_Atlantic_Bathymetry.csv')
XY= data.frame(pll3$lon, pll3$lat)
names(XY)=c("lon","lat")
{XYZ=get.depth(NATL,x=XY$lon,y=XY$lat,locator=FALSE)}
pll3= cbind(pll3,XYZ)
write.csv(pll3,'pll_observer_with_ocean_depth.csv')


#Calculate DEPTH GRADIENT
bdiff <- function(x) c(NA,diff(x))
dx <- t(apply(NATL,1,bdiff)) #calculate differences in at 5 min (grid cell resolution) in x direction
dy <- apply(NATL,2,bdiff) #calculate differences in at 5 min (grid cell resolution) in y direction
grad= sqrt(dx^2 + dy^2) #gradient is slope but this a rudimentary function, in reality distances in the x direction are shorter further
#north. The XY data needs to be converted to an equidistant set of units so this is an approximation
dimnames(grad)=dimnames(NATL) #replace the "NA" in dimnames
class(grad)='bathy'
XYZgrad=get.depth(grad, x=XY[,1], y=XY[,2], locator=FALSE)
names(XYZgrad)=c('x','y','gradient')
pll4= cbind(pll3,XYZgrad)
write.csv(pll4,'pll_observer_with_depth_gradient.csv')

# ASSIGN FORAGING HABITAT - note that this is not currently operational

#require(R.matlab)
#require(raster)

# Find Files
#load(file="C:/users/matthew.lauretta/desktop/Bluefin/Habitat_Index_Druon/ForageRasterStack") # returns FeedClim
#files = list.files("MAT_nw_atl_reduced")

# coordinates are for the bottom right corner of each cell
#Lat = seq(30.08333, 55, 1/24)-(1/24)
#Lon = seq(-80, -45.08333, 1/24)

# create a raster stack of the feeding climatology
#if(!exists('FeedClim'))
#       {
#       for(i in files)
#               {
#               if(!is.na(as.numeric(substr(i,1,4))))
#                       {
#                       # read data from file
#                       a = readMat(con=paste("MAT_nw_atl_reduced","/",i,sep=""))
#                       # create an empty raster layer and stack
#                       x = raster(ncol=length(Lon), nrow=length(Lat), xmn=min(Lon),
#                               xmx=max(Lon), ymn=min(Lat), ymx=max(Lat))
#                       if(!exists("FeedClim")) {FeedClim = stack(x)}
#                       # add values to layer
#                       values(x) = a$FeedCompo30
#                       names(x) = substr(i,1,7)
#                       # add layer to stack
#                       FeedClim = stack(FeedClim,x)
#                       }
#               }
#       }
#
# coordinates to extract
#pll4$year_month=with(SWOobs,paste(YEAR,'_',MONTH,sep=""))
#xy <- with(pll4,cbind(lon,lat))
#colnames(xy)=c("lon","lat")
#
# extract the feeding from each layer for each coordinate
```

```
# extract of about 500 values and taking 50th percentile
#extract(FeedClim[[3]],xy[1:2,],buffer=50000,fun=length)
#
## Only work with the correct raster grid for each record
#FCname=names(FeedClim)
#Column = match(pll4$year_month,paste(substr(FCname,2,5),
#                                      as.numeric(substr(FCname,7,8)),sep='_'))
#dat=NULL
#for(i in 1:length(Column)){
#  if(!is.na(Column[i])){
#    dat[i] = extract(FeedClim[[Column[i]]], t(as.matrix(xy[i,])),
#                   buffer=50000,
#                   fun=function(x) quantile(x,.5,na.rm=T))}
#  else{dat[i] = NA}
#  print(i)
#  flush.console()}
#
#sum(is.na(dat))
#
## Combine with Dataset
#pll4$forage = dat
#
#sum(is.na(pll4$forage[pll4$lat>31&pll4$lon<(-45)]))
#length(pll4$forage[pll4$lat>31&pll4$lon<(-45)])
#a=head(pll4[is.na(pll4$forage)&pll4$YEAR>2002&pll4$lon>-80&pll4$lon<(-45)&pll4$lat>(30),],10)
#b=pll4[is.na(pll4$forage)&pll4$YEAR==2003&pll4$MONTH==7&pll4$lon>-80&pll4$lon<(-45)&pll4$lat>(30),]
#plot(FeedClim[[7]])
#points(b$lon,b$lat,col=2,pch=15,cex=0.5)
#

#COARSE-SCALE SPATIAL_TEMPORAL VARIABLES
pll4=pll3
pll4$lat_5x5=trunc(pll4$lat/5)*5+2.5
pll4$lon_5x5=trunc(pll4$lon/5)*5-2.5

#REQUIRED R PACKAGES
library(sp)
#DEFINED STOCK AREA X (LON) AND Y (LAT) BOUNDARIES
        BFT1=list(x=c(-80,-88,-95,-100,-100,-85,-80), y=c(20,20,16.5,20,35,35,25))
        BFT2=list(x=c(-82.5,-75,-75,-65,-65,-55,-55,-70,-95,-88,-80,-80,-82.5),
                y=c(30,30,25,25,20,20,0,0,16.5,20,20,25,30))
        BFT3=list(x=c(-70,-70,-60,-55,-55), y=c(45,55,55,50,45))
        BFT4=list(x=c(-70,-55,-55,-65,-65,-75,-75,-82.5,-85,-70,-55,-55,-60,-70,-80,-100,-100,-45,-45,-30,-30,-25,-25,-70),
                y=c(0,0,20,20,25,25,30,30,35,45,45,50,55,55,50,60,80,80,10,10,5,5,-50,-50))
        BFT5=list(x=c(-30,-45,-45,-30), y=c(40,40,80,80))
        BFT6=list(x=c(-30,-45,-45,-30), y=c(10,10,40,40))
        BFT7=list(x=c(-30,45,45,15,15,-15,-15,-30,-30), y=c(80,80,50,50,60,60,50,50,80))
        BFT8=list(x=c(-30,-30,-15,-15,15,15,5,-5), y=c(40,50,50,60,60,50,50,40))
        BFT9=list(x=c(-30,-30,-5,-5,20,20,-25,-25,-30), y=c(10,40,40,30,30,-50,-50,5,5))
        BFT10=list(x=c(-5,-5,5,23,23), y=c(30,40,50,50,30))
        BFT11=list(x=c(23,45,45,23) ,y=c(50,50,30,30))

lat=pll4$lat
lon=pll4$lon
BFT_area=c("GOM", "CAR", "GSL", "W_ATL", "NC_ATL", "SC_ATL", "NE_ATL", "E_ATL", "SE_ATL", "W_MED", "E_MED")
pll4$STOCK_AREA=as.character(sapply(1:length(pll4[,1]),function(i)BFT_area[which(c(
        point.in.polygon(lon[i],lat[i],BFT1$x,BFT1$y),
        point.in.polygon(lon[i],lat[i],BFT2$x,BFT2$y),
        point.in.polygon(lon[i],lat[i],BFT3$x,BFT3$y),
        point.in.polygon(lon[i],lat[i],BFT4$x,BFT4$y),
        point.in.polygon(lon[i],lat[i],BFT5$x,BFT5$y),
        point.in.polygon(lon[i],lat[i],BFT6$x,BFT6$y),
        point.in.polygon(lon[i],lat[i],BFT7$x,BFT7$y),
        point.in.polygon(lon[i],lat[i],BFT8$x,BFT8$y),
        point.in.polygon(lon[i],lat[i],BFT9$x,BFT9$y),
        point.in.polygon(lon[i],lat[i],BFT10$x,BFT10$y),
        point.in.polygon(lon[i],lat[i],BFT11$x,BFT11$y))==1)]))

 ######################NEED########
#GOM_AREAS 5 areas
GOM_AREA1=   data.frame(    x=c( -98, -94.5, -94, -92.5,-92.5,-98) , y=c(24  , 22 ,19.5,  19,18,18 )   )
GOM_AREA2=   data.frame(    x=c( -92.5, -94, -94.5, -92.5, -88 , -88 ) , y=c(19 ,19.5, 22 ,24 , 24,19  )   )
GOM_AREA3 =  data.frame(    x=c(  -94.5,  -98 , -98 , -88,  -88,  -92.47178) ,  y=c (22  ,24 , 30, 30 , 24 , 24   )     )
GOM_AREA4 =   data.frame(    x=c(-82, -88, -88, -82)  ,  y=c(20, 20, 30, 30))
```

```
BFTClosureA<-list( x= c(-(94+40/60) , -(94+40/60) , -89, -89 ) , y= c(26+30/60 ,  27+30/60  ,  27+30/60,  26+30/60  )  )
BFTClosureB<-list( x= c(-88,-88,-86,-86 ) ,y= c(27+40/60 ,  28  ,  28,     27+40/60   )  )
Desoto1=list(x=-c(88,88,86,86), y= c(28,30,30,28))
Desoto2=list(x=-c(84,84,86,86), y= c(26,28,28,26))
library(maps)
map('world', fill = 1, col = 16, ylim=c(15, 35), xlim=c(-100,-80))
map.axes()
polygon( GOM_AREA1, col=2,  density= 0)
polygon( GOM_AREA2, col=4,  density= 0)
polygon( GOM_AREA3, col=5,  density= 0)
polygon( GOM_AREA4, col=6,  density= 0)
polygon( BFTClosureA, col=3,  density= 30)
polygon( BFTClosureB, col=3,  density= 30)
polygon(Desoto1, col=2,  density= 20)
polygon(Desoto2, col=2,  density= 20)

#labsloc=locator()

labsloc=data.frame(x=c(-95.89600 ,-92.26769 ,-92.17699 ,-85.23784 ,-93.99114  ) ,
y=c( 20.82006 ,22.34378, 25.35004, 26.09131 ,27.03849      )  )
text(labsloc$x[1] , labsloc$y[1], "area 1")
text(labsloc$x[2] , labsloc$y[2], "area 2")
text(labsloc$x[3] , labsloc$y[3], "area 3")
text(labsloc$x[4] , labsloc$y[4], "area 4")
text(labsloc$x[5] , labsloc$y[5], "area 5")

pll4$GOM_AREA =   NA
  pll4[point.in.polygon(pll4$lon ,pll4$lat,GOM_AREA1$x,GOM_AREA1$y)==T,]$GOM_AREA =1
  pll4[point.in.polygon(pll4$lon,pll4$lat ,GOM_AREA2$x,GOM_AREA2$y)==T,]$GOM_AREA =2
  pll4[point.in.polygon(pll4$lon,pll4$lat,GOM_AREA3$x,GOM_AREA3$y)==T,]$GOM_AREA =3
  pll4[point.in.polygon(pll4$lon,pll4$lat,GOM_AREA4$x,GOM_AREA4$y)==T,]$GOM_AREA =4
  pll4[point.in.polygon(pll4$lon,pll4$lat,BFTClosureA$x,BFTClosureA$y)==T,]$GOM_AREA =5
  pll4[point.in.polygon(pll4$lon,pll4$lat,BFTClosureB$x,BFTClosureB$y)==T,]$GOM_AREA =5
 table( pll4$GOM_AREA )

####################################

pll4$year= pll4$YEAR
pll4$month=pll4$MONTH
pll4$season= ifelse(pll4$month%in%c(3,4,5),'spring', ifelse(pll4$month%in%c(6,7,8),'summer',
              ifelse(pll4$month%in%c(9,10,11),'fall', ifelse(pll4$month%in%c(1,2,12),'winter','NA'))))
write.csv(pll4,"pll_observer_coarse_Spatial.csv")

#Calculate average approximate depths of hooks
pll4$min_Depth = pll4$HOOK_DEPTH_MINIMUM*1.8288 #(dropline_length + gangion_length + leader_length), converted fathoms to
meters

DistBetFloats=  63+35.5* pll4$NUMBER_HOOKS_BETWEEN_FLOATS

pll4$max_Depth = pll4$min_Depth+ DistBetFloats*.75

 #obtained by Pythagorean theorem where d=sqrt((DistBetFloats /.8)^2-( DistBetFloats)^2); where the first term is the hypotenuse  obtained
as #using the shortening ratio of 0.8 (DistBetFloats/0.8). This simplifies to DistBetFloats*.75


pll4$avg_Depth =  round(( pll4$min_Depth +  pll4$max_Depth)/2,0)
pll4$fHookDepth   = cut(pll4$avg_Depth , seq(0,500,25))    #strawman breaks

#Define day vs night set
pll4$set_time=substr(pll4$BEGIN_SET_DATE,11,15)
pll4$DAY_NIGHT= ifelse(substr(pll4$set_time,1,2)<12, "DAY","NIGHT") #if set starts before noon then day, else night

pll4$MainLineLength=pll4$MAINLINE_LENGTH*1.852 #is the length of the longline, in km, from start to end (Not the amount of
mainline paid out.

pll4$depth=NA
pll4$gradient=NA

# DATA FILTER TO REMOVE EXTRA VARIABLES and create output dataset
Flag=c("USA")
Gear=c("LL")
pll5=with(pll4,cbind(
              Flag, Gear, month, year, season, lat_5x5, lon_5x5, STOCK_AREA, GOM_AREA, SST=round(SSTemp,1), depth, gradient,
              min_Depth, max_Depth, avg_Depth, fHookDepth,
              as.character(HOOK_SIZE), as.character(HOOK_TYPE), as.character(BAIT_TYPE_SUMMARY),
as.character(BAIT_KIND_SUMMARY),
```

```
        Hooks, BFT, SWO, BET, YFT,
        DAY_NIGHT,
        round(MainLineLength,0)
 ))
colnames(pll5)=c("Flag", "Gear", "Month", "Year", "Season", "Lat_5x5", "Lon_5x5", "BFT_Area", "GOM_Area", "SST", "Depth",
"Depth_Gradient",
        "Min_Depth", "Max_Depth", "Ave_Depth", "fHookDepth" ,
        "Hook_Size","Hook_Type", "Bait_Type", "Bait_Kind",
        "Effort", #in number of hooks
        "nBFT","nSWO", "nBET", "nYFT",   #in number
   #"GOM_AREA", #This is the Gulf of mexico subarea
        "DAY_NIGHT",
        "MainLineLength" #distance of longline
        )
head(pll5)
write.csv(pll5, "USA_PLL_OBSERVER_Filtered.csv")
```

Appendix 2

Data variables and descriptions.

Flag	Canada, Japan, Mexico, Japan
Gear	longline
Month	month
Year	year
Season	(spring, summer, fall, winter)
Quarter	1: Jan-Mar, 2: Apr-June, 3: July-Sep, 4: Oct-Dec
Lat_5x5	5x5 latitude
Lon_5x5	5x5 longitude
BFT_Area	Bluefin tuna areas
SST	Satellite-derived Sea surface temperature in Celsius
Min_Depth	minimum depth of hooks (float line + gangion or leader length)
Max_Depth	max depth of hooks (min depth + depth=f(Hooks between floats))
Ave_Depth	(min + max depth) /2
Hook_Size	hook size (not harmonized, needs work)
Hook_Type	hook type (not harmonized, needs work)
Bait_Type	bait type (live or dead, not harmonized, needs work)
Bait_Kind	bait type (fish, squid, mackerel or other, not harmonized, needs work)
Effort	Effort in number of hooks
nBFT	number of bluefin tuna
nYFT	number of yellowfin tuna
nSWO	number of swordfish
nBET	number of bigeye tuna
GOM_AREA	Area in GOM, see map
DAY_NIGHT	Day vs night setting
MainLineLength	Linear distance from start of set to end of set

Appendix 3

Data caveats

1. This dataset was created in Cercedilla, Spain on July 22, 2016 by representatives of Japan, Canada, United States and Mexico. Given the sensitivity of the data and the primary purpose to undertake the evaluation for only WBFT, access to the combined data will be restricted to the members of the CPUE working group. Use of these data for any other purpose or species is prohibited.

2. Note that this data, and any indices that one might construct with it, may not reflect all data treatments that might occur for individual CPC indices, in particular these plots use Calendar year rather than fishing year as used for the Japan index.

3. This is a preliminary, merged Canadian US Mexican Japan dataset, use with care and please notify the group if there appear to be any anomalous records

4. US longline dataset does not account for the implementation of weak hooks, all data from closed areas (except the NED area) has been removed back in time, however the data has not been corrected for potential regulatory impacts such as weak hooks, bycatch quotas or other likely changes due to regulations. These should be considered in the construction of any index.

5. The treatments of hook type, hook size and bait type require some substantial further consideration before they can be used in modeling. Many of the hook type and size conventions have not been harmonized across fleets. Similarly with bait kind and bait type, these have not been made consistent yet.

6. The Gulf of Mexico data is for the entire year. Most BFT indices for the Gulf of Mexico only use data from December through June.

7. All Atlantic data is only from 30 degrees north.

8. The CAJ fleet seems like it has extremely low catch rates for most species (max number of BFT is 1). This dataset needs to be explored in some more detail.

9. There are some operations East of 45, for the purposes of plotting and creating any index these should be removed as they would technically be classified as EBFT.

10. Sets with hooks less than 100 should be removed for plotting and analyses.

Appendix 4

Draft terms of reference to conduct a small (1-2 representatives from each CPC), 3-4 day intersessional workshop that builds on the previous joint Japan, Mexico, Canada, U.S meeting (Cercedilla, July 2016) to investigate whether it is possible to statistically model the combined datasets to produce one or several CPUE indices for western bluefin tuna. This meeting will evaluate feasibility of statistically modeling combined datasets, primarily focusing on whether the disparities between target and non-target fleets can be reconciled in the modeling process. If statistical modeling is deemed feasible for 2 or more of the fleet/area combinations, then this meeting will produce combined indices in advance of the 2017 DW for eventual consideration in the stock assessment.

Specific terms as follows:

1. Check/clean/confirm combined dataset

2. Develop proposed statistical modeling framework

3. Specific hypothesis tests/diagnostics may include:

    a) Standard model diagnostics (qq plots, histograms of data, model fit)

    b) Test year*fleet interactions for significance, trend and magnitude

    c) Cross-validation, leave out 1 fleet, fit models with remaining fleets, predict on data or the left-out fleet.

    d) Test magnitude of 'fleet' effect versus other factors, does including gear and environmental covariates reduce 'fleet' effect?

4. If diagnostic performance is adequate, then proceed with standardization

5. Produce combined CPUE indices if possible.