AN EVALUATION OF 1979 AND 1980 COMPARATIVE CRAB FISHING EXPERIMENTS WITH THE ALTERNATE TAIL ATTACK (ATA) METHOD

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Population or biomass estimates are frequently derived from trawl surveys of marine populations using the "area swept" technique (Alverson and Pereyra, 1969). As applied to eastern Bering Sea crab populations a trawl is assumed to sweep a path of constant width (w) over some measured distance (d). If the swept area contains N crabs initially, the catch is Y=Nq, where q is the gear efficiency of the trawl. Gear efficiency, also called vulnerability, can be viewed as the probability that an encountered crab is captured. The population of crab in the area swept by the i-th trawl set is Y_i/q and the density of the population is:

$$D_i=Y_i/qdw \qquad (1)$$

Typically, populations are estimated by multiplying the average density by some suitable area. Such averages may be either simple or stratified.

One problem with equation (1) is that values of q are rarely known and not easily measured. Gear associated with the trawl (doors, cables, etc.) may have the effect of leading crabs into its path, and values of q could conceiveably exceed 1.0. In what follows, such effects are considered to be negligible and q is the probability that a crab is captured when it is encountered.

Methods

Ikeda (1979) described a procedure for measuring q called the alternate tail attack (ATA) method. The method requires that two vessels trawl over the same section of sea-bed in a manner such that one trawl includes the area trawled by the other. Such a pair of trawls constitutes a set.

Trawls should follow each other as closely as possible, and the vessels should alternately lead and follow. It is desirable for one trawl (A) to be smaller than the other (B), in order to increase the chance that trawl A's path is entirely contained in trawl B's path.

Ikeda (1979) defines two types of sets. Type 1 sets are those where the smaller trawl (A) leads the larger (B) and type 2 sets are those in the opposite order. Ikeda's derivation shows that if the ratio of areas towed (S) is constant then the gear efficiencies of the two trawls are:

$$Q_A = \frac{S(Y_2 - Y_1)}{Y_2(Y_1+1)} \text{ , and} \quad (2)$$

$$Q_B = \frac{Y_2 - Y_1}{Y_2 + 1} \text{ .} \quad (3)$$

In equations (2) and (3), $Y_i = y_{iB}/y_{iA}$ is the ratio of the catches of the larger to the smaller vessel. If many type 1 and type 2 sets of trawls are performed, the vulnerabilities may be determined from any type 1 set in combination with any type 2 set. According to Ikeda, n pairs of sets would yield n^2 that can be averaged to obtain estimates of gear efficiency. If the ratios of the areas towed are not constant, these equations may be generalized so that any combination of type 1 and type 2 tows yields:

$$Q_A = \frac{S_1 Y_2 - S_2 Y_1}{Y_2(Y_1 + 1)} \text{ , and} \quad (4)$$

$$Q_B = \frac{S_1 Y_2 - S_2 Y_1}{S_1 Y_2 + S_2} \text{ ;} \quad (5)$$

where S is the ratio of larger to smaller swept areas.

Experiments with the ATA method were conducted during 1979 by the United States R/V _Oregon_ and the Japanese R/V _Wakatake Maru_. Experiments were continued in 1980 by the M/V _Ocean Harvester_ and the R/V _Wakatake Maru_. Experiments were conducted northwest of the Pribilof Islands on similar grounds in both years. Data collected in both years included distance towed by each vessel as well as catch data. Catch was tabulated by various size groups for two species of Tanner crabs (_Chionoecetes_ spp.) as shown in the Appendix. A previous report on the 1979 experiments

(Takeshita and Fujita, 1979) gives a more detailed description of trawls and experimental procedure.

There were some minor differences in the experiments conducted in 1979 and 1980. The 1979 experiment took place from August 21 to 26 and a total of 14 sets of tows were judged to be successful. Nine leading and nine following tows were made by each vessel in a "high" concentration area for *C. opilio*; and five leading and five following tows were made in a "low" concentration area. The 1980 ATA experiment took place July 20 to 24. A total of 27 sets of tows were completed and 26 of these were judged to be successful. Five of the sets were "monitor tows" that consisted of side by side towing by the *Ocean Harvester* and the *Wakatake Maru*. Monitor tows were not used in the ATA calculations. In the remaining 21 tows, the *Ocean Harvester* lead for 10 tows and the *Wakatake Maru* lead for 11 tows. No distinction was made between areas in the 1980 experiment.

Results

Analysis of the 1979 ATA data presented by Takeshita and Fujita (1979) resulted in q values for large male Tanner crabs ($\geq$ 80 mm carapace width, species combined), but our analysis of their data produced somewhat different results (Table 1). Differences in the q values obtained by the two analyses largely reflect Takeshita and Fujita's practice of ignoring all combinations of Y_1 and Y_2 that result in negative values of Q_A or Q_B.

Our analysis suggests that a majority of the q values were negative. There were no differences between vessels within high and low density areas. Differences in catchabilities between areas are not decipherable since the values of q obtained are either negative or are not significantly different from zero.

Various considerations indicated that further analysis was necessary. Otto *et al* (1979) suggested that *C. bairdi* and *C. opilio* may not be equally vulnerable to each trawl and hence errors could derive from combining species in the analyses. Differences in vulnerability for various sizes of crab are also possible.

Because of the above reservations we combined further analyses of 1979 data with analyses of the 1980 data. For the 1979 data we combined high and low density areas and computed gear efficiencies for various species, sex, and size categories as well as for aggregates of them. Computations were analogous for the 1980 data. Results of these computations showed that a minority of values for q_A and q_B were positive (Table 2). None of the categories or aggregates of them had positive average values of q_A or q_B in either year. Average q_A and q_B values ranged from -0.04 to -3.74 and -0.03 to -2.49 respectively. Only two average q values are within two standard errors of zero. While there are numerous statistically significant differences between average efficiency values, we see no meaningful way of interpreting them.

Discussion

It is our contention that the 1979 and 1980 ATA experiments are of no value in determining gear efficiency. The proportion of zero values is far higher than can be explained by sampling error or other probability related considerations. We are then left with attempting to explain how so many negative values of gear efficiency might arise.

Assumptions that must be made in order to accept Ikeda's (1979) derivation of equations (2) - (5) include: (1) the area swept by the smaller trawl must be wholly contained within that of the larger trawl; (2) interaction between trawls must be such that gear efficiency remains constant regardless of whether a given trawl is leading or following; (3) gear associated with the trawl does not effect gear efficiency of either vessel in either type of set; (4) crab are randomly distributed with respect to the area trawled; and (5) immigration to or emigration from the projected path of the following trawl is negligible.

Ikeda's major assumption is that the area of the smaller trawl is wholly contained within that of the larger trawl. The width of the area swept by the Japanese research trawl is 25.5 m, while the U.S. trawl sweeps 12.2 m. If the centers of the two trawl paths coincided, 6.65 m would be left on either side of the U.S. trawl. Trawling occurred in water of 90 to 120 meters and U.S. vessels use a 3:1 ratio of trawl cable to depth. Hence, approximately 300 meters separated the U.S. vessel and the trawl doors (ignoring catenary effects). The trawl is separated from the doors by an additional 45 meters. If the trawl were only 300 m from the U.S. vessel and the two vessels were exactly on track, a difference of only about 1 degree in the angular displacement of trawls from vessel tracks results in half of the smaller trawl's path falling outside of the area swept by the larger trawl. Further, even if the vessel tracks of the two vessels were exactly parallel, they would only have to be 6.6 m apart to cause a similar effect. While visual observations by scientists and radar tracking indicate that the two vessels were usually on the same track, there was no measurement of the relative position of the trawls. If the _Waketake Maru_ uses a different amount of cable than the U.S. vessel, trawls could easily be in entirely different paths.

The net effect of deviations from the above assumptions is not easily evaluated. We suspect that all of the assumptions were violated to some degree at various times and that such violations will not be distinguishable from various measurement and sampling errors by examination of the data. This means that systematic errors (leading to bias) and random errors (leading to increased variance) are confounded. We believe that the net effect of these errors leads to a great deal of scatter in estimates of Y_1 and Y_2. If Y_1 and Y_2 are nearly identical and highly variable then the term (Y_2-Y_1) in the numerator of equations (2) to (5) can easily be negative. Since the denominators are always positive, negativity of (Y_1-Y_2) results in negative values of q_A and q_B.

Other problems with estimating gear efficiencies using Ikeda's methods are mathematical. It is tacitly assumed that the n^2 measures of gear efficiency are independent. This assumption appears to arise from the fact that Y_1 and Y_2 are independent of population density. While Y_1 and Y_2 are functionally independent of density, variation in them is not. For example, if q is considered as a probability, and N crabs are in the path of a trawl, the variance of catch is Nq(1-q). There will hence be a non-zero co-variance between catches (and ratios of them) taken in areas of similar density. Sequential sets of tows would be an example of this. Further, if a given set of tows is invalid, one simply compounds errors by using it n times rather than once. Another problem is that gear efficiency is calculated as a ratio (of ratios) and averaging ratios is frequently questionable. We believe it is better to compute a single value of Y_1 and Y_2 from the ratio of average catches.

In order to test the hypothesis that Y_1 and Y_2 are nearly identical, we consider them as parameters as follows:

$$y_{1B} = Y_1 y_{1A} \quad \text{, and} \tag{6}$$

$$y_{2B} = Y_2 y_{2A} \quad . \tag{7}$$

Further, if trawls are not following in the same path, Y_1 and Y_2 should not be distinguishable from Y_3 where

$$y_{3B} = Y_3 y_{3A} \quad \text{and} \tag{8}$$

y_A and y_B are catches by trawls A and B during monitor (side by side) towing (set type 3). Since large male C. opilio are the most important resource in the U.S.-Japan joint survey area, we used 1979 and 1980 data for this group to examine the relationships between Y_1, Y_2, and Y_3 (Figure 1).

The scatter of points relating catches of leading and following vessels strongly suggests that values of Y_1 and Y_2 should be considered identical in each year. Catches of both trawls are subject to considerable variability and we know little about the distribution of errors around regression lines corresponding to equations (5) - (8). According to Ricker (1973), geometric mean regression is appropriate to this situation. Geometric mean regression lines (Figure 1) were computed and tested for differences in slope (Y_1 and Y_2) within years. No significant differences are found and the positioning of the lines strongly suggests that Y_1 and Y_2 are nearly identical. We did not attempt to compute Y_3 since only five data points were available. Plotted points from the monitor tows do, however, coincide closely with both regression lines. We conclude that Y_1 and Y_2 are not distinguishable from Y_3.

Near identity of Y_1, Y_2, and Y_3 occurs either because q_A and q_B are very small or because results of type 1 and type 2 sets of ATA data are equivalent to monitor tows. We contend the latter and further note that a probable cause is that the two trawls may not have been fishing the same segment of bottom during most of the experiments.

LITERATURE CITED

Alverson, D.L. and W.T. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean - an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Bd. Can., 26:1985-2001.

Ikeda, Ikuo. 1979. Estimation of Vulnerability of Trawl Nets by Alernate Tail Attack (ATA) method. Far Seas. No. 34, pp.1-4.

Otto, R.S., A.H. Fukuyama, T.M. Armetta, R.M. MacIntosh, and J. McBride. 1979. United States King and Tanner Crab Research in the Eastern Bering Sea, 1979. (Doc. submitted to annual meeting of INPFC, 1979, Tokyo). National Marine Fisheries Service. Kodiak. 61 p.

Ricker, W.E. 1973. Linear regressions in fishery research. J. Fish. Res. Bd. Can., 30:409-434.

Takeshita, H. and H. Fujita. 1979. Interim Report of the 1979 U.S.-Japan Joint Survey for the Bering Sea Tanner Crabs. Fisheries Agency of Japan. 11 p. Unpublished.

Table 1 - Catchability estimates of trawl survey gear for Tanner crab males $\geq$ 80 mm carapace width, from the 1979 U.S.-Japan comparative tow operations in the eastern Bering Sea.

	Average Catchability (from Takeshita and Fujita, 1979)		Average Catchability (present analysis)	
	Oregon q_A	Wakatake q_B	Oregon $q_A - S_E$	Wakatake $q_B \pm S_E$
High-density Area	0.417	0.540	0.10 ± 0.06	-0.04 ± 0.09
Low-density Area	0.327	0.316	-0.49 ± 0.14	-0.80 ± 0.25

Table 2 - Results of 1979 (R/V *Oregon*, R/V *Wakatake Maru*) and 1980 (M/V *Ocean Harvester*, R/V *Wakatake Maru* comparative fishing experiment. Calculations follow Ikeda (1979).

YEAR	SPECIES	SEX	WIDTH MM	AVG. q_A	STD. ERR.	AVG. q_B	STD. ERR.	NUMBER OF q VALUES	POSITIVE VALUES %
1979	*C. bairdi*	♂	>80	-0.34	0.08	-0.96	0.19	196	47.4
	"	♂	<80	-0.52	0.14	-0.43	0.08	196	45.4
	"	♂	ALL	-0.37	0.09	-0.56	0.12	196	47.4
	"	♀	ALL	-0.40	0.10	-0.66	0.11	196	43.9
	"	♂ + ♀	ALL	-0.37	0.10	-0.59	0.11	196	46.4
	C. opilio 1/	♂	>80	-0.04	0.04	-2.49	0.67	196	48.5
	"	♂	<80	-0.60	0.10	-1.56	0.40	196	46.4
	"	♂	ALL	-0.13	0.04	-0.42	0.06	196	40.3
	"	♀	ALL	-0.23	0.15	-0.03	0.01	168	45.8
	"	♂ + ♀	ALL	-0.34	0.09	-0.44	0.08	196	45.4
	C. spp.	♂ + ♀	ALL	-0.33	0.07	-0.31	0.05	196	42.8
1980	*C. bairdi*	♂	>80	-2.14	0.60	-0.26	0.05	110	35.5
		♂	<80	-1.31	0.21	-0.67	0.08	110	20.0
	"	♂	ALL	-1.18	0.25	-0.34	0.05	110	21.8
	"	♀	ALL	-0.72	0.13	-0.42	0.06	110	23.6
	"	♂ + ♀	ALL	-1.15	0.23	-0.39	0.05	110	17.3
	C. opilio	♂	>80	-0.73	0.20	-0.51	0.20	110	34.5
	"	♂	<80	-1.21	0.23	-1.42	0.20	110	27.3
	"	♂	ALL	-0.74	0.20	-0.54	0.12	110	33.6
	"	♀	ALL	-3.74	0.45	-0.14	0.01	110	15.5
	"	♂ + ♀	ALL	-2.31	0.46	-0.20	0.05	110	40.0
	C. spp.	♂ + ♀	ALL	-2.16	0.44	-0.22	0.05	110	39.1

1/ Some following tows caught no *C. opilio* females. These tows were deleted from the computation of averages.

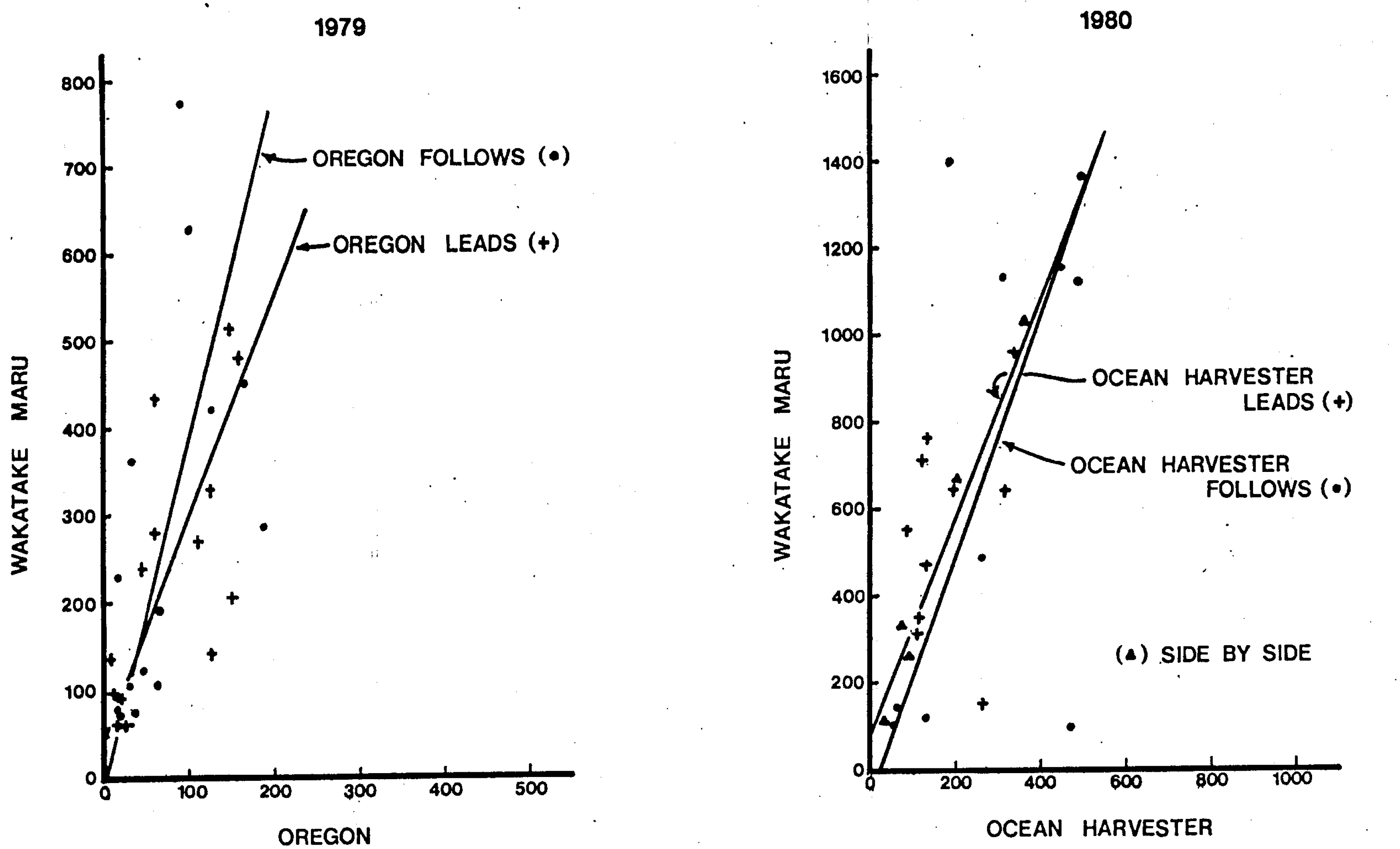

Figure 1 - Relationships between catches of large (≥ 80 mm carapace width) male C. opilio made by U.S. and Japanese vessels during Alternate Tail Attack (ATA) experiments.

APPENDIX -- TABLE 1. CATCH DATA FROM THE 1979 ATA EXPERIMENTS.

		OREGON (O)							WAKATAKE MARU (W)						
	VSL	TOW	C. BAIRDI			C. OPILIO			TOW	C. BAIRDI			C. OPILIO		
TOW	IN	DIST							DIST						
NO.	LEAD	(MI)	LM	SM	F	LM	SM	F	(MI)	LM	SM	F	LM	SM	F
1	O	1.3	6	38	48	144	22	258	1.7	14	128	185	512	121	453
2	W	1.3	6	36	33	126	28	244	1.6	8	58	94	421	87	509
3	O	1.2	4	41	55	124	32	600	1.3	3	55	56	142	50	557
4	W	1.0	1	6	9	24	61	184	1.2	14	41	55	227	118	988
5	O	1.2	6	30	37	110	20	855	1.4	3	32	40	270	116	567
6	W	1.3	7	58	86	33	204	549	1.4	7	112	186	362	87	631
7	O	1.0	12	49	112	150	18	360	1.4	15	82	199	206	57	592
8	W	1.2	4	20	23	162	12	200	1.5	13	29	79	451	102	369
9	O	1.3	4	12	16	122	8	129	1.3	8	26	78	334	88	233
10	W	1.1	5	29	46	186	72	540	1.4	4	36	59	286	107	482
11	O	1.6	4	1	5	58	24	384	1.5	64	5	60	436	236	952
12	W	1.4	1	8	9	98	28	450	1.5	11	33	60	626	176	851
13	O	1.4	0	59	62	156	24	348	1.5	19	33	82	480	112	478
14	W	1.0	17	6	29	63	9	395	1.4	26	12	109	192	50	716
15	O	1.2	8	19	30	61	8	172	1.6	19	67	116	280	34	332
16	W	1.3	3	2	7	46	2	222	1.5	16	12	31	123	21	208
17	O	1.5	6	10	16	44	1	91	1.6	23	72	145	241	53	465
18	W	1.1	11	4	33	90	2	68	1.4	36	11	63	774	56	237
19	O	1.5	34	32	23	15	5	2	1.5	65	36	75	91	11	3
20	W	1.2	91	86	110	34	13	1	1.2	57	48	94	73	10	1
22	W	1.5	28	38	47	29	5	1	1.6	30	30	80	102	23	0
23	O	1.6	28	21	29	1	16	3	1.6	97	111	155	136	26	1
24	W	1.3	39	65	120	15	1	29	1.6	35	56	89	77	15	24
25	O	1.1	22	34	62	10	4	18	1.5	53	40	93	95	17	25
26	W	1.4	18	9	35	16	3	1	1.5	90	17	77	81	25	1
27	O	1.5	20	11	41	16	3	0	1.4	16	14	58	61	9	0
28	W	1.1	90	108	106	62	14	0	1.3	49	24	36	105	8	0
29	O	1.0	60	106	66	25	2	0	1.3	65	28	36	61	11	1

APPENDIX -- TABLE 2. CATCH DATA FROM THE 1980 ATA EXPERIMENTS.

		OCEAN HARVESTER (O)							WAKATAKE MARU (W)						
	VSL	TOW	C. BAIRDI			C. OPILIO			TOW	C. BAIRDI			C. OPILIO		
TOW	IN	DIST							DIST						
NO.	LEAD	(MI)	LM	SM	F	LM	SM	F	(MI)	LM	SM	F	LM	SM	F
2	O	1.6	14	3	21	81	35	4693	1.6	22	0	47	557	293	13979
3	W	1.3	97	42	24			1015	1.5	48	13	13	512	7	981
4	O	1.3	44	51	21	105	12	1165	1.4	95	116	71	314	27	3378
5	W	1.5	77	43	46	53	23	2127	1.5	93	50	83	102	43	3490
7	O	1.5	63	74	40	129	6	804	1.5	85	150	102	467	30	3672
8	W	1.6	53	23	3	186	6	96	1.5	88	5	7	1398	43	58
9	O	1.3	28	16	9	117	6	401	1.3	65	30	25	707	62	1888
10	W	1.4	54	27	15	264	15	2314	1.4	84	48	46	485	26	3771
12	O	1.6	66	38	29	194	14	2252	1.5	100	86	61	639	104	4006
13	W	1.4	50	30	13	310	16	1460	1.5	124	35	27	1127	47	1873
14	O	1.4	49	3	6	131	6	352	1.3	108	15	10	765	15	123
15	W	1.3	29	31	14	59	13	3190	1.4	38	43	25	138	36	4187
17	O	1.3	48	35	27	262	36	2778	1.4	16	17	18	143	21	2453
18	W	1.4	89	49	17	472	36	2675	1.5	5	13	5	96	8	762
19	O	1.3	42	25	15	316	26	1174	1.3	72	42	34	640	41	3069
20	W	1.2	57	35	10	448	16	663	1.3	116	29	21	1151	36	306
21	W	1.4	78	37	26	484	36	1132	1.4	109	36	31	1126	11	1391
23	O	1.4	34	9	12	124	1	516	1.4	50	11	35	347	10	1744
24	W	1.4	47	47	22	129	13	2804	1.5	28	19	16	115	13	3309
25	O	1.2	43	14	9	336	9	378	1.3	59	33	24	955	68	655
26	W	1.3	82	14	7	496	20	320	1.3	121	18	14	1361	87	221