MARINE RECREATIONAL INFORMATION PROGRAM

Addressing Recommendations from the MRIP Sponsored Review of Monitoring of Washington's Ocean Sampling Program: Evaluation of recreational catch and effort during off peak months on Washington's coast

Washington Department of Fish and Wildlife

February 6, 2015

INTRODUCTION

Comprehensive and sound management of recreational finfish fisheries in Washington State requires information on catch, effort, and stock-specific fishery impacts necessary to meet established conservation and allocation mandates. These data are federally required to open and manage recreational fisheries, especially considering the need to limit and monitor impacts to threatened species. For the Washington ocean Marine Catch Areas (Areas 1-4), these critical fishery information needs are met through the Washington Department of Fish and Wildlife (WDFW) Ocean Sampling Program (OSP).

To generate estimates of marine fish catch and effort in ocean Marine Catch Areas (for the "private boat" and "charter boat" modes), WDFW employs a procedure based on data collected by an access point intercept survey. The OSP survey is designed to provide both total effort and catch per unit effort (CPUE). These data are used to generate estimates of total catch and effort by Marine Catch Area, month, and fishing mode which are provided to the Recreational Fishery Information Network (RecFIN, www.recfin.org).

Currently, ocean fishery sampling occurs in all major ocean access ports during "peak" effort months, May through September. Some access sites are also sampled at a lower rate during March, April, and/or October. Effort and catch are assumed to be insignificant during all non-sampled temporal/spatial combinations. This assumption had been tested only once, in a limited study in 2002, with inconclusive results. This is the final year of a three-year proposal to test this assumption, with this final year focusing on the higher-effort "shoulder" months – March, April, October, and November.

The objective of this project was to test the assumption that ocean fishing effort and catch are indeed insignificant during the months between September and May. This was a recommendation resulting from the Marine Recreational Information Program's (MRIP) recent review of the WDFW OSP. Based on the findings of the initial stages of the project, work on this project was conducted in two segments October 1, 2013 thru November 30, 2013 and March

1, 2014 thru April 30, 2014. In comparison, prior related work (Stage 1) began October 1, 2011 and ceased on April 30, 2012 while Stage 2 began October 1, 2012 and ceased on April 30, 2013.

METHODS

Methods were identical to those used in the initial stages of this project. One field sampler was stationed in each major Washington coastal access site: Ilwaco, Westport, La Push, and Neah Bay; the small ports of Chinook (near Ilwaco) and Snow Creek (near Neah Bay; access to this site is closed during winter months) were not sampled. One Scientific Technician and one Biologist worked to coordinate sampling, collect data, and generate monthly estimates of catch and effort. One Biometrician analyzed the resulting catch data, comparing "shoulder" months to normally sampled months.

In each port, most weekend days were sampled, and sampled weekdays were assigned using a random number generator to total 40 hours per week. Each port was sampled 3 to 5 days per week and days were stratified by weekend and weekday.

The OSP mainly uses a two-stage design for each port, with days constituting the primary sampling units (PSU) and boats within each sampled day as the secondary sampling units (SSU). Selection of days follows simple random procedures. Although sampling of boats is approximately systematic (e.g., every k*th* boat), the selection procedure is not exact and this stage is treated as simple random for estimation purposes. Daily estimates are expanded over days within strata to produce weekly, monthly and annual estimates.

Effort is measured in units of boat-trips and angler-trips, and on sampled days, is measured throughout the entire period of boat activity, i.e., from the time when the first boat leaves a port until the last boat returns. On a given sampling day, the total number of boats that left a port is counted. Boat effort was measured during this project through an <u>entrance count:</u> a count of all boats entering that marina.

The catch per boat is sampled through intercept surveys. Returning boats are systematically sampled at a minimum target rate of 20% within each boat type (charter and private). Every *k*th boat to enter the harbor is included in the sample regardless of size, mooring location, trip type, etc. The size of the sample (leading to the calculation of *m*) depends on the projected effort and the number of available samplers. Overall, the sampling rate during normally sampled timeframes in each port in a year averages over 50% for charter boats and over 40% for private boats. For this project, the sampling goal was 100% of the vessels entering the port on each sampled day, which should result in an overall sampling rate of approximately 60% in each port for the season.

Data collected from each sampled boat trip include target species, area fished, number of anglers, landed catch by species, released salmon by species, releases of all marine fish by species, depth at which the majority of rockfish in the catch were hooked, and other biological data.

Catch and Effort Estimation

The OSP generates preliminary estimates of catch and effort in-season to meet the demands of ocean fishery management. Catch estimates for quota fisheries (currently salmon and halibut) are generated weekly; catch estimates for all other species are generated monthly and provided to the RecFin database by the end of the following month. Final post-season catch and effort estimates for all species are generated by February 1 each year; these post-season estimates replace any existing in-season estimates. For this project, final estimates of effort and catch were generated monthly and provided to the RecFin database by the end of the following month

OSP Estimated Stratum Totals (Primary Stage)

Combined (total) catch estimates are typically stratified by weekend/holiday and weekday. In some strata, every day is sampled. In those strata the combined estimates are simply sums of the daily catches. In other strata, where some days are not sampled, the average catch per day over all sampled days is multiplied by the number of days in the stratum to estimate the total catch.

Let:

a = the marine catch area,

i = trip type,

t = Weekend/holiday or Weekday stratum,

N_t = the number of days in stratum t,

T_t = collection of all days in stratum t,

n_t = the number of days sampled in stratum t, (rather than the number of boats sampled as above),

S_t = collection of sampled days in stratum t (when S=T, n=N),

Y_{taik} = estimated catch (or effort) on day k for stratum t in area a from trip type i,

C_{tai} = catch for stratum t in area a from trip type i,

Then

$$\hat{C}_{tai} = N_t \frac{\sum_{k \in S_t} \hat{Y}_{taik}}{n_t}$$

with estimated variance (Thompson 1992, p. 129):

$$\hat{V}\left(\hat{C}_{tai}\right) = \frac{N_t(N_t - n_t)}{n_t} \frac{\sum_{k \in S_t} \left(\hat{Y}_{taik} - \hat{\bar{Y}}_{tai}\right)^2}{n_t - 1} + \frac{N_t}{n_t} \sum_{k \in S_t} \hat{V}\left(\hat{Y}_{taik}\right)$$

where

$$\hat{\bar{Y}}_{tai} = \frac{\sum_{k \in S_t} \hat{Y}_{taik}}{n_t}.$$

For strata with all days sampled, $n_t = N_t$, and the catch and variance estimators reduce to:

$$\hat{C}_{tai} = \sum_{k \in T_t} \hat{Y}_{taik}$$

and

$$\hat{V}\left(\hat{C}_{tai}\right) = \sum_{k \in T_t} \hat{V}\left(\hat{Y}_{taik}\right).$$

OSP Daily Catch and Effort Estimation (Secondary Stage)

Both catch and effort are post-stratified by trip-type and area fished. Effort in terms of boat-trips is simply the sample number of boats for each trip-type and area expanded by the appropriate boat-type (charter or private) exit/entrance count. Effort in terms of angler-trips is calculated as the mean number of anglers per boat (indexed by trip-type and area) expanded by the counted total population of boats.

The total catch for a given species on a sampled day is the product of the population of boats and the estimated catch per boat, again post-stratified by trip-type and area fished. Key assumptions in the current estimation procedures are that:

1) All boats exiting/entering a port are included in the exit/entrance count
2) Exit/entrance counts are made without error
3) The approximate systematic sample of boats can be treated as a simple random sample
4) Anglers answer questions accurately and do not conceal fish

In the following discussion, subscripts referring to port and boat-type are suppressed. Let:

M_t = total exit or entrance count for a given port on day *t* (assumed known without error),

m_t = total boats sampled on day *t*,

m_{tai} = number of boats sampled of trip type *i* fishing in area *a* on day *t*,

a_{taij} = number of anglers on the *j*th boat from trip type *i* fishing in area *a* on day *t*,

y_{taij} = number of species specific fish caught on the *j*th boat from trip type *i* in area *a* on day *t*, and

Y_{tai} = total catch of specific species caught from trip type *i* in area *a* on day *t*.

The estimate of the number of boat-trips of trip-type *i* and area *a* follows the procedure outlined in Lai et. al. (1991) where the proportion of boats in each category is estimated by:

$$\hat{p}_{tai} = \frac{m_{tai}}{m_t}$$

with estimated variance (Cochran 1977, p. 52):

$$V(\hat{p}_{tai}) = \frac{\hat{p}_{tai} \cdot (1 - \hat{p}_{tai})}{(m_t - 1)} \cdot (\frac{M_t - m_t}{M_t})$$

The estimated total boat-trips is then obtained by:

$$\hat{M}_{tai} = M_t \cdot \hat{p}_{tai}$$

with estimated variance:

$$\hat{V}(\hat{M}_{tai}) = M^2{}_t \cdot \hat{V}(\hat{p}_{tai})$$

Effort expressed in terms of angler-trips is the product of the average anglers per boat-trip times the total number of boat-trips. The mean number of anglers per boat-trip (for trip-type *i* and fishing area *a*) is estimated as:

$$\hat{\hat{a}}_{tai} = \frac{\sum_j a_{taij}}{m_t}$$

with variance:

$$\hat{V}(\hat{\hat{a}}_{tai}) = \frac{\sum_j (a_{taij} - \hat{\hat{a}}_{tai})^2}{m_t(m_t - 1)} \cdot (\frac{M_t - m_t}{M_t})$$

Thus the estimated total number of angler-trips is:

$$\hat{a}_{tai} = M_t \cdot \hat{\hat{a}}_{tai}$$

with variance:

$$\hat{V}(\hat{a}_{tai}) = M^2{}_t \cdot \hat{V}(\hat{\hat{a}}_{tai})$$

The catch (or number released) for a specific species on sampled day *t* in area *a* from trip type *i* is similarly estimated by:

$$\hat{Y}_{tai} = \frac{\sum_j y_{taij}}{m_t} M_t$$

with estimated variance:

$$\hat{V}\left(\hat{Y}_{tai}\right) = \frac{\sum_j \left(y_{taij} - \hat{\bar{y}}_{tai}\right)^2}{m_t\left(m_t - 1\right)} M_t\left(M_t - m_t\right)$$

This estimate and its variance differs somewhat from that described in Lai et al. (1991) since the total count, M_t (assumed to be a known quantity), is used to expand the estimated CPUE (calculated over all sampled boats) rather than the estimated boat-trips by trip-type and area fished.

RESULTS

In the first report (Stage 1) on this project, March and April in some areas were included as “normally sampled months” in our calculations since some areas have been sampled at a reduced rate during these time periods. After discussion, we felt it more appropriate not to include these as “normally sampled months”, but rather as winter months since (1) sample rates and the number of days sampled during these months has been at rates well below normal, and (2) funding for sampling these months is not dedicated or secure. In addition, halibut and tuna catches were removed from the analysis and preliminary estimates were replaced with finalized estimates for the 2011-2012 and 2012-2013 seasons. Consequently, the analyses for the 2011-12 and 2012-2013 seasons have been modified.

“Winter” months in this analysis are defined as the months of October through April. Catch in the months of December, 2013, and January and February, 2014 is assumed to be zero. “Normally sampled” months are defined as the months of May through September.

Creel sampling of months not currently fully covered by the ocean sampling program (October – April) during the first two years of the project demonstrated that there is a small harvest of marine finfish during this time period in Ilwaco and La Push, and a more significant harvest in Westport and Neah Bay. Creel sampling of “shoulder” winter months during the 2013-14 season supported the determination that Westport and Neah Bay experience a significant harvest of marine finfish, and La Push experiences a small harvest. Ilwaco demonstrated a more significant harvest during the “shoulder” winter months of the 2013-2014 season than in previous years. During the 2013-14 season, the winter catch ranged from 3.5% of yearly total catch in the north coast of Washington state (La Push) to 15.1% in the south coast (Ilwaco). During the 2012-13 season, the winter catch ranged from 7.7% of total yearly catch in the south coast (Ilwaco) to 18.6% of the total in the central coast (Westport) (Table 2), while 2011-12 winter catches ranged from 4.5% in Ilwaco to 15.7% in Westport (Table 3).

Table 4 shows the percent of canary and yelloweye rockfish encounters occurring in winter versus normally-sampled months for each coastal port. Canary and yelloweye are federallylisted threatened rockfish species that are intensively managed following federal rebuilding plans. These two rockfish species currently limit the Washington ocean groundfish fisheries, so precision in estimating impacts on these species is a high priority to fishery managers.

La Push consistently showed the highest rates of canary and yelloweye encounters along the coast during winter months. Westport also demonstrated significant canary and yelloweye encounters during winter months. There was little consistency year-to-year in canary and yelloweye rockfish encounter rates in any port except Neah Bay.

Table 5 shows the catch contribution by month for each port for the three seasons sampled. In all ports, April was the biggest contributor to winter months catch, followed by March in most ports.

The marine fish catch by species during normally sampled and winter months is shown for each port in Appendix 1. Only port/species combinations that indicate winter months catch exceeded 10% of the total harvest are included.

Catch estimates derived from sampling only the May – September time period are underestimated in all ports. The following section examines the effect of the bias on the total uncertainty of catch estimates and considers a correction based on the results of the sampling effort.

Table 1. 2013-2014 Groundfish catch estimates and associated standard errors from each major port for the months normally sampled by WDFW's Ocean Sampling Program, for the additional winter months funded by this project, total harvest for the year, and the percentage of the catch from the winter months.

	Normally-Sampled Months		Winter Months		TOTAL CATCH		
PORT	**Catch** $\hat{C}_{OSP}$	**Standard Error** $S\hat{E}(\hat{C}_{OSP})$	**Catch** $\hat{C}_{W}$	**Standard Error** $S\hat{E}(\hat{C}_{W})$	**Catch**	**Standard Error**	**Percent Catch from Winter months**
Ilwaco	14,289	813	2,537	390	16,826	902	15.1%
Westport	179,892	5,796	29,420	2,673	209,312	6,382	14.1%
La Push	41,147	1,611	1,481	133	42,628	1,616	3.5%
Neah Bay	94,094	4,667	10,381	1,321	104,475	4,851	9.9%
Catch regardless of target trip type							

Table 2. 2012-2013 Groundfish catch estimates and associated standard errors from each major port for the months normally sampled by WDFW's Ocean Sampling Program, for the additional winter months funded by the previous MRIP sampling project, total harvest for the year, and the percentage of the catch from the winter months.

PORT	Normally-Sampled Months		Winter Months		TOTAL CATCH		Percent Catch from Winter months
	Catch $\hat{C}_{OSP}$	Standard Error $S\hat{E}(\hat{C}_{OSP})$	Catch $\hat{C}_{W}$	Standard Error $S\hat{E}(\hat{C}_{W})$	Catch	Standard Error	
Ilwaco	12,899	635	1,074	149	13,973	652	7.7%
Westport	156,247	5,288	35,599	1,841	191,846	5,599	18.6%
La Push	36,044	1,504	3,096	346	39,140	1,543	7.9%
Neah Bay	80,308	2,743	9,326	630	89,633	2,814	10.4%
Catch regardless of target trip type							

Table 3. 2011-2012 Groundfish catch estimates and associated standard errors from each major port for the months normally sampled by WDFW's Ocean Sampling Program, for the additional winter months funded by the previous MRIP sampling project, total harvest for the year, and the percentage of the catch from the winter months.

PORT	Normally-Sampled Months		Winter Months		TOTAL CATCH		Percent Catch from Winter months
	Catch $\hat{C}_{OSP}$	Standard Error $S\hat{E}(\hat{C}_{OSP})$	Catch $\hat{C}_{W}$	Standard Error $S\hat{E}(\hat{C}_{W})$	Catch	Standard Error	
Ilwaco	15,250	631	721	73	15,970	635	4.5%
Westport	165,813	3,933	30,990	1,779	196,803	4,316	15.7%
La Push	36,480	1,682	2,427	111	38,907	1,686	6.2%
Neah Bay	59,594	1,568	8,172	837	67,766	1,777	12.1%
Catch regardless of target trip type							

Table 4. Percent of total canary rockfish and yelloweye rockfish encounters (retained and released) by time period for each WA coastal port during the 2011-12, 2012-13, and 2013-14 sampling seasons.

	2011-2012		2012-2013		2013-2014	
PORT/ SPECIES	Winter months	Normally-sampled months	Winter months	Normally-sampled months	Winter months	Normally-sampled months
Ilwaco						
CANARY	**0%**	**100%**	**0%**	**100%**	**13%**	**87%**
YELLOWEYE	**2%**	**98%**	**0%**	**100%**	**7%**	**93%**
Westport						
CANARY	**16%**	**84%**	**24%**	**76%**	**8%**	**92%**
YELLOWEYE	**7%**	**93%**	**20%**	**80%**	**5%**	**95%**
La Push						
CANARY	**17%**	**83%**	**50%**	**50%**	**26%**	**74%**
YELLOWEYE	**14%**	**86%**	**34%**	**66%**	**13%**	**87%**
Neah Bay						
CANARY	**5%**	**95%**	**6%**	**94%**	**5%**	**95%**
YELLOWEYE	**2%**	**98%**	**4%**	**96%**	**2%**	**98%**

Table 5. Catch contribution by month for each WA coastal port during the 2011-12, 2012-13, and 2013-14 sampling seasons.

	ILWACO			WESTPORT			LA PUSH			NEAH BAY		
MONTH	**2013-14**	**2012-13**	**2011-12**	**2013-14**	**2012-13**	**2011-12**	**2013-14**	**2012-13**	**2011-12**	**2013-14**	**2012-13**	**2011-12**
January	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
February	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
March	2.9%	2.8%	0.1%	2.3%	7.8%	2.1%	0.5%	2.8%	1.3%	0.1%	0.1%	0.2%
April	8.7%	4.2%	2.3%	10.6%	9.6%	12.6%	1.6%	5.1%	4.7%	9.3%	10.3%	11.4%
May	18.9%	15.2%	9.0%	19.0%	19.2%	19.0%	39.0%	40.2%	31.0%	40.9%	41.3%	33.5%
June	23.8%	33.0%	16.3%	17.5%	20.9%	16.9%	9.8%	12.1%	18.7%	10.2%	14.4%	14.0%
July	19.3%	21.2%	28.9%	21.2%	16.1%	20.1%	15.3%	12.4%	22.8%	18.0%	15.1%	20.0%
August	15.7%	16.3%	25.6%	19.5%	20.2%	20.2%	26.8%	24.9%	17.8%	16.2%	16.4%	16.0%
September	7.2%	6.5%	15.7%	8.7%	5.0%	8.1%	5.6%	2.4%	3.5%	4.8%	2.4%	4.5%
October	3.5%	0.6%	1.7%	1.2%	1.1%	1.0%	1.4%	0.0%	0.3%	0.4%	0.0%	0.4%
November	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
December	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Bias correction for unsampled months

One metric used to evaluate estimators is through comparing the mean squared error (MSE) which takes into account both bias and variance, expressed mathematically as

$$MSE(\hat{C}) = Bias^2(\hat{C}) + Variance(\hat{C})$$

Often the most desirable estimator is one with the smallest MSE. However, a zero bias does not always equate to a smaller MSE. At times, additional sampling to reduce or eliminate bias can increase the variance of an estimator, particularly if additional parameters are required to obtain an unbiased estimate of the target quantity. Alternatively, the cost of additional sampling may not decrease an MSE sufficiently to justify the use of additional resources.

If the total, unbiased catch in a year is the sum of the current OSP estimate plus the catch from winter months, then

$$Bias(\hat{C}) = \hat{C}_{OSP} - (\hat{C}_W + \hat{C}_{OSP}),$$
$$Bias(\hat{C}) = -\hat{C}_W$$

where $\hat{C}_{OSP}$ = catch as estimated by the current OSP program,
$\hat{C}_W$ = catch from the winter months, or months currently not sampled,
$\hat{C}$ = the total catch for the year.
Total catch is underestimated by the amount of harvest in winter months.

Under the assumption that winter harvest is small or non-existent and $\hat{C}_{OSP}$ is used for total harvest, the MSE is

$$MSE(\hat{C}) = (\hat{C}_w)^2 + Variance(\hat{C}_{OSP}). \qquad \text{Eq. 1}$$

The MSE of total harvest calculated by sampling all months is

$$MSE(\hat{C}) = Variance(\hat{C}_{OSP} + \hat{C}_w),$$
$$MSE(\hat{C}) = Variance(\hat{C}_{OSP}) + Variance(\hat{C}_w) \qquad \text{Eq. 2}$$

because the bias is zero and all months are sampled independently. The MSE of $\hat{C}_{OSP}$ is larger than total harvest, $\hat{C}$, across all ports based on 2011-2012 sampling (Table 2), although the difference decreases with $\hat{C}_W$.

Current OSP catch estimates can be corrected for negative bias using a the following bias correction,

$$\hat{C}_{corr} = \frac{\hat{C}_{OSP}}{BiasCorr} \qquad \text{Eq. 3}$$

where $BiasCorr = \frac{\hat{C}_{OSP}}{\hat{C}_{OSP} + \hat{C}_W}$. The corrected catch estimate $\hat{C}_{corr}$ is unbiased to the first term of a Taylor series expansion,

$$E\left(\hat{C}_{corr}\right) \doteq \frac{E\left(\hat{C}_{OSP}\right)}{\frac{E\left(\hat{C}_{OSP}\right)}{E\left(\hat{C}_{OSP}+\hat{C}_{W}\right)}},$$

$$E\left(\hat{C}_{corr}\right) \doteq E\left(C_{OSP}+C_{W}\right)$$

$$E\left(\hat{C}_{corr}\right) \doteq C$$

The variance of the bias corrected estimate, $\hat{C}_{corr}$, is as follows,

$$Var\left(\hat{C}_{corr}\right) \doteq \hat{C}_{corr}^{2}\left(\frac{Var\left(\hat{C}_{OSP}\right)}{\hat{C}_{OSP}^{2}}+\frac{Var(BiasCorr)}{BiasCorr^{2}}\right) \qquad \text{Eq. 4}$$

where $Var(BiasCorr)$ is a function of the $\hat{C}_{OSP}$, $\hat{C}_{W}$, and their associated variances,

$$Var(BiasCorr) \doteq \left(\frac{\hat{C}_{W}}{\hat{C}_{OSP}+\hat{C}_{W}}\right)^{2}\left(\frac{Var\left(\hat{C}_{OSP}\right)}{\hat{C}_{OSP}^{2}}+\frac{Var\left(\hat{C}_{W}\right)}{\left(\hat{C}_{OSP}+\hat{C}_{W}\right)^{2}}\right) \qquad \text{Eq. 5}$$

Note that Eq. 3 is derived under the assumption that a bias correction would be independently estimated. Table 2 provides a comparison of the MSE's for current OSP estimates (Eq. 1), total catch, $\hat{C}$ (Eq. 2), and corrected catch, $\hat{C}_{corr}$ (Eq. 3). Because $\hat{C}_{corr}$ is unbiased, the MSE is equal to the variance.

Table 5. 2013-2014 mean squared error among different estimates of groundfish catch.

	Mean Square Error		
Port	**Current OSP catch estimate**	**Total Catch Winter Included**	**Corrected catch estimate**
Ilwaco	7,148,707	813,670	950,276
Westport	903,919,899	40,736,903	46,839,257
La Push	5,034,038	2,613,621	2,798,531
Neah Bay	132,589,016	23,562,769	27,142,965

Table 6. 2012-2013 mean squared error among different estimates of groundfish catch.

	Mean Square Error		
Port	**Current OSP catch estimate**	**Total Catch Winter Included**	**Corrected catch estimate**
Ilwaco	77,563,118	76,432,067	86,853,065
Westport	1,285,886,757	22,034,750	33,166,183
La Push	12,507,257	3,042,252	3,565,161
Neah Bay	89,426,498	2,855,156	3,860,571

Table 7. 2011-2012 mean squared error among different estimates of groundfish catch.

Port	Mean Square Error		
	Current OSP catch estimate	**Total Catch Winter Included**	**Corrected catch estimate**
Ilwaco	1,156,573	642,346	703,071
Westport	23,752,177	19,368,689	19,854,154
La Push	3,714,371	3,288,801	3,403,412
Neah Bay	15,801,230	15,720,879	15,832,764

With the exception of Ilwaco in 2012-2013, estimates of total groundfish catch based on sampling in all months have the lowest MSE, followed by the corrected catch estimates () for all years. Differences among MSEs decrease as the bias decreases. The MSE of the corrected estimates is between that of $MSE\left(\hat{C}_{OSP}\right)$ and $MSE\left(\hat{C}\right)$, but closer to $MSE\left(\hat{C}\right)$.

We noted some consistency in the percentage of total catch attributable to the winter months for Westport, La Push and Neah Bay, suggesting that a bias correction could be used for these ports for the total. We verified this by calculating the coefficient of variation (CV) of the percentage of total catch observed during winter months over the 3 years of this study for Neah Bay and Westport (Table 8). In La Push, the CV for the catch in typically unsampled months was higher at 38% however the percentage across all years was less than 10%. The percentage of catch in winter months doubled in Ilwaco each year of the study. Subsequently we cannot recommend a bias correction for Ilwaco at this time.

Current OSP catch estimates for Neah Bay, La Push and Westport can be corrected for negative bias by Eq. 2 using the values in Table 8. We estimated the bias corrections as follows,

$$\overline{BiasCorr} = \frac{\hat{\hat{C}}_{OSP}}{\hat{\hat{C}}_{OSP}+\hat{\hat{C}}_{W}},$$

where $\hat{\hat{C}}_{OSP}$ = the average catch from the regularly sampled months for the three years of the study calculated as $\hat{\hat{C}}_{OSP} = \frac{\sum_{i=1}^{3} \hat{C}_{OSP,i}}{n}$, and

$\hat{\hat{C}}_{W}$ = the average catch from the winter sampled months for the three years of the study calculated as $\hat{\hat{C}}_{W} = \frac{\sum_{i=1}^{3} \hat{C}_{w,i}}{n}$,

The associated variance of $\overline{BiasCorr}$ is calculated as in Eq. 5, with the appropriate substitutions as follows,

$$Var\left(\overline{BiasCorr}\right) \doteq \left(\frac{\hat{\bar{C}}_W}{\hat{\bar{C}}_{OSP} + \hat{\bar{C}}_W} \right)^2 \left(\frac{Var\left(\hat{\bar{C}}_{OSP}\right)}{\hat{\bar{C}}_{OSP}^2} + \frac{Var\left(\hat{\bar{C}}_W\right)}{\left(\hat{\bar{C}}_{OSP} + \hat{\bar{C}}_W\right)^2} \right).$$

Although there was less consistency in percentage of winter catch for individual species across years for total catch, the bias correction could be still be used as a conservative measure to account for harvest of species of concern. Table 8 shows proposed bias corrections that could be used to account for catch during unsampled months.

Table 8. The proposed bias correction ($\overline{BiasCorr}$) to account for unsampled winter months for the four ports that were part of this study.

Port	CV (% catch winter months)	Bias Correction ($\overline{BiasCorr}$)	SE ($\overline{BiasCorr}$)	PSE ($\overline{BiasCorr}$)
Ilwaco	60%	None		
Westport	14%	16.1%	1.3%	7.9%
La Push	38%	5.8%	0.3%	5.3%
Neah Bay	10%	10.6%	0.7%	6.2%

DISCUSSION

This three-year study was designed to test the assumption that ocean fishing effort and catch are insignificant during the months between September and May, which are typically either not sampled or sampled at very low rates. The two seasons of sampling year-round and one year of sampling “shoulder” months in Washington coastal ports demonstrated that both Westport and Neah Bay experience significant (comprising 10% or greater of the total annual groundfish harvest) early spring groundfish harvest. March and April in Westport and April in Neah Bay proved important contributors to total groundfish catch. Early-season catch in La Push comprised less than 10% of the total annual catch in each year of the study, but contributed significant canary and yelloweye rockfish impacts in March and April. The early spring groundfish harvest in Ilwaco was significant in the final study year only and was inconsistent seasonally.

One of the objectives of this study was to determine whether a catch bias correction would be feasible to apply to months that are typically not sampled or are sampled at a low rate in the Washington ocean recreational fisheries. Based on the three years of data collected, a bias correction appears feasible in Westport, La Push, and Neah Bay. However, fishery managers have concerns about the precision of groundfish bias corrected catch estimates particularly for canary and yelloweye rockfish, given the rebuilding status and restrictive catch constraints on these species and the economic and social impacts of in-season regulation changes or closures. Although a catch bias correction is least feasible in Ilwaco, that area contributes the smallest overall groundfish catch, and specifically, fewer impacts on canary and yelloweye than any other ocean area.

Based on the results of this study, we have prioritized how available sampling funding might be used for ocean recreational sampling in future years. Taking into consideration the potential for catch bias correction, the desired catch estimation precision for intensive fishery impact management, the contribution (in numbers of fish) that each area makes to total Washington ocean recreational groundfish catch, and the economic and social impacts of in-season regulation modifications, we recommend that sampling resources be prioritized as follows:

1. Maintain resources to sample core months (May – September).
2. Sample in March and April in Westport and April in Neah Bay and La Push.
3. Sample March in La Push.
4. Sample April in Ilwaco.
5. Sample March in Neah Bay.
6. Sample October in all ports.
7. Sample other winter months as funding allows.

Appendix 1

Ocean marine fish recreational catch by species that exceeded 10% harvest[1/] in the winter months during the 2013-2014 season.

Port Sampled	Species Name	TOTAL CATCHES (NUMBERS OF FISH)			
		Normally-Sampled Months	Winter Months	Percent landed in normally-sampled months	Percent landed in winter months
Ilwaco	BLACKROCK	11,170	1,861	86%	14%
Ilwaco	BLUEROCK	1	11	11%	89%
Ilwaco	CABEZON	113	18	86%	14%
Ilwaco	CANARY (released)	37	5	87%	13%
Ilwaco	CHINA	7	2	79%	21%
Ilwaco	KELPGREENLING	262	46	85%	15%
Ilwaco	LINGCOD	1,031	415	71%	29%
Ilwaco	MISCELLANEOUS	361	154	70%	30%
Ilwaco	QUILLBACK	46	19	71%	29%
Ilwaco	TIGER	10	2	85%	15%
La Push	BLUEROCK	144	23	86%	14%
La Push	CANARY (released)	91	35	72%	28%
La Push	MISCELLANEOUS	48	12	79%	21%
La Push	QUILLBACK	30	15	67%	33%
La Push	VERMILLION	1	4	27%	73%
La Push	YELLOWEYE (released)	304	45	87%	13%
La Push	YELLOWTAIL	138	85	62%	38%
Neah Bay	LINGCOD	12,341	1,946	86%	14%
Neah Bay	MISCELLANEOUS	258	91	74%	26%
Neah Bay	PERCH	12	8	60%	40%
Neah Bay	YELLOWTAIL	1,294	392	77%	23%
Westport	BLACKROCK	128,969	25,070	84%	16%
Westport	BLUEROCK	37	40	48%	52%
Westport	LINGCOD	16,125	3,507	82%	18%
Westport	TIGER	3	1	75%	25%

[1/] Analysis of harvest includes released canary and yelloweye rockfish.

Ocean marine fish recreational catch by species that exceeded 10% harvest[1/] in the winter months during the 2012-2013 season.

Port Sampled	Species Name	TOTAL CATCHES (NUMBERS OF FISH)			
		Normally-Sampled Months	Winter Months	Percent landed in normally-sampled months	Percent landed in winter months
Ilwaco	CABEZON	101	33	75%	25%
Ilwaco	KELPGREENLING	344	56	86%	14%
Ilwaco	LINGCOD	1,025	218	82%	18%
La Push	BLUEROCK	63	8	88%	12%
La Push	BOCACCIO	15	2	88%	12%
La Push	CANARY (released)	68	67	50%	50%
La Push	LINGCOD	4,180	766	85%	15%
La Push	MISCELLANEOUS	40	20	66%	34%
La Push	QUILLBACK	21	6	77%	23%
La Push	TIGER	6	1	85%	15%
La Push	YELLOWEYE (released)	146	76	66%	34%
La Push	YELLOWTAIL	75	128	37%	63%
Neah Bay	CABEZON	1,464	256	85%	15%
Neah Bay	LINGCOD	12,117	2,515	83%	17%
Neah Bay	MISCELLANEOUS	195	98	67%	33%
Neah Bay	YELLOWTAIL	1,720	347	83%	17%
Westport	BLACKROCK	124,103	28,227	81%	19%
Westport	BLUEROCK	56	26	68%	32%
Westport	CABEZON	175	45	80%	20%
Westport	CANARY (retained)	-	2	0%	100%
Westport	CANARY (released)	288	91	76%	24%
Westport	COPPER	16	3	85%	15%
Westport	KELPGREENLING	272	206	57%	43%
Westport	LINGCOD	11,824	5,849	67%	33%
Westport	PERCH	11	3	79%	21%
Westport	QUILLBACK	209	77	73%	27%
Westport	TIGER	13	2	86%	14%
Westport	YELLOWEYE (released)	277	69	80%	20%

[1/] Analysis of harvest includes released canary and yelloweye rockfish.

Ocean marine fish recreational catch by species that exceeded 10% harvest[1/] in the winter months during the 2011-2012 season.

Port Sampled	Species Name	TOTAL CATCHES (NUMBERS OF FISH)			
		Normally-Sampled Months	Winter Months	Percent landed in normally-sampled months	Percent landed in winter months
Ilwaco	BLUEROCK	47	10	82%	18%
Ilwaco	COPPER	8	1	88%	12%
La Push	BLUEROCK	139	34	80%	20%
La Push	COPPER	24	7	78%	22%
La Push	CANARY (released)	144	31	82%	18%
La Push	KELPGREENLING	396	51	89%	11%
La Push	LINGCOD	5,830	790	88%	12%
La Push	QUILLBACK	117	21	85%	15%
La Push	TIGER	10	6	65%	35%
La Push	YELLOWEYE (released)	610	98	86%	14%
La Push	YELLOWTAIL	319	254	56%	44%
Neah Bay	BLACKROCK	36,641	5,889	86%	14%
Neah Bay	BOCACCIO	229	53	81%	19%
Neah Bay	CABEZON	1,655	186	90%	10%
Neah Bay	CANARY (retained)	87	15	85%	15%
Neah Bay	LINGCOD	8,780	1,572	85%	15%
Westport	BLACKROCK	132,931	25,370	84%	16%
Westport	BLUEROCK	80	74	52%	48%
Westport	CANARY (released)	326	63	84%	16%
Westport	COPPER	38	6	87%	13%
Westport	FLATFISH	1,087	182	86%	14%
Westport	KELPGREENLING	459	119	79%	21%
Westport	LINGCOD	18,028	4,085	82%	18%
Westport	PERCH	39	26	60%	40%
Westport	TIGER	7	1	84%	16%

[1/] Analysis of harvest includes released canary and yelloweye rockfish.