Procedures for Bycatch Estimation of Prohibited

Species in the 1989 Bering Sea Domestic

Trawl Fisheries

by

Jerald D. Berger, Russell F. Kappenman,

Loh-Lee Low, and Richard J. Marasco

Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Building 4, BIN Cl5700
7600 Sand Point Way N.E.
Seattle, Washington 98115

October **1989**

ABSTRACT

'"In August 1989, the Bering Sea-Aleutian Island Groundfish Fishery Management Plan was amended in order to control the bycatch of prohibited species in the domestic groundfish fisheries. This paper: 1) describes the procedures used by the National Marine Fisheries Service to estimate the prohibited species bycatch, 2) summarizes how these procedures were developed, 3) presents prohibited species catch estimates through 5 August 1989.

iii

CONTENTS

INTRODUCTION

Amendment 12A, an amendment to the Bering Sea-Aleutian Island Groundfish Fishery Management Plan for controlling bycatch of prohibited species in the domestic groundfish fisheries, was approved in late August 1989. The National Marine Fisheries Service (NMFS) is charged with its implementation. One of the requirements of the amendment is the estimation of the amount of prohibited species--Pacific halibut (<u>Hippoglossus stenolepis</u>), snow (Tanner) crabs (<u>Chionoecetes</u> spp.), and king crabs (<u>Paralithodes</u> and <u>Lithodes</u> spp.)--taken as bycatch in both joint venture and domestic fisheries.

Observers have been required on board all foreign processor vessels to sample the catch delivered by U.S. catcher vessels. Bycatch of prohibited species can be estimated for joint venture processing (JVP) from these samples.

The estimation of bycatch in the domestic annual processing (DAP) fisheries, on the other hand, is considerably more difficult. The level of observer coverage in DAP fisheries to date is insufficient for estimation of bycatch. Therefore, other procedures had to be found. This report explains two methods developed to estimate DAP bycatch.

METHODS AND DATA

Data Base

Information collected from joint venture fisheries make up the largest data set for investigating bycatch in the eastern Bering Sea. The data are aggregated into cells defined by week, area, and fishery type.. The areal divisions are fisheries management areas established by the North Pacific Fishery Management Council (Fig. 1). The fishery types are defined by gear and target species, namely Atka mackerel (<u>Pleurogrammus mononteryaius</u>), walleye pollock (<u>Theragra chalcosramma</u>) bottom trawl, other groundfish bottom trawl, walleye pollock midwater trawl, and flatfish bottom trawl. For each cell, the data file includes the catch of various groundfish species as well as bycatches of the prohibited species (halibut and crabs).

Bycatch rates for crabs and halibut are provided by the NMFS observer program and are expressed in terms of numbers of animals per metric ton of groundfish. Halibut bycatch rates are also expressed in terms of kilograms per metric ton of groundfish.

Estimation Procedures

Robust Linear Regression Estimator

A robust linear regression estimator for estimating bycatch for halibut and C. <u>bairdi</u> crab is proposed for DAP fisheries in the eastern Bering Sea. The linear estimator is of the form:

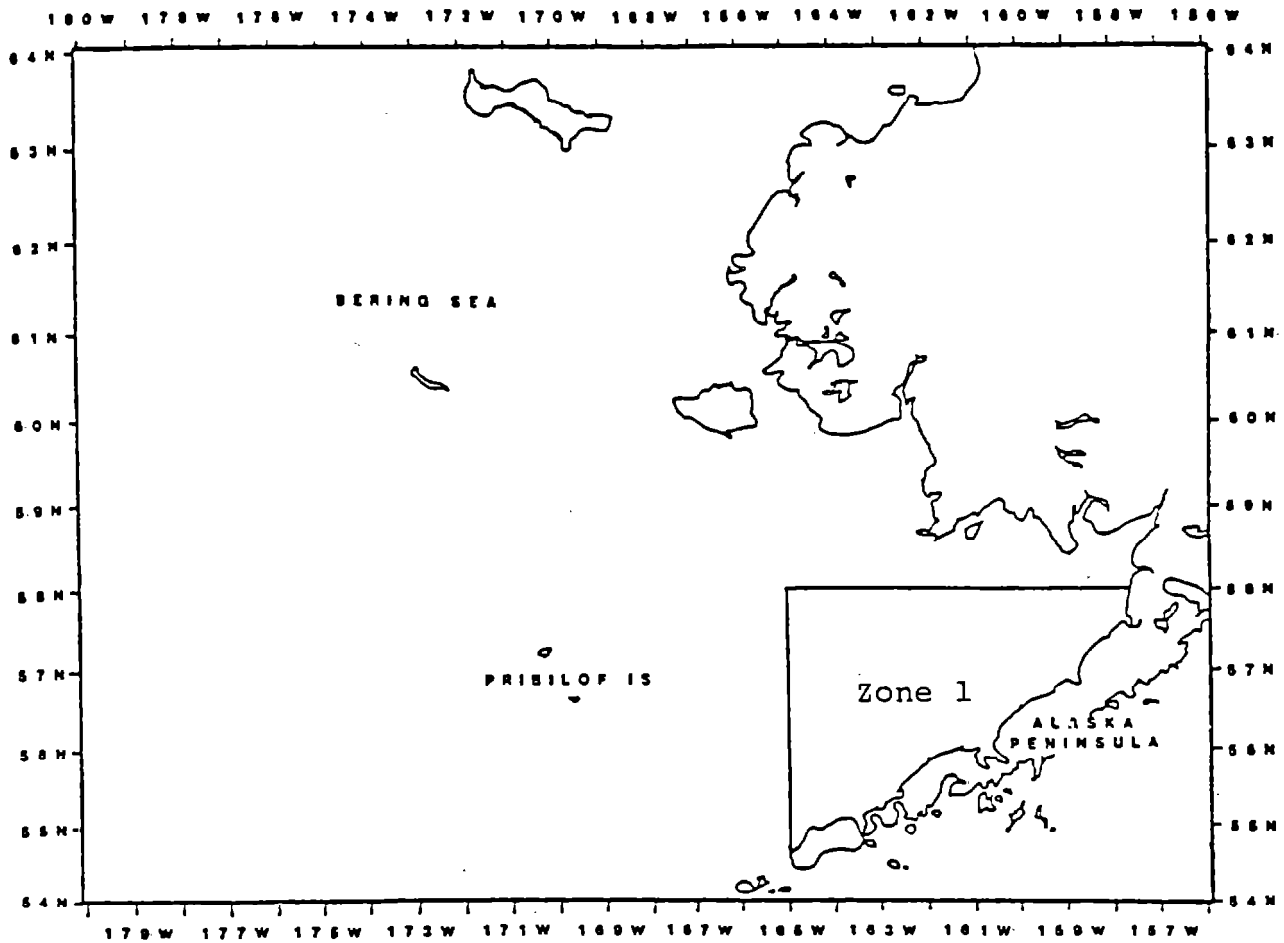$$y = b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4, \qquad (1)$$

Figure 1. --Bering Sea by catch management, Zone 1.

where y represents total bycatch of a given prohibited species and x_1, x_2, x_3 and x_4 represent, respectively, the total pollock, Pacific cod (<u>Gadus macrocephalus</u>), yellowfin sole (<u>Limanda aspera</u>)., and other flatfish catches, for a given week by a group of boats fishing in the same subarea for the same target species. The values of the coefficients, b,, b_2, b,, and b,, depend upon which prohibited species bycatch is being estimated and, possibly, on the time and location of the fishery (i.e., year, quarter and subarea).

Data obtained from the monitoring of 1986-88 JVP operations by observers were used to estimate values for the coefficients in Equation (1). These data were in the form $(y_1, x_{11}, x_{21}, x_{31}, x_{41}), \ldots, (y_n, x_{1n}, x_{2n}, x_{3n}, x_{4n})$, where $(y_i, x_{1i}, x_{2i}, x_{3i}, x_{4i})$ represents the i-th observation.

A robust linear regression analysis procedure developed by Kappenman (1988) was used for determining the bj's in Equation (1). Since interest is in estimating total prohibited species bycatch, the following constraint was imposed:

$$\Sigma \, y_i = \Sigma(\, b_1 \, x_{1i} + b_2 \, x_{2i} + b_3 \, x_{3i} + b_4 \, x_{4i}). \qquad (2)$$

The Kappenman regression procedure leads to the following procedure for determining the b_j's in Equation (1). Set

$$z_i = y_i - (\Sigma y_i / \Sigma x_{1i}) x_{1i}, \qquad w_{1i} = x_{2i} - (\Sigma x_{2i} / \Sigma x_{1i}) x_{1i},$$

$$w_{2i} = x_{3i} - (\Sigma x_{3i} / \Sigma x_{1i}) x_{1i}, \qquad w_{3i} = x_{4i} - (\Sigma x_{4i} / \Sigma x_{1i}) x_{1i},$$

$$v_i = (1 \, / \, (1 + (z_i - b_{20} w_{1i} - b_{30} w_{2i} - b_{40} w_{3i} / d)^2)),$$

and d = **median** { $|z_i - b_{20}w_{1i} - b_{30}w_{2i} - b_{40}w_{3i}|$ }. Here b_{20}, b_{30}, and b_{40} are the least absolute value estimates of b_2, b_3, and $b_,$, that is, the values of b_2, b_3, and b_4 which minimize

$$\Sigma |y_i - b_2 w_{1i} - b_3 w_{2i} - b_4 w_{4i}|.$$

Then appropriate values for b_2, b_3, and b_4 are the values of these coefficients which minimize

$$\Sigma v_i (z_i - b_2 w_{1i} - b_3 w_{2i} - b_4 w_{3i})^2. \tag{3}$$

Once these values are found, an appropriate value for $b_,$ is

$$b_1 = (\Sigma y_i - b_2 \Sigma x_{2i} - b_3 \Sigma x_{3i} - b_4 \Sigma x_{4i}) / \Sigma x_{1i}.$$

The analysis of the 1986-88 JVP observer data indicated that the linear regression error distributions are reasonably symmetric and have tails which are much heavier than those of the normal distribution. This suggests that least squares regression analysis is not appropriate for use in estimating the coefficients, and a linear regression analysis, which works well when the error distribution is heavy tailed and symmetric, should be used.

The values of b_2, b_3, and b_4 which minimize Equation (3) are approximations for maximum likelihood estimates of these coefficients, if the error distribution belongs to the Student "t" family of distributions with heavier than normal tails.

In order to determine whether or not appropriate values for the b_j's in Equation (1) depend upon year, quarter, or subarea, the following eight models were examined:

M_1 : the values of the $b_,$'s depend upon the year, the subarea, and
    the quarter in which the x_1's are observed.

M_2: the values of the b_j's depend upon the year and the quarter
in which x_1's are observed, but not on the subarea.

M_3: the values of the b_j's depend upon the year and the subarea
in which the x_1's are observed, but not on the quarter.

M_4: the values of the b_1's depend upon the year in which the x_j's
are observed, but not the quarter and subarea.

$M_,$: the values of the b_1's depend upon the subarea and the
quarter in which the x_1's are observed, but not the year.

M_6: the values of the b_j's depend upon the quarter in which the
x_i's are observed, but not the year and subarea.

$M_,$: the values of the b_j's depend upon the subarea in which the
x_1's are observed but not the year and the quarter.

$M_,$: the values of the b_j's depend upon neither the year nor the
quarter nor the subarea in which the x_1's are observed.

The n vectorial observations $(y_1, x_{11}, x_{21}, x_{31}, x_{41}), \ldots,$
$(y_n, x_{1n}, x_{2n}, x_{3n}, x_{4n})$ may be used to select an appropriate model from
among those just listed.

For a given model and a given observed prohibited species
catch, y_j' we can calculate a predicted value for y_i as follows:

    a.   **delete the vectorial observation** $(y_j, x_{1j}, x_{2j}, x_{3j}, x_{4j})$
from the data;

    b.   use the remaining n-1 vectorial observations to estimate
values for the parameters in the model;

    c.   apply the model, with parameters replaced by their
estimates, to $(x_{1j}, x_{2j}\ x_{3j}, x_{4j},$ to get a predicted value
for y_j.

A predicted value for each of $y_1, y_2, \ldots, y_n$ is obtained in this manner for each model being considered. Let

$$y_{1M_h}, \ldots, y_{nM_h}$$

represent the predicted values of $y_1, \ldots, y_n$ for model M_h, h=1,...,8. Set

$$PRESAV(M_h) = \sum_{i=1}^{n} |y_i - y_{iM_h}| \quad ,$$

for h=1,...,8. To select an appropriate model, we examine the prediction sum of absolute values (PRESAV) for the various models and look for those models which produce small PRESAV's.

The following values for prediction sum of absolute values were found when 19-87-88 JVP observer-obtained weekly summary data were used:

Prohibited Species

Model	Halibut	C. bairdi	Red king crab
M_1	2785873	883891	243265
M_2	2051550	773516	284550
M_3	1982720	726718	228474
M_4	2207621	809114	273780
M_5	2076229	752599	169257
M_6	1929829	817961	263936
M_7	2195205	769056	210867
M_8	2089256	889060	255506

These results indicate that reasonable models appear to be M_6 for halibut and M_5 for C. _bairdi_ and red king crab (_Paralithodes camtschatica_). If subarea is unknown, as is frequently the case with DAP trawl catch, M_6 might also be used as a model for C. _bairdi_ and red king crab bycatch estimation.

The 1986-88 JVP observer data were used to get appropriate values for the b_j's in Equation (1). When the bycatch of Pacific halibut is to be estimated, the b_j coefficients are

Quarter	b_1	b_2	b_3	b_4
1	1.1007	11.2288	0.9586	0.6760
2	2.3226	19.3926	0.4108	6.3910
3	3.1192	8.1258	4.6134	0
4	2.2913	24.4234	7.2488	0

When the bycatch of C. bairdi is to be estimated, the b_j coefficients are

Quarter	b_1	b_2	b_3	b_4
1	0	2.3951	0.9307	1.2952
2	0	9.1384	0	1.5194
3	0.5658	0	0	2.3976
4	0.7548	0	1.6668	5.8105

When the bycatch of red king crab is to be estimated, the b_1 coefficients are:

Quarter	b_1	b_2	b_3	b_4
1	0.2991	0	0.2931	0.2931
2	0.2300	0	0.4428	0.4428
3	0.2671	0	0.0715	0.0715
4	0.9551	0	0.0641	0.0641

To check the reliability of these regression coefficients, a comparison was made using the 1989 joint venture data base. Groundfish catches from the joint venture vessels in this fishery were multiplied by the regression coefficients, and prohibited species catch estimates (regression estimates) were made. These

estimates were then compared to the actual catches of the vessels as reported by U.S. observers.   The results are as follows:

Species	Regression estimate	Actual catch
Pacific halibut (kg)	489,233	430,818
C. bairdi (nos)	205,825	203,846
Red king crab (nos)	45,131	161,001

Best Blend Estimator

The best blend procedure for estimating bycatch is based upon the selection of the most appropriate expected bycatch rate for each prohibited species.   Once a rate is selected, it is multiplied by the reported DAP groundfish catch to produce an estimate of the bycatch.

The procedure is based upon the assumption that DAP bycatch rates are the same as those experienced by other fisheries targeting the same or similar species.   The procedure was implemented as follows:

1) The DAP groundfish data are cumulated by week, target, and subarea.   (When subarea is not reported by the vessels, it is assigned based upon catch composition.)

2) Next, the cumulated DAP groundfish data are multiplied by prohibited species rates (PSR) which are selected on the basis of the following criteria:

a)   select PSR from the current year's (1989) DAP data for the same week, target, and subarea.   If no match (i.e., no DAP prohibited species data for the same week, target, and subarea), then

b)   select PSR from current year's (1989) JVP data for the same week, target, and subarea.   If no match, then

c)   select PSR from the current year's DAP data for the same month (monthly average), target, and subarea. If no match, then

d)   select PSR from the JVP 3-year (1986-88) historical average for the same month, target, and subarea (no historical subarea data for 516 and 517, so use 511 rate for 516 and 513 rate for 517).   If no match, then

e)   select PSR from the current year's JVP data for the same month (monthly average), target, and subarea. If no match, then

f)   select PSR from the current year's DAP data for the same quarter (quarterly average), target, and subarea. If no match, then

4)   select PSR from the JVP 3-year historical average for the same quarter (quarterly average), target, and subarea.   If no match, then

h)   select PSR from the current year's JVP data for the same quarter (quarterly average), target, and subarea. If no match, then

i)   select PSR for the current year's DAP data for the
year (yearly average), for the same target and subarea.
If no match, then

3   select PSR from the JVP 3-year historical average
for the year (yearly average), for the same target and
subarea.   If no match, then

k)   select PSR for the current year's JVP data for the
year (yearly average), for the same target and subarea.
If no match, then

1)   examine the data and find a target and subarea
likely to have rates similar to the target and subarea
in question.

Groundfish Target Categories

The bycatch management regime requires that the DAP
bycatches be separated by target fisheries and zones. At
present, the management units are defined as target fisheries for
"flatfish" versus that for "other fish," inside Zone 1 (Fig. 1)
and outside of Zone 1.   This results in four fishery-subarea
categories.   The following rules were used to assign the weekly
catches to the appropriate categories:

1) "DAP flatfish fishery" means DAP fishing operations which
retain, on a weekly basis, yellowfin sole, rock sole
(Leoidoosetta bilineata), and other flatfish in an amount greater
than or equal to 20% of the total amount of groundfish retained.

2) "DAP other fishery" means DAP fishing operations which retain, on a weekly basis, any combination of groundfish species which does not qualify the fishery as a "flatfish fishery."

3) Catches identified as being taken in area 511 are designated inside Zone 1.

4) Catches not identified as being taken in area 511 are designated outside Zone 1.

The weekly DAP catch data so designated by the four fishery-subarea categories were then multiplied by their corresponding best blend bycatch rates to estimate bycatch in DAP fisheries.

RESULTS

A summary compilation of Zone 1 and outside of Zone 1 bycatches for two major target fisheries (flatfish and other fish) are shown in Tables 1-4. Estimates contained in these tables are for DAP fisheries conducted in the eastern Bering Sea through 5 August 1989.

As explained earlier, the robust linear regression estimator is a good predictor of bycatch for Pacific halibut and C. bairdi crab. Therefore, the bycatch of these two species was estimated using the results of the regression analysis. The best blend procedure was used for red king crab, because of the inabilitly of the regression method to accurately predict the 1989 JVP fishery bycatch for this species in the 1989 JVP fishery.

Table 1.-- Estimates of the prohibited species catches (through
5 August 1989) in the domestic annual processing
flatfish fishery inside Zone 1.

Species	Qtr 1	Qtr 2	Qtr 3	Total
Pacific halibut (kg)	133,114	3,924	0	137,038
C. bairdi (nos.)	63,339	789	0	64,128
Red king crab (nos.) (regression estimate)	23,822	600	0	24,422
Red king crab (nos.) (best blend estimate)	64,714	1,440	0	66,154

Table 2.-- Estimates of the prohibited species catches (through
5 August 1989) in the domestic annual processing
other fish fishery inside Zone 1..

Species	Qtr 1	Qtr 2	Qtr 3	Total
Pacific halibut (kg)	72,474	184,345	42,766	299,586
C. bairdi (nos.)	13,015	70,949	4,464	88,428
Red king crab (nos.) (regression estimate)	3,082	3,500	1,408	7,990
Red king crab (nos.) (best blend estimate)	3,045	11,244	10,300	24,589

Table 3.-- Estimates of the prohibited species catches (through
         5 August 1989) in the domestic annual processing
         flatfish fishery outside Zone 1.

Species	Qtr 1	Qtr 2	Qtr 3	Total
Pacific halibut (kg)	19,979	280	74	20,332
C. _bairdi_ (nos.)	7,863	65	131	8,059
Red king crab (nos.) (regression estimate)	2,468	20	8	2,496
Red king crab (nos.) (best blend estimate)	85	1	4	90

Table 4.-- Estimates of the prohibited species catches (through
         5 August 1989) in the domestic annual processing
         other fish fishery outside Zone 1.

Species	Qtr 1	Qtr 2	Qtr 3	Total
Pacific halibut (kg)	159,523	615,922	245,852	1,020,896
C. _bairdi_ (nos.)	25,307	188,485	38,023	251,815
Red king crab (nos.) (regression estimate)	3,428	21,702	17,673	42,803
Red king crab (nos.) (best blend estimate)	34	54	1,041	1,129

In summary, the best bycatch estimates for the three prohibited species by the DAP fisheries in the eastern Bering Sea through 5 August 1989 are as follows:

Species/Zone	Qtr 1	Qtr 2	Qtr 3	Total
Pacific halibut (kg)	385,090	804,471	288,692	1,478,253
Inside Zone 1	205,588	188,269	42,766	436,623
Outside Zone 1	179,502	616,202	245,926	1,041,630
C. bairdi (nos.)	109,524	260,288	42,618	412,430
Inside Zone 1	76,354	71,738	4,464	152,556
Outside Zone 1	33,170	188,550	38,154	259,874
Red king crab (nos.)	67,878	12,739	11,345	91,962
Inside Zone 1	67,759	12,684	10,300	90,743
Outside Zone 1	119	55	1,045	1,219

REFERENCES

Kappenman, Russell. 1988. Robust symmetric distribution
     location estimation and regression. J. Stat. Plan. Infer.
     19:55-72.