Appendix D

Catch Projection Model Detail

Pacific Coast Groundfish Fishery 2019–20 Harvest Specifications and Management Measures

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D.1 *Non-Nearshore*

The non-nearshore model projects bycatch impacts for limited entry and open access fixed gear vessels that are fishing seaward of the non-trawl RCA. The main focus is on bycatch of yelloweye rockfish. This model was reviewed by the Pacific Fishery Management Council's (PMFC) Scientific and Statistical Committee (SSC) in 2013 and endorsed as "best available science and appropriate for use in the 2015-16 specifications process." (Agenda Item F.7.b, Supplemental SSC Report, June 2013) West Coast Groundfish Observer Program (WCGOP) observations on discards and landed catch 2002-2016 provide the primary data input for estimating bycatch with Pacific Fishery Information Network (PacFIN) fish ticket data also providing information on the distribution of catch among gear types. Data from 2016 were the most recent data available at the time of the analysis.

As also described in the Integrated Alternatives analysis, sablefish is the primary target for vessels fishing in these sectors. The sablefish (*Anoplopoma fimbria*) annual catch limit (ACL) north of 36° N lat. is apportioned according to the formal intersector allocations shown in Figure D-1. Management measures are intended to keep the total mortality—i.e., discard mortality and landings—within the allocation for each sector. Because of the economic importance of sablefish, the bycatch impact analysis assumes that the annual sablefish allocation will be fully attained by the fixed gear fleets seaward of the Rockfish Conservation Area (RCA). WCGOP bycatch observations are therefore expressed as a ratio to the expected landings of sablefish.

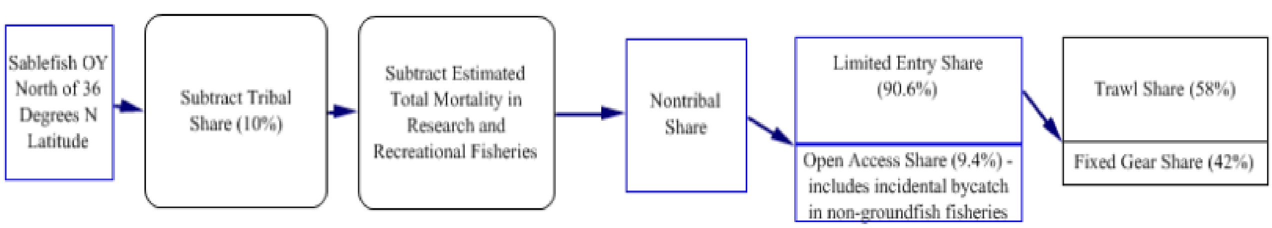

Figure D-1. The formal intersector allocations of sablefish north of 36° N lat.

The core structure of the projection model has not been changed from that used during the past five analyses (2009-10 through 2017-18). However, the 125 and 150 fathom projection bins were removed for 2019–20 as yelloweye bycatch has been fairly static in the fishery and if an issue were to arise inseason, the PFMC Groundfish Management Team (GMT) would assess the movement of the line at that time with the most recent data. Furthermore, with higher yelloweye rockfish ACLs proposed for 2019–20, there was less of a need to consider deeper depth restrictions.

Newly available observations were added such that the model now combines data from the fixed gear sablefish fishery north and south of 40° 10' N lat. from the years 2002-2016. Data from each year is weighted equally. There are tradeoffs with data accuracy and precision involved with stratifying observations to finer levels across attributes (i.e., time, area, depth, and gear type). Aggregating data across years allows reporting of retained and discarded catch of groundfish species by gear type at a finer latitudinal and depth scale than would otherwise be possible. Differences in the encounter rate of yelloweye (and previously canary) between depths and areas are the major focus of the model and so these stratifications have taken priority. The data is stratified by gear because of the differences in the rate of encounter between pot and longline gear types.

Data summarizing observed retained and discarded catch from fishing efforts north of 40° 10' N lat. are stratified across three alternative depth ranges that are used to evaluate the potential impact of extending the seaward boundary of the non-trawl RCA on bycatch levels. As described in the Integrated Alternatives, the seaward RCA boundary is the key bycatch management measures in these non-nearshore sectors. Although the range of depths recorded for an individual fixed gear set by observers is commonly much smaller than for observed trawl tows, there is some uncertainty in the assignment of catch and discard from many sets to a specific 25 fm interval. For this exercise, the average of the beginning and ending depths of each set was used to represent the depth at which all fish on the set were caught.

The area stratification used in this model was developed first for use in the 2009-10 biennial management cycle. This stratification was arrived at through consideration of canary and yelloweye bycatch north of 40° 10' N lat. by depth and area and provides the Council with the option of employing differential seaward RCA boundaries within these areas. Four subareas were identified bounded by: 1) Cape Mendocino 40°10' N lat. to the boundary of the northern Eureka International North Pacific Fishery Commission (INPFC) statistical area at 43°30' N lat.; 2) Northern Eureka INPFC boundary to Cascade Head at 45°03' N lat.); 3) Cascade Head to Point Chehalis (46°54' N lat.), and 4) Point Chehalis to the U.S.-Canada border (49° N). Several alternative boundaries were evaluated. Analysts determined that the four listed above provided the greatest contrast and reliability between areas of high and low yelloweye bycatch. Since rockfish bycatch in the pot gear fleet is very small and there are very limited numbers of pot gear observations in some areas, results for this group are summarized with respect to depth only (without subareas). Note that the seaward non-trawl RCA was moved from 150 fm at 34°27´ N lat. in 2016 to 125 fm at 40°10´ N lat. in 2017.

To produce estimates of catch by area, the model must assume a distribution of sablefish catch between the areas north and south of 40°10' N lat. and between longline and pot gear types for both the open access and limited entry sectors. The assumed distribution is based on fish ticket landings for the years 2002-2016 (Table D-1). The 2002-2016 average of WCGOP observed landings are then used to project the distribution of the longline catch north of 40°10' N lat. among the four management subareas (Table D-2). The model then applies WCGOP observed discard rates to these projected catch distributions using the appropriate area, depth, and gear stratification to produce annual estimates of discard for the rebuilding rockfish encountered by the non-nearshore fixed gear sectors. Discard rates were calculated by dividing the total observed discard weight for each species by the weight of retained sablefish and are reported in Table D-3, Table D-4, and Table D-5. Data is available for all species encountered in the non-nearshore sectors; however, this projection model focuses on the rebuilding rockfish stocks and the potential need to adjust the seaward boundary of the RCA to lower their catch. The total mortality of other groundfish species discarded and landed by these sectors is reviewed and accounted for annually and will be addressed if catch reaches levels where a sector allocation or other catch limit is at risk of being exceeded. If necessary, the structure and data in this model could be used to project bycatch of species for which discard becomes a concern in the non-nearshore sectors.

Table D-1. Distribution of fish ticket landings among longline (hkl) and pot gear types in the limited entry and open access non-nearshore fixed gear sectors, 2002-2016.

Year	LIMITED ENTRY					OPEN ACCESS				
	36° - 40°10' N lat		N of 40°10' N lat		Total	36° - 40°10' N lat		N of 40°10' N lat		Total
	hkl	pot	hkl	Pot		hkl	pot	hkl	pot	
2002	142	15	770	345	1,271	116	81	134	16	346
2003	180	24	962	587	1,753	119	143	236	29	527
2004	193	58	1,202	573	2,025	86	156	175	13	431
2005	194	0	1,273	618	2,085	109	262	406	105	881
2006	165	50	1,351	562	2,127	71	156	256	186	668
2007	181	39	1,078	392	1,690	29	108	159	33	330
2008	196	38	1,145	398	1,777	56	130	236	25	447
2009	238	55	1,495	440	2,228	38	137	277	38	490
2010	308	57	1,448	464	2,277	53	123	198	29	403
2011	322	56	1,176	303	1,858	69	145	157	45	416
2012	266	65	989	203	1,523	37	82	110	22	251
2013	217	41	664	253	1,174	25	51	50	8	135
2014	235	65	614	277	1,191	62	125	47	13	247
2015	274	50	797	312	1,433	62	174	117	37	391
2016	311	56	859	315	1,541	39	163	135	34	371
Total	3,422	667	15,821	6,042	25,952	971	2,037	2,693	633	6,334
% of Total	13%	3%	61%	23%	100%	15%	32%	43%	10%	100%

Table D-2. Distribution of observed sablefish landings north of 36°' N lat., 2002-2016, among longline (hkl) and pot gears.

Observed landings	36° - 40°10' N		N of 40°10' N	40°10' N[1] to 43°30 N	43°30'N[2] to 45°03' N	45°03' N[3] to 46°54' N	N of 46°54' N	N of 40°10' N
	hkl	pot	hkl	hkl				pot
Pounds	935,384	841,272	8,312,583	1,497,160	2,443,181	1,572,324	2,799,918	4,275,374
Metric tons	424	382	3,771	679	1,108	713	1,270	1,939

Table D-3. Percent totals of observed sablefish landings in each management subarea north of 40°10' N lat. (2002-2016).

% of Total in each Sub- Area	**40°10' to 43° N**	**43°30' to 45°03' N**	**45°03' to 46°54' N**	**N of 46°54' N**
Total	18%	29%	19%	34%
min	6%	5%	4%	8%
max	35%	40%	45%	55%
mean	18%	28%	19%	35%
stdev	9%	10%	11%	15%

Table D-4. Rates of species discard (2002-2016 average) observed on fixed gear sablefish sets deeper than 100 fm for rebuilding rockfish species, relative to retained sablefish, used to project bycatch impacts for longline gear north of 36° N lat.

Rebuilding Species	**36° - 40°10' N**		**N of 40°10' N**	
	hkl	**pot**	**hkl**	**pot**
Cowcod Rockfish	0.0000	0.0000	0.0000	0.0000
Yelloweye Rockfish	0.0000	0.0000	0.0006	0.0000

[1] Col/Eur Line
[2] Cascade Head, OR
[3] Pt Chehalis, WA

Table D-5. Rates of species discard (2002-2016 average) observed on fixed gear sablefish sets deeper than 100 fm for rebuilding rockfish species, relative to retained sablefish, used to project bycatch impacts for longline gear by management subareas north of 40°10' N lat.

Rebuilding Species	40°10' to 43° N	43°30 N to 45°03' N	45°03' N to 46°54' N	N of 46°54' N
Cowcod Rockfish	0.0000	0.0000	0.0000	0.0000
Yelloweye Rockfish	0.0003	0.0006	0.0004	0.0008

D.1.1 Sablefish Daily Trip Limit Model Description

The catch projection models used in this analysis are multiple linear regression models that relate trip limits and other predictor variables to bimonthly or monthly landings, separately for each fishery. They are also used for inseason management. Detailed descriptions of the models can be found in Appendix A of the 2011-2012 harvest specifications EIS. Models were originally produced by members of the GMT, Oregon Department of Fish and Wildlife (ODFW), National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center (SWFSC) and Northwest Fisheries Science Center (NWFSC) in 2006 (limited entry) and 2009 (open access). Changes in model specification are made as needed over time, to increase accuracy of projections where possible. Changes since the 2017-18 harvest specifications include: New landings data through 2017 were added to all four models. The time range of data included in each model varies between from 2008-2017, to 2015-2017, depending on its information content for making projections. Furthermore, due to recent high attainment in the OA North, landings were weighted towards more recent years in order to account for recent trends and the variability. Accuracy of prediction varies among the four models. Of the four, the best fit of predicted to actual, bimonthly landings is produced by the limited entry (LE) fishery North model, with an R^2 value of 0.8973. Under the most recent data, the worst fit between predicted and actual landings comes from the Open Access (OA) fishery South model, with an R^2 value of 0.6014. However, in spite of the relatively low model fit, landings in the OA South have been extremely low in recent years and therefore there is little concern of exceeding the landing share.

D.1.2 Model Input Data

Landings and catch data were acquired from PacFIN Comprehensive FT database using the “GMT Sablefish Flags”. This flag initially assigns vessel-daily landings data to each sector based on the fields described in Table D-6.

Starting in 2017, all sablefish landings were required to be reported on electronic fish tickets. For the LE North fishery, the software tracks landings accumulation by vessel, against their sablefish endorsed tier permits. If the vessel has active sablefish endorsed primary tier permits attached, the season is open, and there is room on the attached permits, landings are counted as primary. When either the tier permits on the vessel are exhausted, or the season ends, landings are then counted as daily trip limits (DTL). The algorithm in the software adheres to the specific federal regulations concerning primary and DTL landings in 50 CFR 660.232. If a vessel is not landing against a tier permit, but has a fixed gear endorsement (with or without a trawl endorsement), then it is landed in LE. If only a trawl endorsement is present, it is OA. To separate by area, all landings north of the INPFC Conception area (Mexico/US border to Point Conception) are counted against the limits south of 36°N lat., while all other landings are considered north.

Table D-6. PacFIN codes used to assign vessel-daily landings and catch data to each sector

Field	Value	Description
Council_Code	P	PFMC only
Is IFQ landing	F	No IFQ landings included
PacFIN Species Code	SABL	Sablefish Only
Round_weight_lbs	>0	Must have landed at least 1 pound of sablefish
Participation group code	C	Commercial tickets only
Removal type code	Not in "R" or "E"	Not research or EFP
PacFIN group gear code	Not in "TWL" or "TWS"	No trawl gear used

D.1.3 Accounting for Discards and Discard Mortality

Harvest guidelines applicable the sablefish DTL fisheries were reduced in order to account for discard mortality, which resulted in landed shares for use in projection modeling to predict landings, and determine necessary trip limits. A harvest guideline is defined as numerical management harvest objective which is not a quota. These are either cited in regulation or calculated from other higher level numerical management objectives appearing in regulation.

For sablefish north of 36° N lat., the applicable harvest guideline was multiplied by 23.0 percent (discard rate estimate), and by 20 percent (discard mortality rate estimate); for sablefish south of 36° N lat. the discard rate estimate was 11 percent. Then that product (estimated dead discarded sablefish) was subtracted from the harvest guideline, resulting in a "landed share", which projected landings should be beneath, in order to keep total catch within the harvest guideline. The estimated discard rate used by GMT was taken from the report "Estimated Discard and Catch of Groundfish Species in the 2016 US West Coast Fisheries" by Somers et al. (2017). The discard mortality rate estimate was taken from information in Davis (2001) and Shirripa and Colbert (2006). Shirripa (2008) used experimental data and sea surface temperature to predict varying release mortality by gear. The GMT considered that Davis (2001) demonstrated high sensitivity to temperature and deck time, along with high variability of predicted discard mortality in Shirripa and Colbert (2006) informed by sea surface temperature data, and adopted an estimate of 20 percent. This value was also used in the 2015 update assessment (Johnson, *et al.* 2015).

D.1.4 Nearshore Fisheries

The Nearshore fishery is comprised of small vessels operating of the coasts of Oregon and California that are considered OA federally, but operate under state limited entry programs. While the fishery predominately caters to the live fish markets as they receive much greater prices for live “plate-sized” fish, there is also a smaller secondary component that caters to the fillet markets. Federally managed species that comprise the fishery are nearshore rockfishes, lingcod, cabezon, California scorpionfish, and kelp greenling.

In terms of catch accounting, all landings for the nearshore fishery are recorded on fish tickets. However, discard mortality has to be estimated since less than 20 percent of total trips are observed each year. To estimate total discard mortality for both observed and unobserved trips, discards from the portion of observed trips are applied to the unobserved trips by the WCGOP. This same general approach is also used to project future discard mortality for the nearshore (described in greater detail below).

D.1.5 Methods for Projecting Nearshore Landings and Discard Mortality

Separate approaches are used to project future landings and discard mortality for the nearshore fisheries. Landings are projected using three different approaches: (1) full attainment of landings targets is assumed for high attainment stocks (e.g., Oregon black rockfish); (2) via trip limits models for stocks where changes are proposed (e.g., lingcod and canary rockfish); and (3) via trend analysis (including averages where trend is flat) for low attainment stocks of which regulations are similar to the past.

To project total economic value associated with nearshore landings, the total ex-vessel price (i.e., paid to the fishermen) associated with these landings is expanded to include the “multiplier” effects that these landings also generate to processors, fishery-related businesses (e.g., boat yards), and coastal communities in general. In short, the value generated by fishing extends far beyond just the price paid to fishermen. These secondary effects of additional value as fish sale proceeds trickle throughout coastal communities are generated using the IO-PAC model (not just for the nearshore fishery, but for all fisheries).

Future discard mortality projections are produced by the nearshore model, which was designed to directly mimic the procedures used by WCGOP to estimate post-season “actual” catch. This mimicry is important since the WCGOP estimates are the official mortality source used in the management of the nearshore fishery. Mismatches would compromise the ability of the model to reliably produce projections to meet management objectives. Note that there has been desire to improve the nearshore model. If improvements were identified, it would be prudent to first update the WCGOP estimation procedures and then make the same changes to the nearshore model to maintain mimicry.

Desire to improve the nearshore model has predominately stemmed from some rather large inaccuracies in the past of yelloweye rockfish (e.g., the model projected 1.1 mt of yelloweye for 2013, but the actual WCGOP estimate was 2.7 mt). However, it should be noted that past inaccuracies were mainly attributed to model inputs (i.e., projected landings and multi-year grand mean bycatch rates) not matching the WCGOP catch estimation inputs (i.e., actual landings and year-specific bycatch rates) and not due to model itself since it once again it directly mimics the WCGOP estimation procedures. Therefore, the best means to improve the accuracy of the nearshore model would be to better predict actual landings or the yearly bycatch rates used in WCGOP estimates.

One of the main suggestions to possibly improve the accuracy of yelloweye rockfish projections was to investigate using recent bycatch rate data instead of the multi-year grand means that date back to 2004. However, the GMT determined in 2017 there has not been much if any trend in annual bycatch rates that would warrant only using more recent years. Further, if only more recent years were used, it would reduce the ability to evaluate future uncertainty of which is better defined by more years of data.

The GMT concluded that the main source of inaccuracy with the nearshore model has been very high volatility in annual bycatch rates that are used by WCGOP for estimates of catch. Since the annual bycatch rates fluctuate by a large degree from year to year and cannot be accurately predicted at this time, this means that the bycatch rate inputs from the nearshore model that are based on averages will oftentimes differ from the annual bycatch rates (and sometimes by large degrees).

The main issue with the nearshore model has therefore been an overreliance in the accuracy of the point estimate projections. Until the annual bycatch rates can be better predicted, the nearshore model projections should be only viewed as "ball-park". The GMT has developed a preliminary bootstrap model to project the uncertainty associated with future nearshore projections, but more work needs to be done until it can be used for management purposes.

In regards to methodology, the nearshore model uses a multi-species bycatch rate approach that is depth- and area-specific (described in detail in 2009-2010 FEIS). A walk-through of how the model works is provided in Table D-7.

There have been numerous recent improvements to both the WCGOP estimation procedures and the nearshore model since the 2017-2018 biennial harvest specifications and management measures. These are described in detail in Appendix A of the integrated alternatives for 2019–20.

Table D-7. Methods and data sources used in the nearshore model to project discard mortality of overfished rockfish.

	STEP 1:				STEP 2:	STEP 3:				STEP 4:				STEP 5:				STEP 6:				STEP 7:			
	Bycatch rates by depth from WCGOP observed trips				Users enters projected Landings of targets	Depth of Landings provided by WCGOP				Landings of each species split by depth = Step 2 x Step 3. Then summed (black shading)				Discarded mt computed = Bycatch rates (Step 1) by depth applied to sum of landings by depth				Discard mortality rates applied to discarded mt (from step 5)				Discarded mortality by depth = Step 5 x Step 6. Sum is the total mortality			
	Depth bin (fathoms)					Depth bin (fathoms)				Depth bin (fathoms)				Depth bin (fathoms)				Depth bin (fathoms)				Depth bin (fathoms)			
	0-10	11-20	21-30	30+		0-10	11-20	21-30	30+	0-10	11-20	21-30	30+	0-10	11-20	21-30	30+	0-10	11-20	21-30	30+	0-10	11-20	21-30	30+
Bycatch stock																									
Yelloweye Rockfish	0.003	0.012	0.043	0.003	0.000	53.6%	46.4%	0.0%	0.0%					0.318	1.533	0.196	0.005	28%	45%	67%	100%	0.089	0.690	0.131	0.005
Target stocks																									
Black Rockfish					120.000	47.1%	51.0%	1.4%	0.5%	56.53	61.16	1.69	0.62												
Cabezon					23.385	40.6%	55.9%	3.2%	0.2%	9.51	13.08	0.75	0.05												
Lingcod					65.000	37.5%	59.5%	2.1%	0.9%	24.40	38.65	1.34	0.61									TOTAL MORTALITY = 0.915 MT			
Black and Yellow Rockfish					0.017	0.0%	42.9%	57.1%	0.0%	0.00	0.01	0.01	0.00												
Blue/Deacon Rockfish					7.458	26.3%	70.6%	2.6%	0.6%	1.96	5.26	0.19	0.04												
Brown Rockfish					0.017	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00												
China Rockfish					6.498	30.5%	65.1%	3.7%	0.7%	1.98	4.23	0.24	0.04												
Copper Rockfish					1.007	38.1%	58.7%	3.2%	0.0%	0.38	0.59	0.03	0.00												
Gopher Rockfish					0.045	78.2%	21.8%	0.0%	0.0%	0.04	0.01	0.00	0.00												
Grass Rockfish					0.222	100.0%	0.0%	0.0%	0.0%	0.22	0.00	0.00	0.00												
Nearshore Rockfish Unid					0.000	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00												
Olive Rockfish					0.000	57.1%	42.9%	0.0%	0.0%	0.00	0.00	0.00	0.00												
Quillback Rockfish					1.307	17.1%	70.2%	11.8%	1.0%	0.22	0.92	0.15	0.01												
Greenling Unid					0.000	29.6%	70.4%	0.0%	0.0%	0.00	0.00	0.00	0.00												
Kelp Greenling (Oregon)					18.144	49.7%	49.2%	1.0%	0.2%	9.01	8.92	0.18	0.03												
Painted Greenling					0.000	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00												
						Total landings by depth =				104.3	132.8	4.6	1.4												

D.2 *Washington Recreational*

The Washington Ocean Sampling Program (OSP) generates catch and effort estimates for the recreational boat-based groundfish fishery, which are provided to Pacific States Marine Fisheries Commission (PSMFC) and incorporated directly into RecFIN The OSP provides catch in total numbers of fish, and also collects biological information on average fish size, which is provided to RecFIN to enable conversion of numbers of fish to total weight of catch. Boat egress from the Washington coast is essentially limited to four major ports, which enables a sampling approach to strategically address fishing effort from these ports. Effort estimates are generated from exit-entrance counts of boats leaving coastal ports while catch per effort is generated from boat intercepts at the conclusion of their fishing trip. The goal of the program is to provide information to RecFIN on a monthly basis with a one-month delay to allow for inseason estimates. For example, estimates for the month of May would be provided at the end of June. Some specifics of the program are:

- **Exit/entrance count -** boats are counted either leaving the port (4:30 AM - end of the day) or entering the port (approximately 8:00 AM through end of the day) to give a total count of sport boats for the day.
- **Unit of sample** – The unit of sample used by the OSP is a single boat trip.
- **Interview -** boats are encountered systematically as they return to port; anglers are interviewed for target species, number of anglers, area fished, released catch data and depth of fishing (non-fishing trips are recorded as such and included in the effort expansion). The OSP collects information on released catch but does not collect information on the condition of the released fish. Therefore, released catches must be post-stratified as live or dead based upon an assumed discard mortality rate. Onboard observers are deployed on charter vessels throughout the salmon season primarily to observe hatchery salmon mark rates but also to collect rockfish discard information on these trips.
- **Examination of catch -** catch is counted and speciated by the sampler. Salmon are electronically checked for coded wire tags and biodata are collected from other species.
- **Sampling Rates -** vary by port and boat type. Generally, at boat counts less than 30, the goal is 100% coverage. The sampling rate goal decreases as boat counts increase (e.g., at an exit count of 100, sample rate goal is 30%; over 300, sample rate goal is 20%). Overall sampling rates average approximately 50% coastwide through March-October season.
- **Sampling Schedules -** due to differences in effort patterns, weekdays/weekend days are stratified. Usually, both weekend days and a random 3 of 5 weekdays are sampled.
- **Personnel -** OSP sampling staff include two permanent biologists coordinating data collection, one permanent biologist generating in-season estimates of groundfish catch, approximately twenty-four port samplers, and two on-board observers.
- **Volume of data -** Between 20,000 and 30,000 boat interviews completed per season coastwide.

D.2.1 Data Expansion Algorithms

Algorithm for expanding sampled days:

$$P_t = \frac{Exit\ Count}{Total\ Boats\ Sampled} * P_s\ sampled$$

Where:

P_s = any parameter (anglers, fish retained, fish released) within a stratum,
P_t = total of any parameter with stratum for the sample day

Algorithm for expanding for non-sampled days:

$$Total\ Weekday\ Catch = \frac{\Sigma(P_t) on\ sampled\ weekdays}{\#\ of\ weekdays\ sampled} * \#\ of\ weekdays\ in\ stratum$$

$$Total\ Weekend\ Catch = \frac{\Sigma(P_t) on\ sampled\ weekend\ days}{\#\ of\ weekend\ days\ sampled} * \#\ of\ weekend\ days\ in\ stratum$$

$$Total\ catch\ in\ stratum = Total\ Weekend\ catch + Total\ weekday\ catch$$

Notes on Data Expansion:

Salmon and halibut catch estimates are stratified by week; catch estimates for all other species are stratified by month. All expansions are stratified by boat type (charter or private), port, area and target species trip type (e.g., salmon, halibut, groundfish, and albacore).

D.2.2 Washington Recreational Fishery Impact Modeling

Projected impacts for Washington's recreational fishery are essentially based upon recent years harvest as estimated by the Ocean Sampling Program (OSP) and incorporated in RecFIN. This is especially true if recreational regulations remain consistent.

Washington's management measures have relied on the use of depth closures in waters deeper than 20 or 30 fathoms since 2006 and therefore recent historical catch estimates will be representative of projected mortalities unless changes are proposed to those depth closures. Depth restrictions for Washington's recreational fisheries are primarily designed to reduce encounters with yelloweye rockfish and are necessary to keep yelloweye rockfish impacts below the Washington recreational fishery harvest target.

WDFW doesn't use a formal model to produce estimates of projected impacts under various management measure scenarios but has relied instead on an ad hoc approach that uses historical catch on a case by case basis to evaluate impacts to overfished species.

D.2.3 Catch Projections for 2019–20

D.2.3.1 Yelloweye Rockfish

Yelloweye rockfish ACL alternatives for 2019–20 were sufficient to consider changes to depth restrictions that range from delaying the start date under No Action, to completely eliminating depth restrictions all together under Alternative 2.

Yelloweye catch per angler from 2005, prior to the implementation of depth restrictions, was used as the basis to estimate projected impacts under less conservative depth restrictions. Yelloweye per angler from 2005 was applied to angler effort from 2017 (the most current year with final data) and updated with 2017 average weight to produce a new yelloweye projection for each month in 2019 and 2020 where removing the depth restriction was considered. Final yelloweye estimates from 2017 were used to estimate projected impacts in months where status quo depth restrictions would be in place. These projected estimates rely on older data, and while it is considered the best available information, actual impacts could be higher or lower than projected due to differences in the status of the stock in 2005 compared to 2017.

D.2.3.2 Canary Rockfish

Under a rebuilt canary rockfish stock, limited retention of canary rockfish was permitted in 2017 for the first time since the early 2000s. Based on canary rockfish catch in 2017 which was less than five mt, and the Washington recreational HG for canary rockfish, which would be 47.2 and 44.4 mt in 2019 and 2020 respectively, there is sufficient allocation to consider canary sublimit options that allow retention in all marine areas.

Projected impacts to canary rockfish relied on data from 2017 when limited canary retention was allowed for the first time in many years. As mentioned above, projected mortality was difficult to estimate based on uncertainties surrounding angler behavior around targeting. Final estimates from 2017 showed an increase in canary rockfish mortality in Marine Areas 1 and 2 compared to years when canary rockfish were prohibited but there did not appear to be a shift toward targeting canary rockfish. An updated bag limit analysis using 2017 data was used to produce projected impacts for canary rockfish in all Marine Areas in 2019 and 2020 under a range of sublimit options that assumes similar angler behavior as was seen in 2017. Actual canary rockfish impacts could be higher depending on angler behavior, which might continue to change as anglers get used to retaining canary rockfish. The Washington recreation HG provides a significant buffer for higher than projected canary impacts if angler behavior or encounter rates increase from what was seen in 2017. Additional yelloweye impacts were not estimated under the three canary sublimit options. Inseason catch estimates for yelloweye rockfish could be higher than projected if anglers misreport yelloweye rockfish as canary rockfish. 2017 angler interview data shows that while the amount of retained canary rockfish increased, there was not a notable increase in yelloweye retention as a result of misidentification. If necessary, inseason action can be taken to address higher than anticipated yelloweye impacts.

D.2.3.3 Cabezon

A bag limit analysis was used to project mortality of cabezon rockfish under an option that would reduce the sublimit in Marine Areas 1 – 3 from 2 to 1 fish per day. Because most cabezon are caught in Marine Area 4 where the sublimit is already one fish per day, the reduction in projected impacts as a result of reducing the sublimit is small. However, the change would streamline regulations by making the sublimit the same in all marine areas. Under the No Action Alternative, an option to manage cabezon in a Washington kelp greenling/cabezon Stock Complex is also considered. Projected mortality of cabezon would not change as a result of which stock complex it was managed under. However, if action was needed to keep catch within the proposed stock complex ACL, WDFW could take inseason action immediately.

D.2.4 Angler Effort

Angler effort is expected to increase as a result of more fishing opportunity under less restrictive management measures and in anticipation of continued poor recreational salmon opportunities which has shown to shift more recreational effort to groundfish fisheries. Angler effort in recent years was used to estimate the potential increase in effort that could be focused on recreational groundfish fisheries under less restrictive management measures. More angler effort has shifted to groundfish opportunities as a result of limited salmon fishing opportunities in recent years. There was a general increase in angler effort per month from 2015 to 2016 of approximately 35 percent. Projected angler effort for 2019 and 2020 was estimated by assuming a similar increase of angler effort of 35 percent continues in months where less restrictive depth restrictions are in place. Status quo effort was used in months where depth restrictions were not changed. There was an exception to the 35 percent increase in angler effort in Marine Area 2 during the month of July when there was some salmon fishing opportunity.

WDFW's approach to estimating projected impacts was reviewed and approved by the SSC Economics and Groundfish Subcommittees (SSC E-G/F) in the fall of 2012. With the review, the SSC E-G/F recommended a retrospective analysis of effort projections compared to post-season effort estimates for past SPEX cycles to better understand the historical performance of Washington's ad hoc approach. Table D-8 and Figure D-2 shows that actual angler effort has increased since 2011. Projected fishing effort follows the same trend as actual fishing effort although it is approximately 20 percent less on average than actual effort from 2011 through 2015.

Table D-8. Washington recreational angler trips targeting bottomfish by private and charter vessels as projected pre-season compared to actual post season estimates of effort.

	Projected Effort			Actual Effort		
Year	Private	Charter	Total	Private	Charter	Total
2013	8,299	11,224	19,523	10,622	14,096	24,718
2014	8,299	11,224	19,523	9,800	13,676	23,476
2015	9,026	15,186	24,212	10,505	16,744	27,249
2016	9,026	15,186	24,212	15,105	20,913	36,018
2017	11,239	16,626	27,865	11,705	18,182	29,887

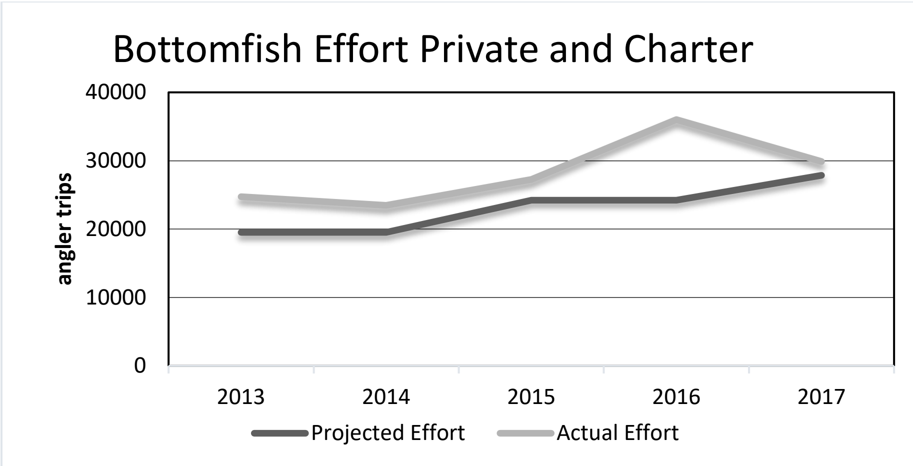

Figure D-2. Washington recreational angler trips targeting bottomfish by both private and charter vessels as projected pre-season compared to actual post season estimates of effort.

D.2.5 Inseason Catch Projections for 2019–20

Inseason catch projections are based upon the most recent OSP estimates and incorporated in RecFIN (with a one-month time lag) with subsequent months extrapolated from the pre-season catch projections. Beginning in 2009, depth dependent mortalities have been applied uniformly to all discarded fish coast wide through RecFIN It should be noted that the precision of recreational groundfish catch estimates based upon previous seasons will continue to be influenced by factors such as the length and success of salmon and halibut seasons, weather and unforeseen factors.

D.3 *Oregon Recreational*

Groundfish mortality associated with regulatory scenarios for each alternative were projected using the Model of Oregon Recreational Groundfish (MORG), which was reviewed by the SCC and found to "use appropriate data and methods and provides a sound basis for management decisions" prior to the 2015-2016 Groundfish Biennial Specifications Process (PFMC 2015).

The model, described below, has been updated since the review to incorporate all Additional updates were made to accommodate new data sources (e.g., mortality rates for rockfish released with descending devices and the proportion of fish release with the devices) and to increase ease of use for users to manipulate model inputs (e.g., a user interface "switchboard" was developed for all model inputs". This updated model was used for the 2017-2018, and continued for the 2019–20 process recommendations made by the SSC (e.g., inclusion of variances to provide measures of uncertainty).

D.3.1 Landings and Discard Mortality Estimation

The MORG produces projections of landings and discard mortality for thousands of combinations of regulation options (i.e., bag limit, size limit, depth closures, and season closures). To produce these projections, MORG manipulates the exact same data inputs that the sport fishery monitoring survey, the Oregon Recreational Boat Survey (ORBS) uses to estimate total landings, discard mortality, and effort. In short, the MORG manipulates the data sets ORBS uses to estimate total catch and effort and then reruns the estimates in the same manner as done by ORBS.

Since MORG functions by manipulating the data sets used by ORBS to estimate catch and effort, it is important to first understand the process and data inputs used by ORBS to estimate total sport catch and effort. To estimate these factors, ORBS assumes un-sampled boats catch the same as sampled boats. In finer detail, ORBS obtains catches from a portion of boats intercepted by the dockside survey for a given trip type (e.g., Newport charter boats) and assumes the un-sampled boats of that similar trip type caught same (strata and domains used to lump similar trips include boat type, port, week, area fished). And by statistical definition, ORBS estimates total catch and effort by multiplying catch rates (catch per boat) for each trip type to the portion of total boats (sample and un-sampled) from that same trip type.

D.3.2 Landings and Discard Mortality Projections

As stated above, the two main survey components used to estimate total catch and effort are the dockside survey and the total boat survey. And the MORG projects catch and effort for regulatory options by manipulating the dockside survey interviews by adjusting what the anglers caught and where they fished, and then reruns the total catch and effort estimates using the same ORBS procedures (along with variance computations). By manipulating the individual trips, this provides the greatest ability to adjust multiple regulations at once – and is manipulating what truly occurs in the fishery.

And to account for total effort, which is used to expand the dockside interviews to total catch and effort, a variety of approaches have been taken. Until recently, the average angler trips were used because the number of trips was relatively consistent across years; however, to account for a major spike in total effort since 2015 (i.e., from ~60,000-70,000 per year prior to 2015 to a record ~110,000 in 2015 and over 100,000 through August in 2017), the model uses a "stair-step" effort ramp with the assumption that 2019–20 will also have similar amounts of high effort.

D.3.3 MORG Model Components

- **Bag limit model component**: The bag limit model adjusts the landings of individual anglers to not exceed the proposed (new) daily bag limit, and any previous landings above the bag limit are converted to discards (with discard mortality rates applied). For example, if three anglers landed nine black rockfish and discarded six with a bag limit of seven, the catches for a bag limit of one would be three black rockfish landed (one per angler) and 12 discarded (six originally discarded plus the six of nine that were landed, but now had to be thrown back). And in a reverse situation where the bag limit is increased, anglers would be able to retain more of their discards (and the mortality rate of these fish would be changed to the discard mortality rate to 100 percent).

- **Size limit model component**: The size limit component functions very similarly to the bag limit component, but is more uncertain since lengths of discarded fish are unknown (and are assumed to match the distribution obtained by the sport observer survey, which records the sizes of discarded fish). For example, if the size limit is decreased to 10" from a current no size restriction, the model forces anglers to discard any catch below 10" (which are then converted to discards with discard mortality rates applied) and they can retain any of their catch above 10".

- **Area closure model component:** The area closure component primarily models projections of catch and effort pertaining to depth closures, as depth is the most common area closure used in the sport fisheries (to limit yelloweye rockfish interactions). And the depth closure component differs from the bag and size limit components; instead of converting landings to discards or vice versa, the depth model moves anglers from areas that become closed to open areas. To do this, the model excludes trips that occur in closed areas from the dataset, and then gives a greater weighting to the existing trips in open areas. And the main assumption is that no effort is lost due to area closures; rather that all effort shifts to open areas (this assumption based on historical data that shows the number of trips years with depth restrictions did not appear to decrease compared to years without).

- **Seasonal closure model component**: The season model component functions rather simply by forcing effort to be zero during closed times. This may result in an underestimate of catch and effort since some anglers may continue to fish during closed periods by practicing catch-and-release (which would result in discard mortality). While the effects of complete season closures may be uncertain, it was deemed reasonable to expect that most anglers would stop fishing if unable to harvest their catch. Further, season closures are the least desired regulation option, and are only used when all other regulatory options have failed to limit mortality to acceptable levels.

- **Regional catch and effort component**: Following review of MORG, the SSC recommended that the model produce regional catch and effort estimates. With one reason being that the economic multipliers used to expand the base value of recreational trips (trip expenditures; money spent on fuel, tackle, etc.) to total economic impacts to communities differ throughout regions in Oregon (i.e., "multiplier" effect of the based spending creating additional value as it cycles through the economy from business to business until all is leaked to outside the community). While regional catch and effort has not yet been coded for in the model, it is a future goal. To complete regional modeling, both data sets (dockside intercept and total effort) and could be filtered for the desired region prior to rerunning the estimation procedures.

- **Multivariate predictors of effort**: At the SSC review, ODFW demonstrated that weather (wind, waves, and wind*wave interaction) and strength of other fisheries (e.g., salmon) are related to sport groundfish effort (but not factors such as economic indicators and other environmental factors) and thus explored whether inclusion of these factors could help model performance (via use of a hybrid GLM / manipulation model). However, following further investigation ODFW concluded that while these factors may affect sport groundfish effort (and thus catch), weather and strength of other fisheries cannot be accurately predicted, and thus cannot be used as explanatory variables in MORG at this time.

- **Other features and specifications**: While MORG is simple in concept; hundreds of pages of code are required account for the approximately 60,000 (and counting) regulatory options for which MORG provides projections for. As such, MORG includes a user interface that allows users, even without any familiarity of the fisheries or modeling details, to simply adjust regulations in order to create projections for different regulation scenarios.

In addition to being able to adjust regulations, users may also adjust alpha to create projection intervals to their desired level of risk tolerance (e.g., 75 percent if more risk tolerant, 95 percent if more risk adverse). This inclusion of measures of uncertainty is new, and addresses the main SSC recommendation during the model review.

Finally, MORG is a duel function inseason tracking tool (of actual landings) and projection model combined. When actual catch and effort are added, projections from that timeframe are replaced with the true values and the remainder of the year remains projections. This allows managers to more closely monitor and manage the fishery throughout the year.

D.4 *California Recreational Groundfish Model for 2019/2020*

D.4.1 Groundfish Fishery Projection Model

The anticipated mortality from the California recreational fishery under various season structure options are modeled using the RecFISH model. The model was developed in 2004 under contract with MRAG Americas, with subsequent augmentation of catch by depth and time parameters by California Department of Fish and Wildlife (CDFW). RecFISH allows projection of catch by depth and season length in each of the five groundfish management areas.

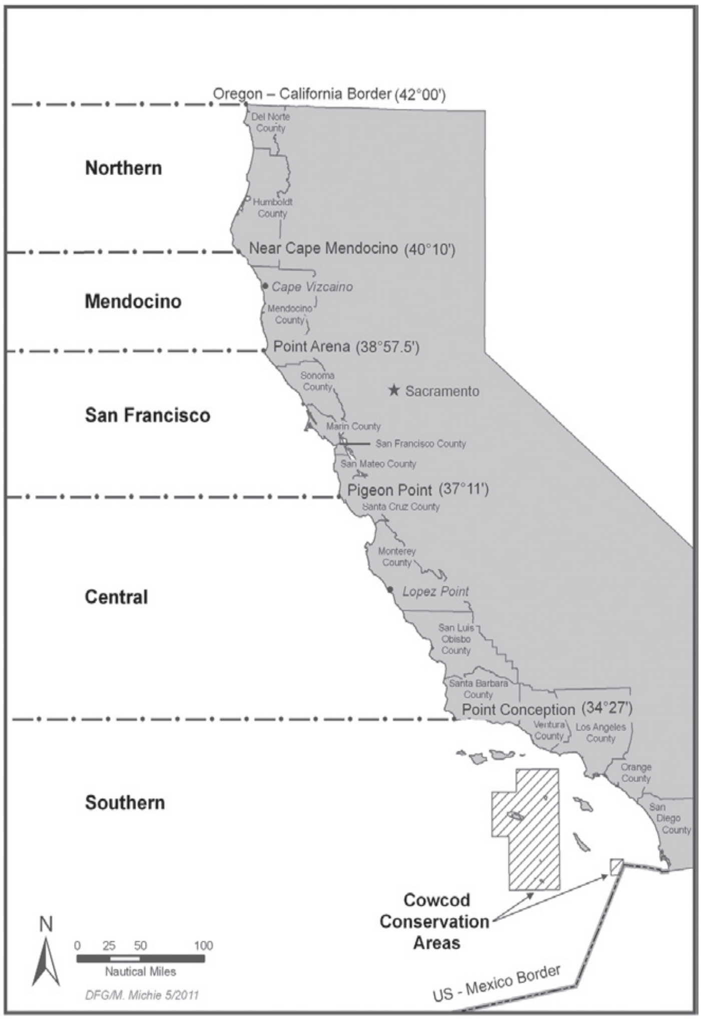

Figure D-3. California recreational groundfish management areas.[4]

[4] Cowcod Conservation Areas are an area designated within the Southern Management Area that have differing regulations, but are not themselves considered a management area.

Due to the need to avoid overfished rockfish species and the desire to provide the longest season possible, depth restrictions and seasonal closures have been the primary management tool used to minimize mortality of these species. Although depth restrictions are a useful tool to reduce overfished species mortality, effort shifts into shallower waters can increase mortality on healthy shallow stocks. Depending on the magnitude of effort shift, it is possible that the fishery would be forced to close early to prevent exceeding harvest limits of the healthy shallow stocks, not overfished species.

D.4.2 Model Description

The model incorporates proportion of catch by depth and time from historical unregulated periods and recent estimates of mortality in each management area to project mortality under given various season structures. The RecFISH model is a catch based model as opposed to an effort based model and has been previously reviewed by the SSC.

D.4.3 Methods

The model utilizes catch data from a recent regulated year ('base year'), and expands that catch for the entire 'unregulated' year. The assumption is that the historical proportion of catch by time and depth is representative of what will occur in the future. While this presents some uncertainties (discussed below) measures are available to mitigate this risk. For the 2019–20 biennial cycle, catch data from the 2015 and 2016 recreational fishery was used as the base years (Figure D-4). Utilizing the most recent years data captures recent trends and is likely more reflective of future fishing behavior.

<table>
<tr><th>Management Area</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Northern</td><td colspan="4">Closed</td><td colspan="6">May 15 – Oct 31, <20fm</td><td colspan="2">Closed</td></tr>
<tr><td>Mendocino</td><td colspan="4">Closed</td><td colspan="6">May 15 – Oct 31, <20fm</td><td colspan="2">Closed</td></tr>
<tr><td>San Francisco</td><td colspan="3">Closed</td><td colspan="9">April 15 – Dec 31, <30fm</td></tr>
<tr><td>Central</td><td colspan="3">Closed</td><td colspan="9">April 1 – Dec 31, <40fm</td></tr>
<tr><td>Southern</td><td colspan="2">Closed</td><td colspan="10">Mar 1 – Dec 31, <60fm</td></tr>
<tr><td>CCA</td><td colspan="2">Closed</td><td colspan="10">Mar 1 – Dec 31, <20fm</td></tr>
</table>

Figure D-4. California recreational groundfish season structure for 2015-2016.

The expected magnitude of unregulated catch by depth and time for the base years is back-calculated to reflect mortality during an unregulated year. This is performed for each management area and species by expanding mortality during the regulated period by what would be expected from an unregulated fishery using the historical proportion of catch by depth and time from unregulated years.

In expanding baseline catch data from regulated seasons to all depths and months, data from other areas were used to supplement the existing historical data. Catch data from Oregon during unregulated periods were added to historical data for the Northern Management to increase sample size.

Further, historical data for California can only be stratified north and south of Point Conception (34°27' N). However, estimates of catch by time north of Point Conception during this period were dominated by the San Francisco and Central Management Areas where more effort was exerted over more months than north of Point Arena. As a result, the proportion of catch by time from Oregon was used in the Northern and Mendocino Management Areas due to greater similarity in the timing of the fishery than that of the fishery south of Point Arena (38°57.5').

To account for depth dependent mortality rates, base catch in each month and depth bin is multiplied by the average proportion of catch from discarded fish (B2 reported discarded live + B3 reported discarded dead) in the base years 2015-2016 for each species and management area. This results in the expected tonnage of discarded fish. The species specific depth dependent mortality rates (by 10 fm depth bin) derived by the GMT (or suitable proxy) are applied to the discarded catch to provide an estimate of the expected discards for each depth bin. The resulting discard mortality estimate is added to the expected tonnage of retained catch to provide a projection of total mortality for each depth bin and month. This is used as the "base season" reflecting the mortality expected in an unregulated fishery.

The model also takes into account effort shifts that are likely to occur with varying depth restrictions. If depths are restricted to 20 fm or 30 fm, the model accounts for effort which would have occurred in deeper depth bins shifting to the shallower depths bins, by applying an increase of 39.3 percent and 27.6 percent respectively.

Projected mortality from the desired depth and season is obtained by summing the projected mortality values for each month and depth bin by species or species group in each management area. Projected mortality is then summed by the relevant management areas to obtain the total projected mortality in relation to the relevant management area (i.e., statewide or north and south of Cape Mendocino 40°10' N lat.).

Once mortality projections are complete adjustments can be made to account for increases or decreases in mortality resulting from other management measures (e.g. bag limits). The anticipated percent reduction or increase in mortality expected from such management measures are estimated using recent California Recreational Fishery Survey data and the Recreational Fishery Information Network bag limit analysis tool.

A step by step explanation of the methodology used in the RecFISH model can be found in greater detail in Appendix B of the 2015-2016 FEIS; no changes were implemented during this cycle.

D.4.4 Model Exceptions

For California scorpionfish mortality from 2014 was used as it likely best reflects current fishing behavior and takes into account changes made in the season structure (i.e., removing closure from September through December).

D.4.5 Model Uncertainty

While the RecFISH model is the best available science, there are some known uncertainties which are explained here. For some species few data are available to inform the model, which is particularly the case for species with deeper depth distributions or species for which retention is prohibited or encounters are infrequent. For these species and depth bins projected impacts may vary from actual impacts.

The model also assumes that fishing behavior during the historic period will be representative of the current fishery. However, many changes have occurred in the fishery which has likely affected behavior and distribution of fishing effort. For example, Marine Protected Areas have been established, closing some areas to recreational fishing which were previously accessible during the “unregulated years”.

Opportunities in other fisheries may also cause model projections to deviate from actual impacts. For example, opportunity in the salmon fishery affects effort and participation in the groundfish fishery. In good salmon years, there is less effort in the groundfish fishery and in poor salmon years effort is much higher. Given the recent drought and its impacts on salmon, model performance will likely be affected in 2019 and 2020.

Along with the availability of other fisheries, changes in oceanographic conditions can cause actual impacts to deviate from projections. For example, in 2015, abnormally warm waters caused a shift in the distribution of many species. In central California, anglers shifted some effort from groundfish to bonito, which are not normally encountered in the region.

D.4.6 Projected Species Impacts from the Groundfish Projection Model

Recreational fisheries management for multi-species rockfish assemblages in California presents many challenges. In recent years, allowable limits of overfished species have dictated recreational groundfish seasons structures. However, for the 2019–20 recreational fishery additional challenges are coupled with those posed by remaining within allowable limits for overfished species, which has traditionally been facilitated by depth restrictions. The allowable limit of lingcod has been reduced compared to previous years. Lingcod are an important recreational target to all management areas. The need to reduce impacts simultaneously on both overfished species, as well as lingcod, has been the primary consideration in developing recreational season structure options for 2019- 2020.

CDFW is contemplating allowing access to deeper depths for 2019- 2020, given the increase in yelloweye rockfish. While the seasons under consideration are all projected to remain within allowable harvest limits, projected impacts may vary from actual impacts.

It should be noted that various depth constraints have been in place in the California recreational fishery for over a decade. Allowing access to previously closed depths may cause an ‘opener effect’ as anglers shift their effort to deeper depths for the novelty of the experience. While it is likely that some degree of an opener effect may occur, the magnitude and duration of such an effect cannot be quantified.

Anglers have also become more socially and ethically conscious, wanting to avoid any inseason disruptions and ensure future opportunities. This may result in anglers seeking other opportunities by shifting effort to deeper depths or to species which are less likely to associate with black rockfish in efforts to minimize impacts on the stock.

While the magnitude and direction of the differences in actual versus projected impacts cannot be quantified, utilization of Yelloweye Rockfish Conservation Areas may be viable options to keep mortality within allowable limits and could reduce the possibility or need for inseason action.

CDFW will continue inseason monitoring and, if needed, inseason action can be taken to reduce additional mortality from accruing and remain within allowable limits. However, in designing season structures, CDFW strives to minimize disruptions to the fishery, while providing as much opportunity as possible.

D.5 *Estimating Effort for use in the IO-PAC Model*

The Northwest Fisheries Science Center's Input-Output model for Pacific Coast Fisheries (IO-PAC) is designed to estimate the changes in economic contributions and economic impacts resulting from policy, environmental, or other changes that affect fishery harvest. IO-PAC was built by customizing the Impact Analysis for Planning (IMPLAN) regional input-output software. The original methodology employed in developing this model was similar to that used in the Northeast Fisheries Science Center's Northeast Region Commercial Fishing Input-Output Model (Steinback and Thunbgerg 2006). The development and design of IO-PAC is documented in detail in Leonard and Watson (2011). The model was subsequently updated as part of an ongoing effort to continually improve the IO-PAC model with the latest available data and improvements in regional impact modeling capabilities. Substantial changes were made to model construction, new commercial fishing sectors were added, and a recreational fishing component was added, and these changes are documented in the final environmental impact statement for the 2015-2016 groundfish harvest specifications and management measures (PFMC, 2015). The current version of IO-PAC is detailed therein, except that there have been several data updates. This section summarizes the data updates that have been made since the documentation in PFMC 2015.

The data updates made include the following. One, the underlying IMPLAN data is changed from the 2012 base year to 2014. Two, the fish-ticket (landings) data from PacFIN is changed from 2014 to 2016. Three, the commercial vessel production functions incorporate the latest data from the voluntary Limited Entry and Open Access Surveys conducted by the Norwest Fisheries Science Center. Four, it incorporates the latest data collected as part of the Economic Data Collection (EDC) program. Five, it incorporates 2012 data from the charter vessel surveys completed by the Norwest and Southwest Fisheries Science Centers. Table 1 provides of a summary of the data that is currently used in IO-PAC and its application.

Table D-9. IO-PAC data sources and applications

Data Year	Open Access Survey	Limited Entry Fixed Gear Survey	Marine Rec. Exp. Survey	WA and OR Charter Vessel Survey	CA Charter Vessel Survey	EDC DATA
	2012	**2012**	**2011**	**2012**	**2012**	**2016**
Application						
Commercial Vessels						
Production Functions	X	X				X
Vessel Industry Output				X	X	X
Vessel Employment	X	X				X
Processors						
Production Functions						X
Processor Industry Output						X
Processor Employment						X
Recreational Fishing						
Expenditures			X			
Charter Prod. Functions				X	X	
Charter Industry Output			X	X	X	
Charter Employment			X	X	X	
Non-Fishing Data						

Table D 9. (continued horizontally). IO-PAC data sources and applications

Data Year	EDC Data	IMPLAN	PacFIN Fish Ticket
	2015	2014	2014
Application			
Commercial Vessels			
Production Functions			X
Vessel Industry Output		X	X
Vessel Employment			X
Processors			
Production Functions	X	X	
Processor Industry Output	X	X	X
Processor Employment	X	X	X
Recreational Fishing			
Expenditures			
Charter Prod. Functions			
Charter Industry Output			
Charter Employment			
Non-Fishing Data		X	

D.6 *IFQ Projection Model Documentation for Biennial Harvest Specifications Environmental Assessment: Summary of the 2019-20 Model*

The role of this model is to produce two outputs for use in the biennial harvest specifications Environmental Assessment (EA): 1) projections of total annual IFQ sector fishing mortality (hereafter referred to as “catch” or “total catch”) of each species, under a suite of allocations, and 2) projections of annual vessel-level landings for input to the Commercial Fisheries Landings Distribution Model, followed by the IO-PAC for subsequent economic analysis, also within the harvest specifications EA. The model is not intended as an inseason management tool. The model projects catch of IFQ species categories only; species managed with trip limits are not included.

Catch forecasts are produced using a combination of three methods, based on attainment of vessel quota, average annual vessel catch, and bycatch for non-target species. Corresponding uncertainty estimates are produced as bootstrapped 95 percent prediction intervals. The model is written in R. See Matson et al. (2017) for a full description of all but the bycatch module. The bycatch module was adapted to the Matson et al. 2017 model for this cycle; from the Matson and Taylor (2012) model, which was used in the 2013-14 harvest specifications.

D.6.1 Methods

The model projects catch of each target species by individual vessel in the fleet using one of two methods; the first is based on weighted mean vessel attainment of annual quota pounds, and the other on weighted mean of annual vessel catch. The model’s choice between the two target catch projection methods is mediated by a vector of parameter values, one for each species, which are determined through an optimization process using residuals from hind casts. Predictions of catch for each species within the entire fleet are produced by aggregating the vessel level predictions to the fleet level.

Inputs to the model include catch data at the fishing trip level for each vessel (with separate landings and discard estimates for each species), IFQ quota pounds (QP) data for each vessel, annual fishery allocation data, and proposed fishery allocations (“alternatives”) under which catch is to be predicted. Each “alternative” consists of a set of proposed values for future allocations of quota pounds to the fishery, with a single fishery level value for each species. Fishery level quota pounds from the “alternative” are then distributed among vessels, according to the fleet allocation distribution in the most recent year. Fleet size (number of vessels participating in the fishery) for the prediction year is assumed to be the same as in the most recent year of data available.

The bycatch method employed here predicts catch of each designated bycatch species, using weighted average annual vessel-specific bycatch rates, according to their ratio to aggregate target catch, in shelf or slope species groups. Each of the 30 species categories is designated as “target” or “bycatch” and “shelf” or “slope” in the model input files. Those estimated bycatch rates are then used to project mortality of bycatch species, according to the predicted catch amounts for appropriate target species. Uncertainty is estimated in the same way for bycatch as target species, using bootstrap simulated distributions.

Given that the projections for some species are extrapolations (predict mortality for allocations outside the range of the input data), in order to provide the best compromise of fit and responsiveness, some bycatch species were predicted using the target method. The method that gave the best fit to 2017 catch estimates was used, and which demonstrated appropriate responsiveness to changing allocations in sensitivity runs.

Weighted average annual vessel and species-specific retention rates were used to convert predicted total catch to predicted landings.

D.6.2 Input Data, Configuration, Tuning, and Fit

Input data were queried from the NMFS IFQ Program Vessel Account System, including debited catch (with mortality rates applied) and quota data, and were aggregated to the vessel-species-year level. Years 2011 through 2016 were used as reference data, with which the model was configured, and retrospectives were run. The model was then tuned to maximize predictive accuracy to 2017 estimates (R-square = 0.9998), using three built-in adjustment parameters, and the attainment threshold parameter (ATP) when it was necessary to adjust expected future responsiveness to the allocation, for some species with alternatives outside the range of allocations in the reference data.

The model was configured with two fleets; shorebased whiting and non-whiting. Whiting trips were assigned in similar manner as the regulations, with total catch per trip being equal to or greater than 50 percent whiting. All other trips were assigned to non-whiting. Trips were defined as vessel days, which eliminated problems of split tickets, and total catch was used rather than landings.

Initial settings of the ATP were accomplished by setting it equal to 1 minus the R-squared value of catch versus allocation of each species, so that species whose catch shows a high correlation with allocation were predicted predominantly using the attainment-based method (along a continuum), while the converse was true for the catch-based method. ATP values were then optimized by profiling annual residuals over the range of ATP values from 0 to 1, at 0.1 increments using hind casts, informed by the reference data (2011-2016). Species were tuned using target prediction methods first, after which bycatch species were configured; this is important due to the influence of target species on the denominator of bycatch ratios.

Finally, in preparation to make forecasts for 2019 and 2020 alternatives, the model was used to predict 2017 estimates, and was tuned using built-in adjustment parameters, multipliers for attainment, average catch, and bycatch ratio. This was done in order to achieve the best fit to 2017 data, the most recent estimates available. The 2017 represented the first year of the current fishery regime with a high canary allocation, which made them uniquely valuable for predicting future years within the same regime (R-squared = 0.9998 including all species but Pacific whiting, which had undue leverage on fit due to outsize annual catch weights). Thus, the model was tuned to behave under the most recent fishery conditions available. Doing so was particularly important for species whose alternatives were outside the range of allocations represented in the reference data. Data from 2017 were incomplete at the time modeling was begun, but were completed in time for tuning and projections to be made; although they were still preliminary, later checks at the sector level revealed that they showed exceedingly little change months later.

The NWFSC's IO-PAC model is designed to estimate the changes in economic contributions and economic impacts resulting from policy, environmental, or other changes that affect fishery harvest. IO-PAC was built by customizing IMPLAN regional input-output software. The original methodology employed in developing this model was similar to that used in the NWFSC Northeast Region Commercial Fishing Input-Output Model (Steinback and Thunbgerg 2006). The development and design of IO-PAC is documented in detail in Leonard and Watson (2011). The model was subsequently updated as part of an ongoing effort to continually improve the IO-PAC model with the latest available data and improvements in regional impact modeling capabilities. Substantial changes were made to model construction, new commercial fishing sectors were added, and a recreational fishing component was added, and these changes are documented in the final environmental impact statement for the 2015-2016 groundfish harvest specifications and management measures (PFMC, 2015). The current version of IO-PAC is detailed therein, except that there have been several data updates. This paper summarizes the data updates that have been made since the documentation in PFMC (2015).

The data updates made include the following. One, the underlying IMPLAN data is changed from the 2012 base year to 2014. Two, the fish-ticket (i.e., landings) data from Pacific Fisheries Information Network is changed from 2014 to 2016. Three, the commercial vessel production functions incorporate the latest data from the voluntary LE and OA Surveys conducted by the Norwest Fisheries Science Center. Four, it incorporates the latest data collected as part of the EDC program. Five, it incorporates 2012 data from the charter vessel surveys completed by the NWFSC and SWFSCs.

D.7 *Commercial Landings Distribution Model*

The purpose of the commercial fishery landings distribution model (LDM) is to inform the PFMC's management processes by projecting where Pacific Fisheries Information Network Port Code Identifier (PacFIN PCID) landings are likely to occur under a set of alternative scenarios (e.g., alternative ACLs or management measures). The projected landings ports can then be mapped onto Port Area aggregations to allow comparison of the geographic distribution of ex-vessel revenues under the alternatives. Since all the alternatives are modeled consistently, projections from the LDM facilitate comparison of the alternatives in an apples-to-apples fashion.

A list of Port Areas, and underlying PCIDs, is shown in Table D-10 and Table D-11. Although used primarily to inform the groundfish management processes, the LDM methodology can be applied to analyze any west coast fishery. In the case of groundfish, ex-vessel revenue results from the LDM, aggregated by Port Area, are fed directly into the IO-PAC input-output and vessel net revenue projection models, where they are used to calculate and compare economic impacts under the different alternatives[5].

D.7.1 Data Elements

The core of the LDM is a recent-year commercial fishing landings data report from the PacFIN data system. The standardized PacFIN daily (vdrfd) or monthly (vfcmrfd) vessel landing summary can be used for this purpose. The PacFIN website briefly describes the vdrfd table thus:

> **Vdrfd table**: The relationship between vessels, tickets, date-of-landing, permit(s), fish-ticket category, and post-distribution species id code. (Produced by prod/refresh_vdrfd.sql.)

For analyzing the alternative 2017-2018 groundfish management specifications, a vdrfd table for 2015 was used.

Key data elements of the LDM provided by the PacFIN landings data report include:

- Inventories of all species (SPIDs including nominal and market categories after application of species composition factors), round weights and ex-vessel values landed by port (i.e., PCID).
- Assignment of landing vessel IDs to current groundfish federal limited entry permits, if applicable.
- Assignment of each landing to a fisheries management sector (dahl_sector).
- Distribution of species landings and ex-vessel revenues by landing vessel ID.
- Distribution of species landings and ex-vessel revenues among first receivers (Processor ID).

This historical information forms one of baselines against which changes under the management alternatives can be measured.

[5] IO-PAC is a set of regional economic impact models constructed using landings data, vessel expenditure estimates, and secondary economic data to estimate income and employment impacts resulting from a change in the distribution of commercial fishery landings. It is maintained by Northwest Fisheries Science Center (NWFSC) and used by the Pacific Fishery Management Council (PFMC) to estimate economic impacts of West Coast fishery management actions.

D.7.2 Model Description

Groundfish landings records in the vessel landings table are categorized by fisheries sector (PacFIN "dahl_sector"). This categorization is based on limited entry permit status, PFMC catch area, port, species and gear used. The fisheries sector categories align with the GMT fishery sector projection models listed below. The GMT models project landings in each of five fishery sectors under the management alternative as part of their overall analysis of harvest specifications and management measure alternatives.

The next step is to compute the base year percentage of landings for each fishery sector by each combination of Area, Vessel (or Permit) ID, Species Identifier (SPID) and PCID. The "area" used for this calculation varies according to the resolution of the corresponding fishery sector projection model, as noted below. The percentages are then applied to the results from the GMT fishery sector projection models to estimate the geographic distribution of landings across ports in each fishery.

To project the geographic distribution of landings under the alternatives, results from the commercial fisheries sector landings projection models are applied to the landings percentages calculated from the vdrfd table as noted above. Unless indicated otherwise (by the GMT model results or the proposed management measures) landings under the alternatives are assumed to occur in the same ports in proportion to landings observed in the base year vdrfd table. Only landings of the main economic groundfish species that are modeled for each fisheries sector are of concern in the LDM. Landings of non-groundfish species, incidentally caught groundfish species and overfished species such as bocaccio and cowcod are generally not modeled, as these are not managed under the Groundfish FMP or do not generate significant revenues in federally managed groundfish fisheries.

The level of detail carried over from the GMT models to the LDM varies considerably by fisheries sector. The most detailed results are produced by the IFQ catch projection model which generates a table of projected landings by species category for each participating vessel/groundfish permit ID.

More aggregated results are used to link the LDM with the non-IFQ fishery sector models. For example, aggregate sablefish catch projected by the Non-nearshore fisheries model is used to model landings by the non-nearshore LE and OA fixed gear sectors north of 36° north lat. Unless otherwise indicated, each PCID north of 36° N is expected to receive the same proportions of coastwide Limited Entry (LE) and open Access (OA) fixed gear sablefish landings under each alternative during the biennial cycle as it received in the base year vdrfd data table.

Linkage between the LDM and the Nearshore fisheries model is similar (Figure D-5), except that additional area detail in the nearshore model is incorporated to distribute projected landings of nearshore groundfish species to ports (PCIDs) in Oregon and in California north and south of 40°10'north lat. in proportion to where those landings occurred in the base year vdrfd data table.

The main features, model inputs and additional procedures used for integrating landings information in the LDM are described below:

- **IFQ catch projection model:** Projected groundfish target species landings by each vessel/permit participating in the IFQ fishery. The list of IFQ target species projected includes sablefish, longspine thornyhead, shortspine thornyhead, Dover sole, arrowtooth flounder, petrale sole, English sole, other flatfish and Pacific whiting. Incidental landings of non-target IFQ and overfished species are also projected by the model, however these landings are not generally very relevant for economic analysis.

- **Non-nearshore fisheries model**: Projected maximum aggregate landings of sablefish and incidentally-caught overfished species by vessels participating in the fixed-gear LE and OA-Daily Trip Limit (DTL) fisheries north of 36° north lat. Only projected sablefish landings are used in the economic analysis. To date sablefish landings south of 36° have not been explicitly modeled by the GMT. Instead the ratios of sablefish OYs/ACLs specified under each alternative are compared with landings and ACLs observed in the base year, and the resulting ratios are applied to project sablefish landings in ports south of 36° north lat. under the alternatives.
- **Nearshore fisheries model:** Projected aggregate landings by area (Oregon, California north of 40°10´north lat., and California south of 40°10´) of nearshore target species (black rockfish, blue rockfish, cabezon, kelp greenling, lingcod, and other minor nearshore rockfish) by vessels participating in the fixed gear OA fishery. Catch of canary and yelloweye rockfish are also projected, although prior to this cycle landings of those species have not been relevant for economic analysis of the nearshore sector.
- **At sea whiting fisheries model:** Projected allocations of Pacific whiting to the at-sea catcher processors and mothership fisheries sectors, constrained by anticipated relevant overfished species allocations and observed bycatch rates, if applicable.
- **Tribal fisheries model:** Projected total whiting (shoreside and at sea) and non-whiting groundfish target species landings by the tribal groundfish fisheries off the Washington Coast.

D.7.3 IFQ Fishery

Information in the final end-of-year run for the relevant year from the IFQ catch projection model is used to adjust landings in the vdrfd table for IFQ fishery participants. This step produces a calibrated landings report that can be linked with IFQ catch projections generated for each groundfish management option or alternative. Projected landings by vessels (i.e., permits) are assumed to distribute to ports (based on where those vessels landed as reported in the base year vdrfd table. Note: Although Pacific whiting harvest is regulated separately from the non-whiting groundfish specifications process, whiting landings by vessels/permits participating in the IFQ fishery are also modeled in this method. A range of Pacific whiting harvests is sometimes analyzed along with the alternative groundfish harvest specifications for purposes of comparison.

D.7.3.1 Non-Nearshore Fisheries

Total sablefish landings projected under each option or alternative by the Non-nearshore fisheries model for fixed gear LE and OA-DTL fisheries north of 36° N lat. are distributed to participating vessels and PCIDs, as show in Table D-10 and Table D-11, in proportion to where sablefish landings were recorded in the base year vdrfd table. For areas south of 36° a different procedure is used. The ratio of sablefish landings in the base year to the corresponding sablefish ACL is calculated. This ratio is then applied to the ACL projected under each option or alternative to estimate total sablefish landings south of 36° N lat. under the corresponding management scenarios. Estimated total landings are then distributed to associated landing ports south of 36° in proportion to where sablefish landings were recorded in the base year vdrfd table.

D.7.3.2 Nearshore fisheries

For the fixed gear OA fishery, total projected nearshore target species landings under each option or alternative projected by the nearshore fishery model are distributed to participating vessels and ports in the same proportions observed in the base year vdrfd table. Nearshore target species distributed in this manner include black rockfish, blue rockfish, cabezon, kelp greenling, lingcod, and other Minor Nearshore Rockfish. The Nearshore OA model includes three nearshore fishery catch area strata: Oregon, California north of 40°10´, and California south of 40°10´ N lat.

D.7.3.3 At-sea Whiting Fisheries

Total projected whiting catch by the two nontribal at sea whiting fisheries (catcher processers and motherships) are distributed among vessels that participated in the whiting fishery in proportion to their participation during the base year. Pacific whiting harvest is regulated separately from the non-whiting groundfish specifications process, but a range of Pacific whiting harvests is sometimes analyzed along with the alternative groundfish harvest specifications for purposes of comparison.

D.7.3.4 Tribal Groundfish Fisheries

Total projected landings and deliveries under each option or alternative by the tribal groundfish fisheries, including shoreside and at-sea whiting, are distributed among ports that participated in those fisheries in proportion to those ports' participation during the base year.

D.7.4 Assumptions and Caveats

Major simplifying assumptions include:

- Average ex-vessel prices observed in the base year will carry over to the projection period(s).
- Average annual ex-vessel prices are assumed to apply in each port no matter when during the year the landings occur.
- There is no cross-hauling of raw product. That is, landings in a given port are not shipped elsewhere for processing.

One concern with this approach is that the more ex-vessel prices deviate from the range of prices observed in the base year, the more inaccurate projected revenue impacts may be. However, if better information is available on future ex-vessel price trends, it is certainly possible to incorporate this type of information into the revenue projections.

Landings and revenue impacts projected by the LDM are used in the IO-PAC model to estimate community income impacts under the management alternatives. To the degree that processing activities, vessels' home ports, or the residences of owners and workers are located in the ports of landing, then a larger portion of the economic impacts generated by these landings will accrue to the port. However to the extent that processing activities, the vessels' home ports, or the residences of workers and owners are located elsewhere, then historical landings patterns may be not be representative of the impact of these activities in the local economy. For example, if landings are made in one port but vessels' home ports or crew's residences are elsewhere, or if first receivers transport landings to another place for processing, then at least a portion of the projected income and employment impacts may be attributed to the wrong port or region.

D.7.5 Results

Results from the LDM are used as inputs to estimate community income and employment impacts and vessel sector net revenues ("profits") under the alternatives. Projected landings and ex-vessel revenues by species, fishery sector and port are fed into the IO-PAC model to generate community personal income and employment impacts under each management alternative. Projected landings and ex-vessel revenues by each groundfish fishery sector coupled with vessel cost estimates derived from IO-PAC are also used to estimate aggregate net revenues accruing to vessel owners participating in west coast groundfish fisheries. The resulting estimates are then used to compare and contrast economic impacts for the range of groundfish management alternatives under consideration.

Table D-10. List of Washington and Oregon Port Groups and PacFIN PCIDs in the Landings Distribution Model.

Port Group Area	County	PCID	Port Name
WASHINGTON			
Puget Sound	Whatcom	BLN	Blaine
	Whatcom	BLL	Bellingham Bay
	San Juan	FRI	Friday Harbor
	Skagit	ANA	Anacortes
	Skagit	LAC	La Conner
	Snohomish	ONP	Other North Puget Sound Ports
	Snohomish	EVR	Everett
	King	SEA	Seattle
	Pierce	TAC	Tacoma
	Thurston	OLY	Olympia
	Mason	SHL	Shelton
North Washington Coast	Jefferson	TNS	Port Townsend
	Clallam	SEQ	Sequim
	Clallam	PAG	Port Angeles
	Clallam	NEA	Neah Bay
	Clallam	LAP	La Push
South & Central WA Coast	Grays Harbor	CPL	Copalis Beach
	Grays Harbor	GRH	Grays Harbor
	Grays Harbor	WPT	Westport
	Pacific	WLB	Willapa Bay
	Pacific	LWC	Ilwaco/Chinook
	Klickitat	OCR	Other Columbia River Ports
OREGON			
Columbia River	Multnomah	CRV	Pseudo Port Code for Columbia River
Astoria-Tillamook	Clatsop	AST	Astoria
	Clatsop	GSS	Gearhart - Seaside
	Clatsop	CNB	Cannon Beach
	Tillamook	NHL	Nehalem Bay
	Tillamook	TLL	Tillamook / Garibaldi
	Tillamook	NTR	Netarts Bay
	Tillamook	PCC	Pacific City
Newport	Lincoln	SRV	Salmon River
	Lincoln	SLZ	Siletz Bay
	Lincoln	DPO	Depoe Bay
	Lincoln	NEW	Newport
	Lincoln	WLD	Waldport
	Lincoln	YAC	Yachats
Coos Bay	Lane	FLR	Florence
	Douglas	WIN	Winchester Bay
	Coos	COS	Coos Bay
	Coos	BDN	Bandon
Brookings	Curry	ORF	Port Orford
	Curry	GLD	Gold Beach
	Curry	BRK	Brookings

Table D-2. List of California Port Groups and PacFIN PCIDs in the Landings Distribution Model

Port Group Area	County	PCID	Port Name
CALIFORNIA			
Crescent City	Del Norte	CRS	Crescent City
	Del Norte	ODN	Other Del Norte County Ports
Eureka	Humboldt	ERK	Eureka (Includes Fields Landing)
	Humboldt	FLN	Fields Landing
	Humboldt	TRN	Trinidad
	Humboldt	OHB	Other Humboldt County Ports
Fort Bragg	Mendocino	BRG	Fort Bragg
	Mendocino	ALB	Albion
	Mendocino	ARE	Arena
	Mendocino	OMD	Other Mendocino County Ports
San Francisco (incl. Bodega Bay)	Sonoma	BDG	Bodega Bay
	Marin	BOL	Bolinas
	Marin	TML	Tomales Bay
	Marin	RYS	Point Reyes
	Marin	OSM	Other Son. and Mar. Co. Outer Coast Ports
	Marin	SLT	Sausalito
	Alameda	OAK	Oakland
	Alameda	ALM	Alameda
	Alameda	BKL	Berkely
	Contra Costa	RCH	Richmond
	San Francisco	SF	San Francisco
	San Mateo	PRN	Princeton
	San Francisco	SFA	San Francisco Area
	San Francisco	OSF	Other S.F. Bay and S.M. Co. Ports
Monterey	Santa Cruz	CRZ	Santa Cruz
	Monterey	MOS	Moss Landing
	Monterey	MNT	Monterey
	Monterey	OCM	Other S.C. and Mon. Co. Ports
Morro Bay	San Luis Obispo	MRO	Morro Bay
	San Luis Obispo	AVL	Avila
	San Luis Obispo	OSL	Other S.L.O. Co. Ports
Santa Barbara	Santa Barbara	SB	Santa Barbara
	Santa Barbara	SBA	Santa Barbara Area
	Ventura	HNM	Port Hueneme
	Ventura	OXN	Oxnard
	Ventura	VEN	Ventura
	Ventura	OBV	Other S.B. and Ven. Co. Ports
Los Angeles	Los Angeles	TRM	Terminal Island
	Los Angeles	SPA	San Pedro Area
	Los Angeles	SP	San Pedro
	Los Angeles	WLM	Willmington
	Los Angeles	LGB	Longbeach
	Orange	NWB	Newport Beach
	Orange	DNA	Dana Point
	Orange	OLA	Other LA and Orange Co. Ports
San Diego	San Diego	SD	San Diego
	San Diego	OCN	Oceanside
	San Diego	SDA	San Diego Area
	San Diego	OSD	Other S.D. Co. Ports

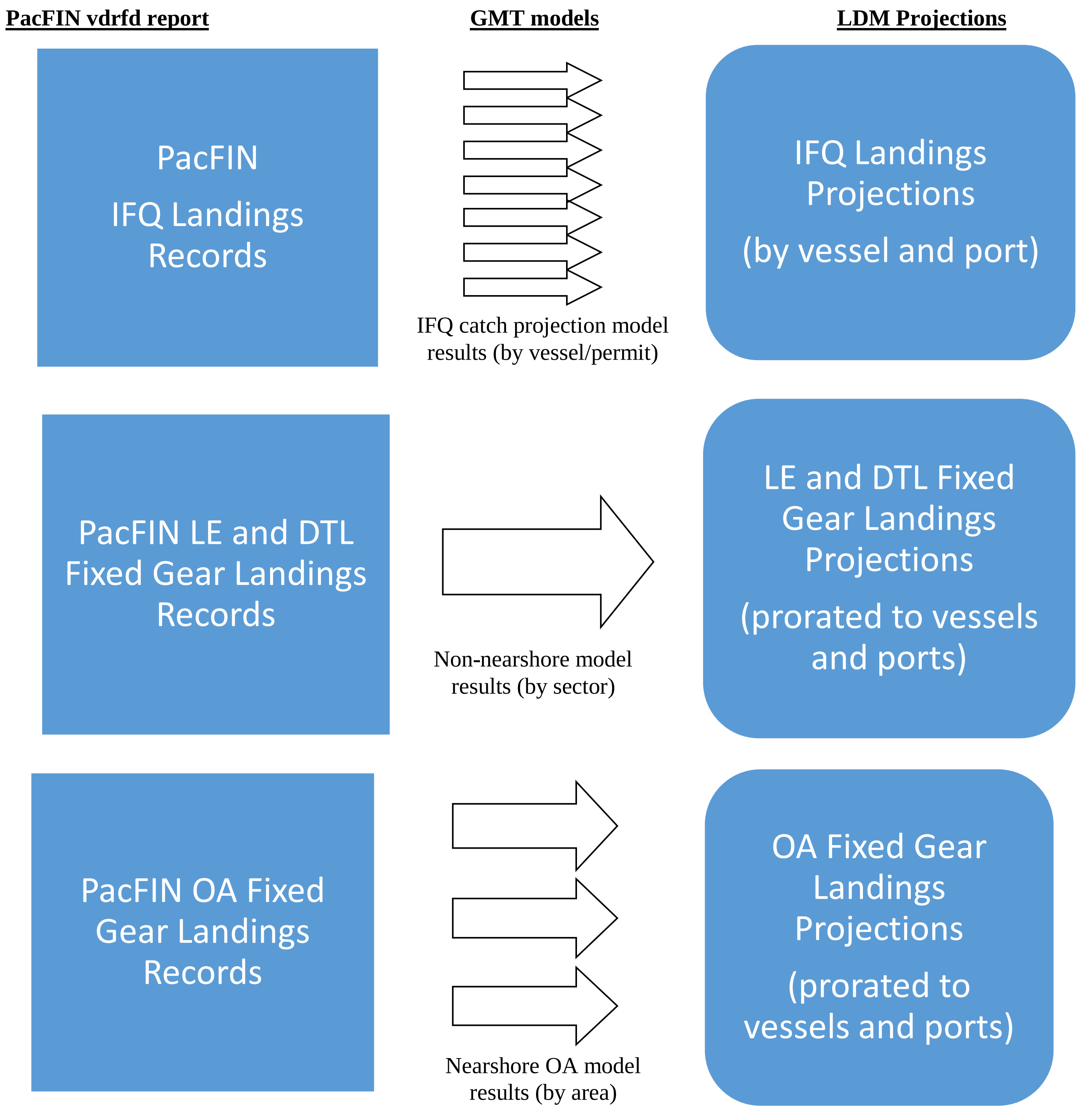

Figure D-1. Linkages between base year data, GMT landings projections, and the LDM.

Note: Results from the at-sea whiting fisheries and tribal fisheries models are incorporated in similar fashion.

D.8 *Literature Cited*

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