Appendix 7
THE FISHING EFFECTS MODEL DESCRIPTION

Introduction

The 2005 and 2010 Essential Fish Habitat (EFH) cycles used the Long-term Effect Index (LEI) model (Fujioka 2006) to assess fishing impacts on essential fish habitat in the North Pacific. The LEI model was developed originally by Dr. J. Fujioka (National Marine Fisheries, retired), and later implemented by Dr. C. Rose (National Marine Fisheries Service, retired) for use in EFH. The LEI model produces an estimate of the long-term equilibrium level of habitat disturbance that would result from a constant rate of fishing impacts and habitat recovery. Habitat disturbance was estimated within 5 km grid cells and split among four general habitat features (epifaunal prey, infaunal prey, biological structures, and physical structures). The model was derived from a set of differential equations, where both impact and recovery were defined as instantaneous rates (Fujioka 2006). While the model was computationally efficient under such a framework, it was not straightforward to convert discrete fishing events and varying effort into a constant instantaneous rate (FAST, 2014).

During the 2015 EFH cycle, the NPFMC requested several updates to the LEI model to make the framework of the model more intuitive and be able draw on the best available data. In response to their requests, the Fishing Effects (FE) model was developed. Like the LEI model, it is run on 5 km grid cells throughout the North Pacific and is based on the interaction between habitat impacts and recovery. These dynamics depend on the amount and spatial extent of fishing effort, the types of gear used, habitat susceptibility to fishing gear, the rate at which habitat recovers, and information about the spatial extent of habitat types. Specifically, the FE model updates the LEI model in the following ways:

1. The FE model is cast in a discrete time framework. This means rates such as impact or recovery are defined over a specific time interval, and can be easily calculated from discrete and variable fishing events.
2. The FE model draws on the best available database of spatially explicit fishing activity processed from VMS data. Fishing activity is represented a line feature in a GIS database that provides high spatial resolution fishing effort. The LEI model, in comparison, used endpoint only representations of fishing activity, which had the effect of unbalanced allotment of fishing effort to grid cells.
3. The FE model implements monthly tracking of fishing impacts and habitat disturbance. While this was possible in the LEI model, the LEI model was developed primarily to estimate long term equilibrium habitat disturbance given a constant rate of fishing and recovery. In contrast, the FE model produces a spatially explicit timeseries of habitat disturbance beginning January 2003, the first month in the VMS database, and is able to update as new data becomes available.
4. The FE model incorporates an extensive global review of habitat disturbance literature (Grabowski et al. 2014) to parameterize the model, providing the most up-to-date peer reviewed information of susceptibility and recovery dynamics.

Fishing Effects model description

The FE model is an iterative model tracking habitat transitions between disturbed and undisturbed states. We let H represent the proportion of habitat disturbed by fishing activities, and h represent the proportion of habitat undisturbed by fishing activities. The two habitat states, H and h are mutually exclusive and complete,

$$H + h = 1 \tag{1}$$

The FE model considers transition between H and h in monthly discrete time steps, t. In implementation of the model, $t = 1$ represents January 2003, the first month of the VMS database. H transitions to h from one month to the next through fishing impacts and h transitions into H through recovery. We let I'_t represent the proportion of H that transitions to h by fishing impacts from month t to month $t + 1$, and ρ'_t as the proportion of h that recovers to H over the same time step. Since they are indexed on t, both I'_t and ρ'_t can vary from month to month. Thus, H_{t+1} is the is the sum of non-impacted H_t and recovered h_t. Conversely, h_{t+1} is the sum of impacted H_t and non-recovered h_t,

$$\begin{aligned} H_{t+1} &= H_t(1 - I'_t) + h_t \rho'_t \\ h_{t+1} &= H_t I'_t + h_t(1 - \rho'_t) \end{aligned} \tag{2}$$

These state transitions are run independently within 5 km x 5 km grid cells across the spatial domain of the model creating a spatial and temporal tracking of H and h. In practice, we only track H since h can easily be back calculated through Eq. 1.

Sediment classes

The I' and ρ' parameters are, in part, determined by the susceptibility and recovery dynamics of the various habitat features that are impacted by fishing. However, since no large-scale maps of habitat features exists for the North Pacific, sediment was used as a proxy for habitat types. In the initial implementation of the model, five sediment types were used (mud, sand, granule/pebble, cobble, and boulder) with associated habitat feature based on Grabowski et al. (2014). Following an October 2016 review by the SSC, it was recommended to include an additional “deep and rocky” sediment category which comprised cobble and boulder sediments deeper than 300 m. The purpose of this addition was to include long-lived habitat features that are found in deep and rocky habitat that were not included in the Grabowski et al. (2014) review.

Each grid cell in the model is attributed with a sediment profile based on the proportion of each of the six sediment types within it. For example, a grid cell may be 50% sand and 50% mud, or 10% mud, 80% sand, and 10% cobble, or any other combination that sums to 100%. Sediments are assumed to be uniformly spread throughout each grid cell based on their proportion. H and h, then are tracked not only within grid cells, but also within sediment classes. The total undisturbed habitat in a given cell is the mean of undisturbed habitat for each sediment, s, weighted by the proportion of sediment with the grid cell, ϕ_s, across all six sediment types,

$$H_{t,\bullet} = \sum_{s=1}^{6} H_{t,s}\,\phi_s \tag{3}$$

Fishing Impacts

The proportion of undisturbed habitat that transitions to disturbed habitat as a result of fishing impact, I', is calculated as the exponentiation of summed impacts, I (for a discussion on this conversion, see Section *Expectation of impact rate*),

$$I' = 1 - \mathrm{e}^{-I} \tag{4}$$

In the FE model implementation, the parameter I is indexed across time periods, t, sediment classes, s, and gears, g. We sum across n gears to calculate I for each time period, and sediment combination. For the remainder of the model discussion, we will omit the t indexing as all parameters are unique to time period unless otherwise stated.

$$I_{s,\bullet} = \sum_{g=1}^{n} I_{s,g} \tag{5}$$

The impact rate for each gear-sediment combination, $I_{s,g}$, is calculated as the product of the gear specific fishing effort, f_g and the gear-sediment susceptibility $q_{s,g}$,

$$I_{s,g} = f_g q_{s,g} \tag{6}$$

f_g is a measure of the total bottom contact by each gear as a proportion of the total grid cell area. It can range from zero, indicating no bottom contact by a gear type, to proportions greater than or equal one, indicating that the total bottom contact area was greater than or equal the area of the grid cell. Proportions exceeding one may occur because f_g is summed across all individual tows of the same gear type within a cell regardless of possible overlap. When $f_g \geq 1$, it does not necessarily mean that the entire grid cell has been contacted by fishing gear, but only that the sum of bottom contact by individual tows is greater than or equal to the grid area. For example, we can consider the two following hypothetical (and unlikely) scenarios both resulting in $f_g = 1$. In the first scenario, one tow may contact the entire grid cell, resulting in 100% contact by one vessel. In the second scenario, 10 vessels may contact the same 10% area of the grid cell, in which case $f_g = 10\times0.1 = 1$. Although, $f_g = 1$ in both scenarios, the actual percent of ground contact differs.

We calculate f_g for each gear as the nominal area swept, A_g, multiplied by contact adjustment, c_g. Nominal area swept is the door-to-door area of a tow not accounting for the degree to which the components of a tow actually touch the sea floor. For this model, it is measured as a proportion of grid cell area. The contact adjustment is the proportion of the nominal area swept in contact with the sea floor. Because we assume a uniform distribution of sediment within a grid cell, f_g is not indexed over sediment, and is assumed to be spread proportionally among all sediments within a grid cell (i.e. $f_g = f_{g,s}$).

Calculating susceptibility

Susceptibility, $q_{s,g}$, is the proportion of habitat affected by bottom contact with fishing gear. It is calculated for each gear-sediment combination as the mean of the susceptibilities of all habitat features associated with a sediment-gear combination (Tables 1-3). Susceptibilities were based on Grabowski et al. (2014) for the five primary sediment types. Susceptibility for the "deep and rocky" sediment type was based on the maximum of the cobble or boulder categories. In a few cases, Grabowski et al. (2014), split habitat feature susceptibility between high and low energy systems. In these cases, we selected the low energy susceptibility. Susceptibilities were not estimated as specific values, but instead were classified into four scores representing a range of values: 0: 0 – 10%; 1: 10 – 25%; 2: 25 – 50%; 3: >50%.

To calculate an average susceptibility for each gear-sediment combination, we first randomly selected a susceptibility for each habitat feature within its range of susceptibilities. We then computed the mean of these randomly selected habitat feature susceptibilities. These random susceptibilities were calculated for each grid cell and time step.

Calculation of fishing effort

Fishing effort, f_g is calculated for each cell, month, and gear type using the Catch-In-Area (CIA) databased processed from VMS data. The CIA database is a polyline feature class representing individual tows from January 2003 through December 2016. Nominal gear widths were joined to each fishing event in the CIA dataset using the following attributes (Table 4): vessel type, subarea, gear, target species, vessel length, season (date), and grid cell depth. Buffers were created around the polylines using one-half the nominal gear width (ArcMap v 10.2.1). Square buffer ends were used to ensure the area swept did not exceed the extent of the polyline as well as to increase the efficiency of subsequent spatial operations. The buffered tows were then intersected with the 5 km grid creating a nominal area swept for individual tows within each cell. Each of these nominal areas were multiplied by a contact adjustment to calculate total ground contact. Ground contacts for each FE model gear type were summed over each grid cell and month and divided by the grid cell area to calculate f_g.

Recovery

Recovery, ρ', is the proportion of disturbed habitat, h, that transitions to undisturbed habitat, H, from one time step to the next. It is indexed over sediment, s, assuming differing recovery dynamics for different sediment classes. ρ' is calculated as the exponentiation of the negative recovery rate, ρ_s subtracted from one,

$$\rho'_s = 1 - \mathrm{e}^{-\rho_s} \tag{7}$$

ρ_s is defined as the inverse of recovery time,

$$\rho_s = \frac{1}{\tau_s} \tag{8}$$

where τ_s is the average number of months it takes for habitat in a sediment class to recover from a disturbed to an undisturbed state. Similar to susceptibility, τ_s is calculated as the mean of recovery times across all habitat features within a sediment class. Recovery times for habitat features (Table 5) were taken from Grabowski et al. (2014). In the few cases where the Grabowski et al. (2014) recovery values differed for high and low energy systems, we chose the low energy values. Also, like susceptibility, recovery times were classified into four ranges: 0: $<$ 1 year; 1: 1 – 2 years; 2: 2 – 5 years; 3: 5 – 10 years. For the “deep and rocky” category, we mapped over the maximum recovery times from the cobble and boulder categories, but we also added a “long-lived” habitat feature class and set its recovery at 10 – 50 years.

Calculation of mean recovery times was the same as for susceptibility. Random recovery times were calculated within the range for each habitat feature, then a mean was calculated for each sediment class.

Expectation of impact rate

We used Eq. 4 to convert summed impacts, I to a proportion I' representing the proportion of undisturbed habitat that converts to disturbed habitat each time step. While I is measured as a proportion, it is calculated within each grid cell for each gear type by summing across the impacted area for each tow and dividing by the grid area. Because we sum across tows, regardless of whether or not they overlap, the value I can exceed of one. Using an untransformed I in the model would be problematic, as this could lead to estimations of disturbed area that exceed the total area of the grid cell. This constraint is alleviated through Eq. 4 as the transformed I' is bounded between zero and one.

We can motive this particular transformation by imagining a grid cell to be composed of N discrete habitat units. We will consider an example with only one gear and sediment type in the grid cell. We will let n be the number of habitat units impacted by fishing as summed across individual tows. Thus n is the product of I and N,

$$n = IN \tag{9}$$

Note that n can exceed N if $I > 1$. Given only I as a measure of fishing activity, we do not know how much of the habitat was actually impacted. For example, if we imagine $N = 100$ discrete habitat units in a grid cell and $I = 1$, then $n = 100$. We do not know if all 100 units of N were impacted in the grid cell or if the same 10 units were impacted by 10 different tows ($I = 0.1$, for 10 tows).

We can simulate this scenario by treating the impact of each unique tow as a sample from N discrete habitat features. For a habitat feature to be "sampled" means that it gets impacted by fishing. We sample with replacement because each tow can disturb a habitat feature that has already been disturbed by another tow. We can think of n as the number of times we take a sample with replacement from N. This assumes that there are n independent tows each with $I = 1/N$. Thus, each habitat unit has a $1/N$ probability of disturbance for each tow. Because a habitat unit can be repeatedly impacted, the probability of disturbance for each unit remains constant over all n tows. So, for any habitat unit, X_i, the probability of being impacted k times follows a Binomial distribution, $\mathbf{Bin}(n, 1/N)$, with the probability mass function given as,

$$f(k; n, \frac{1}{N}) = \Pr(X_i = k) = \binom{n}{k} \frac{1}{N}^{k} (1 - \frac{1}{N})^{n-k} \tag{10}$$

Using Eq. 10, we can calculate the probability of a habitat unit not impacted ($X_i = 0$) over n tows,

$$\Pr(X_i = 0) = (1 - \frac{1}{N})^{n} \tag{11}$$

Thus, the probability of a habitat unit being impacted is,

$$\Pr(X_i > 0) = 1 - \Pr(X_i = 0) = 1 - (1 - \frac{1}{N})^{n} \tag{12}$$

We can treat X_i as a Bernoulli trail, defining X_i^* as a binomial variable (impacted or not) with the expected value of $X_i^* = \Pr(X_i > 0)$,

$$\mathbb{E}[X_i^*] = 1 - (1 - \frac{1}{N})^{n} \tag{13}$$

The expected proportion of impact I' across the entire grid cell will then be the sum of expected impacts for each habitat feature divided by N,

$$\frac{1}{N}\sum_{i=1}^{N}\mathbb{E}\,[\mathrm{X}_i^*] = \frac{1}{N}N\mathbb{E}[\mathrm{X}_i^*] = 1-(1-\frac{1}{N})^n \tag{14}$$

While Eq. 14 models the grid cell and impact in discrete units, this processes can be modeled across a continuous surface by letting $N \to \infty$ and substituting IN for n from Eq. 9,

$$I' = \lim_{N\to\infty} 1-\left(1-\frac{1}{N}\right)^{IN} = 1-e^{-I} \tag{15}$$

We can interpret I' as the expected habitat disturbance, given a summed impact rate of I. Certainly, true measures of actual non-overlapping ground contact will vary around the expected value depending on how much overlap there is among tows. Likewise, we can anticipate higher variance as I increases, as greater impact will allow for greater variance in overlap patterns. We also note that the assumption of n independent tows each with $I = 1/N$, is almost certainly not met. Within a tow, impacts are not independent, and cannot be modeled as a sample with replacement since we know that swath of an individual tow is not randomly distributed throughout a grid cell. For example, if a grid cell contained just one tow with an impact rate of $I = 0.25$, we know that the true proportion impacted is 25% (assuming the tow did not loop around itself). Using Eq. 15, however, we would estimate $I' = 0.22$, a difference of ~0.03. This difference is small, and in general, $I' \approx I$ for low values of I. For grid cell containing only a single tow, I will generally be small, as the width of a tow (max $<$ 300 m) is small compared to the area of a typical grid cell (25 sq. km). At greater values where we would expect multiple tows within a grid cell, I and I' will diverge considerably.

References

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Table 1. Hook and line (HAL) susceptibility codes

Feature Class	Feature	Mud	Sand	Gran/Peb	Cobble	Boulder	Deep/rocky
G	Bedforms		0				
G	Biogenic burrows	1	1				
G	Biogenic depressions	0	1				
G	Boulder, piled					0	0
G	Boulder, scattered, in sand					0	0
G	Cobble, pavement				0		0
G	Cobble, piled				1		1
G	Cobble, scattered in sand				0		0
G	Granule-pebble, pavement			0			
G	Granule-pebble, scattered, in sand			0			
G	Sediments, suface/subsurface	0	0				
G	Shell deposits		0	0			
B	Amphipods, tube-dwelling	1	1				
B	Anemones, actinarian			1	1	1	1
B	Anemones, cerianthid burrowing	1	1	1			
B	Ascidians		1	1	1	1	1
B	Brachiopods			1	1	1	1
B	Bryozoans			1	1	1	1
B	Corals, sea pens	1	1				
B	Hydroids	1	1	1	1	1	1
B	Macroalgae			1	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	0	0	0	0	0	0
B	Mollusks, epifaunal bivalve, Placopecten magellanicus	0	0	0	0	0	0
B	Polychaetes, Filograna implexa		1	1	1	1	1
B	Polychaetes, other tube-dwelling			1	1	1	1
B	Sponges		0	1	1	1	1

Adapted from longline susceptibility table (Grabowski et al. 2014)
Susceptibility codes: 0: 0-10%; 1: 10-25%; 2: 25-50%; 3: >50%
Blank spaces are habitat features not associated with the given sediment class
G = Geological features; B = Biological features

Table 2. Pot (POT) susceptibility codes

Feature Class	Feature	Mud	Sand	Gran/Peb	Cobble	Boulder	Deep/rocky
G	Bedforms		0				
G	Biogenic burrows	1	1				
G	Biogenic depressions	1	1				
G	Boulder, piled					0	0
G	Boulder, scattered, in sand					0	0
G	Cobble, pavement				0		0
G	Cobble, piled				1		1
G	Cobble, scattered in sand				0		0
G	Granule-pebble, pavement			0			
G	Granule-pebble, scattered, in sand			0			
G	Sediments, suface/subsurface	1	1				
G	Shell deposits		0	0			
B	Amphipods, tube-dwelling	1	1				
B	Anemones, actinarian			1	1	1	1
B	Anemones, cerianthid burrowing	1	1	1			
B	Ascidians		1	1	1	1	1
B	Brachiopods			1	1	1	1
B	Bryozoans			1	1	1	1
B	Corals, sea pens	1	1				
B	Hydroids		1	1	1	1	1
B	Macroalgae			1	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	0	0	1	1	1	1
B	Mollusks, epifaunal bivalve, Placopecten magellanicus		0	0	0		
B	Polychaetes, Filograna implexa		1	1	1	1	1
B	Polychaetes, other tube-dwelling			1	1	1	1
B	Sponges		0	1	1	1	1

Adapted from trap susceptibility table (Grabowski et al. 2014)

Susceptibility codes: 0: 0-10%; 1: 10-25%; 2: 25-50%; 3: >50%

Blank spaces are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

Table 3. Nonpelagic (NPT) and pelagic (PTR) trawl susceptibility codes

Feature Class	Feature	Mud	Sand	Gran-Peb	Cobble	Boulder
G	Bedforms		2			
G	Biogenic burrows	2	2			
G	Biogenic depressions	2	2			
G	Boulder, piled					2
G	Boulder, scattered, in sand					0
G	Cobble, pavement				1	
G	Cobble, piled				3	
G	Cobble, scattered in sand				1	
G	Granule-pebble, pavement			1		
G	Granule-pebble, scattered, in sand			1		
G	Sediments, suface/subsurface	2	2			
G	Shell deposits		1	1		
B	Amphipods, tube-dwelling	1	1			
B	Anemones, actinarian			2	2	2
B	Anemones, cerianthid burrowing	2	2	2		
B	Ascidians		2	2	2	2
B	Brachiopods			2	2	2
B	Bryozoans			1	1	1
B	Corals, sea pens	2	2			
B	Hydroids	1	1	1	1	1
B	Macroalgae			1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	1	1	2	2	2
B	Mollusks, epifaunal bivalve, Placopecten magellanicus		2	1	1	
B	Polychaetes, Filograna implexa		2	2	2	2
B	Polychaetes, other tube-dwelling			2	2	2
B	Sponges		2	2	2	2

Adapted from trap susceptibility table (Grabowski et al. 2014)

Susceptibility codes: 0: 0-10%; 1: 10-25%; 2: 25-50%; 3: >50%

Blank spaces are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

Table 4. Gear widths and contact adjustment based on attributes from the CIA database

Fishery	Vessel type	Area	Gear	Target1	Target2	Vessel Length (ft)	Season	Depth Range (fath.)	Gear mod[1]	Nom Width (m)	Min Width (m)[2]	Max Width (m)[2]
GOA Pollock Pelagic Trawl Sand Point	CV	GOA	PTR	P	all others	<75				50	50	50
GOA Pollock Pelagic Trawl	CV	GOA	PTR	P	all (but K, S)	≥75				75	0	30
GOA Slope Rockfish Pelagic Trawl	CV	GOA	PTR	K	S	≥75				75	0	0
GOA Slope Rockfish Pelagic Trawl	CP	GOA	PTR	K	W	all				100	0	0
GOA PCod Bottom Trawl Inshore	CV	GOA	NPT	C	B, P	≥75				90	90	90
GOA Deepwater Flatfish Bottom Trawl	CV	GOA	NPT	D	W, X	≥75			2014	90	23	68
GOA Shallowwater Flatfish Bottom Trawl	CV	GOA	NPT	H	all others	≥75			2014	90	23	68
GOA PCod Bottom Trawl Sand Point	CV	GOA	NPT	C	all others	<75				55	55	55
GOA Deepwater Flatfish Bottom Trawl CP	CP	GOA	NPT	D, W	X	all			2014	193	39	143
GOA Shallowwater Flatfish/Cod Bottom Trawl CP	CP	GOA	NPT	H, C	L, all others	all			2014	193	39	143
GOA Slope Rockfish Bottom Trawl CP	CP	GOA	NPT	K	S	all				75	75	75
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	≥90		62	12	37
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	60-90		58	12	35
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	<60		50	10	30

Fishery	Vessel type	Area	Gear	Target1	Target2	Vessel Length (ft)	Season	Depth Range (fath.)	Gear mod[1]	Nom Width (m)	Min Width (m)[2]	Max Width (m)[2]
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	≥90		77	15	46
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	60-90		73	15	44
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	<60		64	13	38
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	≥90		93	19	56
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	60-90		87	17	52
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	<60		75	15	45
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	≥90		115	23	69
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	60-90		109	22	65
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	<60		96	19	58
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	A	≥90		132	26	79
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	A	60-90		124	25	74
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	A	<60		106	21	64
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	B	≥90		163	33	98
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	B	60-90		154	31	92
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	B	<60		137	27	82
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	A	≥90		142	99	128

Fishery	Vessel type	Area	Gear	Target1	Target2	Vessel Length (ft)	Season	Depth Range (fath.)	Gear mod[1]	Nom Width (m)	Min Width (m)[2]	Max Width (m)[2]
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	A	60-90		133	93	120
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	A	<60		114	80	103
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	B	≥90		175	140	175
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	B	60-90		166	133	166
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	B	<60		147	118	147
BS Pcod Bottom Trawl	CV	BS	NPT	C	all others	≤100				90	90	90
BS Pcod Bottom Trawl	CV	BS	NPT	C	all others	>100 ≤250				110	110	110
BS Pcod YFS Bottom Trawl mothership	CV	BS	NPT	Y	C, all others	>250 (or Processor M)				90	90	90
BS Pcod Bottom Trawl	CP	BS	NPT	C	B, P	<150			2011	193	42	145
BS Rock Sole Bottom Trawl	CP	BS	NPT	R		<150			2011	193	42	145
BS Yellowfin Sole Bottom Trawl a80	CP	BS	NPT	Y		<150			2011	193	42	145
BS Flathead Sole/ Other Flat Bottom Trawl	CP	BS	NPT	L	F, W, all others	<150			2011	193	42	145
BS Pcod Bottom Trawl	CP	BS	NPT	C	B, P	≥150 <225			2011	259	47	189
BS Rock Sole Bottom Trawl	CP	BS	NPT	R		≥150 <225			2011	259	47	189
BS Yellowfin Sole Bottom Trawl a80	CP	BS	NPT	Y		≥150 <225			2011	259	47	189

Fishery	Vessel type	Area	Gear	Target1	Target2	Vessel Length (ft)	Season	Depth Range (fath.)	Gear mod[1]	Nom Width (m)	Min Width (m)[2]	Max Width (m)[2]
BS Flathead Sole/ Other Flat Bottom Trawl	CP	BS	NPT	L	F, W, all others	≥150 <225			2011	259	47	189
BS Bottom Trawl - non a80	CP	BS	NPT	Y	all others	225+			2011	259	47	189
BS POP Bottom Trawl	CP	BS	NPT	K	S, T	<250				100	100	100
AI Pcod Bottom Trawl mothership	CV	AI	NPT	C	all others	>250 (or Processor M)				75	75	75
AI Pcod Bottom Trawl	CV	AI	NPT	C	all others	<99				55	55	55
AI Pcod Bottom Trawl	CV	AI	NPT	C	all others	≥99				90	90	90
AI Atka and Rockfish Bottom Trawl	CP	AI	NPT	A	K, all others	all				100	100	100
AI Pollock		AI	PTR	P	all					100	0	20
GOA PCod Pot		GOA	POT	C	all others					5.6	2.8	5.6
BSAI Pcod Pot		BSAI	POT	C	all others					5.6	2.8	5.6
BSAI Sablefish Pot		BSAI	POT	S	T					5.6	2.8	5.6
GOA Sablefish Pot (few, but future) can combine BS for now		GOA	POT	S	T					5.6	2.8	5.6
GOA Sablefish Longline		GOA	HAL	S	T					2	0	2
GOA SE Demersal Shelf Rock Longline		GOA	HAL	K						2	0	2
GOA Halibut longline		GOA	HAL	I						2	0	2
GOA Pcod Longline		GOA	HAL	C	all others					2	0	2
BSAI Pcod Longline		BSAI	HAL	C	all others					2	0	2

Fishery	Vessel type	Area	Gear	Target1	Target2	Vessel Length (ft)	Season	Depth Range (fath.)	Gear mod[1]	Nom Width (m)	Min Width (m)[2]	Max Width (m)[2]
BSAI Sabelfish/ Greenland Turbot Longline		BSAI	HAL	S	T					2	0	2
BSAI Halibut longline		BSAI	HAL	I						2	0	2
PCod Jig (also rockfish and halibut)		GOA	JIG	C	all others					0.2	0	0.2
BS Pcod Jig		BS	JIG	C	all others					0.2	0	0.2
AI Jig		AI	JIG	C	all others					0.2	0	0.2

[1] Indicates year in which a gear modification regulation went into effect.
[2]Min and max widths are same as nominal width prior to gear modification

Table 5. Recovery codes

Feature Class	Features	Mud	Sand	Gran/Peb	Cobble	Boulder	Deep/rocky
G	Bedforms		0				
G	Biogenic burrows	0	0				
G	Biogenic depressions	0	0				
G	Boulder, piled					3	3
G	Boulder, scattered, in sand					0	0
G	Cobble, pavement				0		0
G	Cobble, piled				3		3
G	Cobble, scattered in sand				0		0
G	Granule-pebble, pavement			0			
G	Granule-pebble, scattered, in sand			2			
G	Sediments, suface/subsurface	0	0				
G	Shell deposits		2	2			
B	Amphipods, tube-dwelling	0	0				
B	Anemones, actinarian			2	2	2	2
B	Anemones, cerianthid burrowing	2	2	2			
B	Ascidians		1	1	1	1	1
B	Brachiopods			2	2	2	2
B	Bryozoans			1	1	1	1
B	Corals, sea pens	2	2				
B	Hydroids	1	1	1	1	1	1
B	Macroalgae			1	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	3	3	3	3	3	3
B	Mollusks, epifaunal bivalve, Placopecten magellanicus		2	2	2		
B	Polychaetes, Filograna implexa		2	2	2	2	2
B	Polychaetes, other tube-dwelling			1	1	1	1
B	Sponges		2	2	2	2	2
B	Long-lived features[1]						4

Adapted from trawl recovery table (Grabowski et al. 2014)

Recovery codes: 0: < 1 year; 1: 1 – 2 years; 2: 2 – 5 years; 3: 5 – 10 years; 4: 10 – 50 years

Blank spaces are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

[1] Long-lived features added to deep and rocky habitat category at request of SSC