Agenda Item G.5
Attachment 3 (**Electronic Only**)
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DRAFT

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Status of the Pacific Spiny Dogfish shark resource off the continental U.S. Pacific Coast in 2021

by

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Acronyms used in this document

ABC	Acceptable Biological Catch
ACL	Annual Catch Limit
AFSC	Alaska Fisheries Science Center
CDFW	California Department of Fish and Wildlife
CRFS	California Recreational Fisheries Survey
DFO	Canada's Department of Fisheries and Oceans
FL	Fork Length
GMT	Groundfish Management Team
IFQ	Individual Fishing Quota
INPFC	International North Pacific Fisheries Commission
IPHC	International Pacific Halibut Commission
LPC	Pre-Caudal Length
MRFSS	Marine Recreational Fisheries Statistic Survey
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
OFL	Overfishing Limit
OSP	Washington Ocean Sampling Program
ORBS	Oregon Ocean Recreational Boat Survey
PacFIN	Pacific Fisheries Information Network
PFMC	Pacific Fishery Management Council
RecFIN	Recreational Fisheries Information Network
SPR	Spawning Potential Ratio
SSC	Scientific and Statistical Committee
SWFSC	Southwest Fisheries Science Center
TL	Total Length
VAST	Vector Autoregressive Spatio-Temporal Package
WCGBT Survey	West Coast Groundfish Bottom Trawl Survey
WCGOP	West Coast Groundfish Observer Program
WDFW	Washington Department of Fish and Wildlife

Executive Summary

Stock

Pacific spiny dogfish (*Squalus suckleyi*) in the Northeast Pacific Ocean occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts. This assessment focuses on a portion of a population that occurs in coastal waters of the western United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The assessment area does not include Puget Sound or any other inland waters. The population within this area is treated as a single coastwide stock, given the migratory nature of the species and the lack of data suggesting the presence of multiple stocks.

The spiny dogfish stock included in this assessment likely has interaction and overlap with dogfish observed off British Columbia. A spatial population dynamics model, which included data from several tagging studies in the Northeast Pacific Ocean, estimated movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada. Given this relatively low estimated rate of exchange, it was considered appropriate to proceed with the assessment for the limited area of the species range, recognizing that the scope of this assessment does not capture all of the removals and dynamics which likely bear on the status and trends of the larger, transboundary population.

Catches

In the coastal waters of the U.S. west coast, spiny dogfish has been utilized since early 20th century, and are caught by both trawl and non-trawl gears (Figure ES-1). The history of dogfish utilization included a brief but intense fishery in the 1940s, which started soon after it was discovered that livers of spiny dogfish contain high level of vitamin A. During the vitamin A fishery, removals averaged around 6,821mt per year reaching their peak of 16,876 mt in 1944. The fishery ended in 1950 with the advent of synthetic vitamins. In the mid-1970s, a food fish market developed for dogfish when the species was harvested and exported to other counties, primarily Great Britain. For the last 10 years landings ranged between 482 and 1,908 mt (Table ES-1). The landings of spiny dogfish were reconstructed back to 1916 from variety of published sources and databases.

Even though spiny dogfish was heavily harvested in the 1940s, this species is not highly prized and is mostly taken as bycatch in other commercially important fisheries. Gear-specific discards were reconstructed outside the model and included as separate fleets.

The fishery removals in the assessment were divided among eight fisheries, including bottom trawl landings, bottom trawl discard, midwater trawl removals, bycatch within the at-sea hake fishery, non-trawl landings, non-trawl discard, non-trawl catches within Vitamin A fishery, and recreational catches.

Table ES-1. Recent removals (mt) of spiny dogfish shark by fleet.

Year	Bottom trawl landings	Bottom trawl discard	Midwater trawl catch	Bycatch within at-sea-hake fishery	Nontrawl landings	Nontrawl discard	Recreational catch	Total Catch
2009	78	525	274	163	56	93	4	1,194
2010	60	368	282	278	10	127	2	1,127
2011	86	303	367	785	11	75	10	1,636
2012	52	291	162	178	2	111	3	799
2013	9	287	105	97	47	96	6	647
2014	53	315	81	60	19	89	2	619
2015	4	191	271	97	43	90	1	699
2016	1	248	203	194	1	134	1	781
2017	3	151	109	140	3	73	3	482
2018	7	228	462	957	2	247	4	1,908
2019	3	252	569	614	2	166	2	1,610
2020	2	210	250	94	1	162	2	721

* The assessment assumes 50% survival of fish in non-trawl discard.

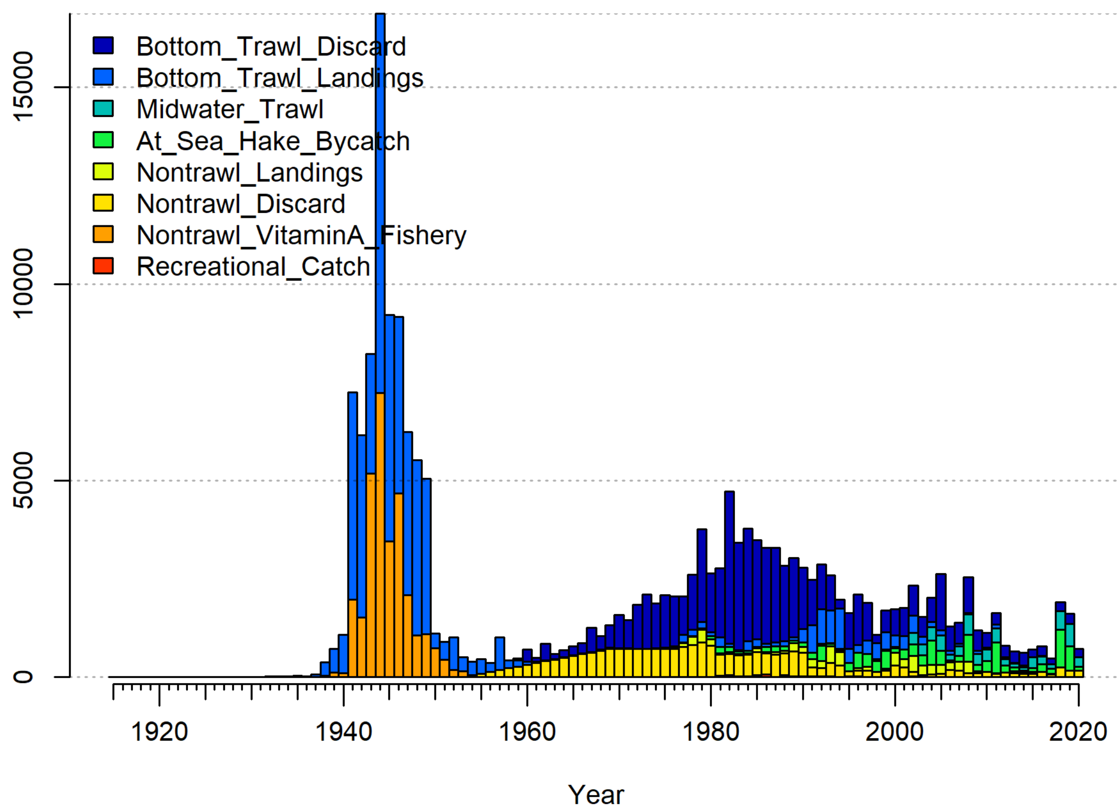

Figure ES-1. Pacific spiny dogfish shark catch history (mt) between 1916 and 2020, used in the assessment.

Data and assessment

The spiny dogfish shark population on the West Coast of the United States was assessed only once before, in 2011, using the Stock Synthesis 2 modeling framework. This current assessment uses Stock Synthesis version 3.30.16, released in September 2020.

The modeling period begins in 1916, assuming an unfished equilibrium state of the stock in 1915. The assessment treats females and males separately due to differences in biology and life history parameters between genders. Types of data that inform the model include catch, length frequency data from commercial and recreational fishing fleets. The model includes eight fishing fleets (bottom trawl landings, bottom trawl discard, midwater trawl catches, bycatch within at-sea hake fishery, non-trawl landings, non-trawl discard, non-trawl catches within Vitamin A fishery, and recreational catches) that operate within the entire area of assessment. Fishery-dependent biological data used in the assessment originated from both port-based and on-board observer sampling programs. Relative biomass indices and information from biological sampling from four bottom trawl surveys were included; these trawl surveys were conducted by the Northwest Fisheries Science Center (NWFSC) and the Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service (NMFS). Spiny dogfish catch in the International Pacific Halibut Commission's (IPHC's) longline survey is also included via an index of relative abundance; IPHC length frequency data are used. Surveys data used in the assessment included abundance indices and fishery-independent length and age frequency data that together provide information on relative trend and demographics of spiny dogfish in the assessed area.

Stock spawning output

The spiny dogfish spawning output in the assessment is reported in thousands of pups. The unexploited level of spawning stock output is estimated to be 28,778 thousands of pups (95% confidence interval: 24,676-32,880). At the beginning of 2021, the spawning stock output is estimated to be 9,895 thousands of pups (95% confidence interval: 5,864-13,926), which represents 34% of the unfished spawning output level (Table ES-2).

Historically, the spawning output of spiny dogfish showed a relatively sharp decline in the 1940s, during the time of the intense dogfish fishery for vitamin A. During a 10-year period (between 1940 and 1950), the spawning output dropped from 99% to under 70% of its unfished level. Between 1950 and 1974 the catches of spiny dogfish were minimal, but given the low productivity of the stock, the spawning output continued to slowly decline. Since late 1970s decrease became a bit more pronounced due to fishery removals (an export food fish fishery developed in the mid-1970s) and low productivity of the stock, but in the last decade catches decreased and the stock decline also slowed down (Figure ES-2).

Table ES-2. Recent trend in estimated spiny dogfish spawning output (1000s of pups), recruitment (1000s of pups) and relative spawning output.

Year	Spawning Output	Interval	Recruitment	Interval	Fraction Unfished	Interval
2009	9,818	5,923–13,713	6,691	4,645–8,738	0.34	0.3–0.4
2010	9,776	5,875–13,677	6,665	4,614–8,716	0.34	0.3–0.4
2011	9,768	5,860–13,677	6,660	4,605–8,715	0.34	0.3–0.4
2012	9,763	5,845–13,681	6,657	4,596–8,717	0.34	0.3–0.4
2013	9,774	5,845–13,702	6,663	4,599–8,728	0.34	0.3–0.4
2014	9,773	5,833–13,714	6,663	4,593–8,733	0.34	0.3–0.4
2015	9,785	5,832–13,737	6,670	4,595–8,746	0.34	0.3–0.4
2016	9,799	5,833–13,765	6,679	4,598–8,761	0.34	0.3–0.4
2017	9,825	5,846–13,804	6,696	4,609–8,782	0.34	0.3–0.4
2018	9,865	5,872–13,858	6,721	4,630–8,812	0.34	0.3–0.4
2019	9,867	5,861–13,873	6,723	4,624–8,821	0.34	0.3–0.4
2020	9,876	5,857–13,895	6,728	4,622–8,833	0.34	0.3–0.4
2021	9,895	5,864–13,926	6,740	4,628–8,851	0.34	0.3–0.4

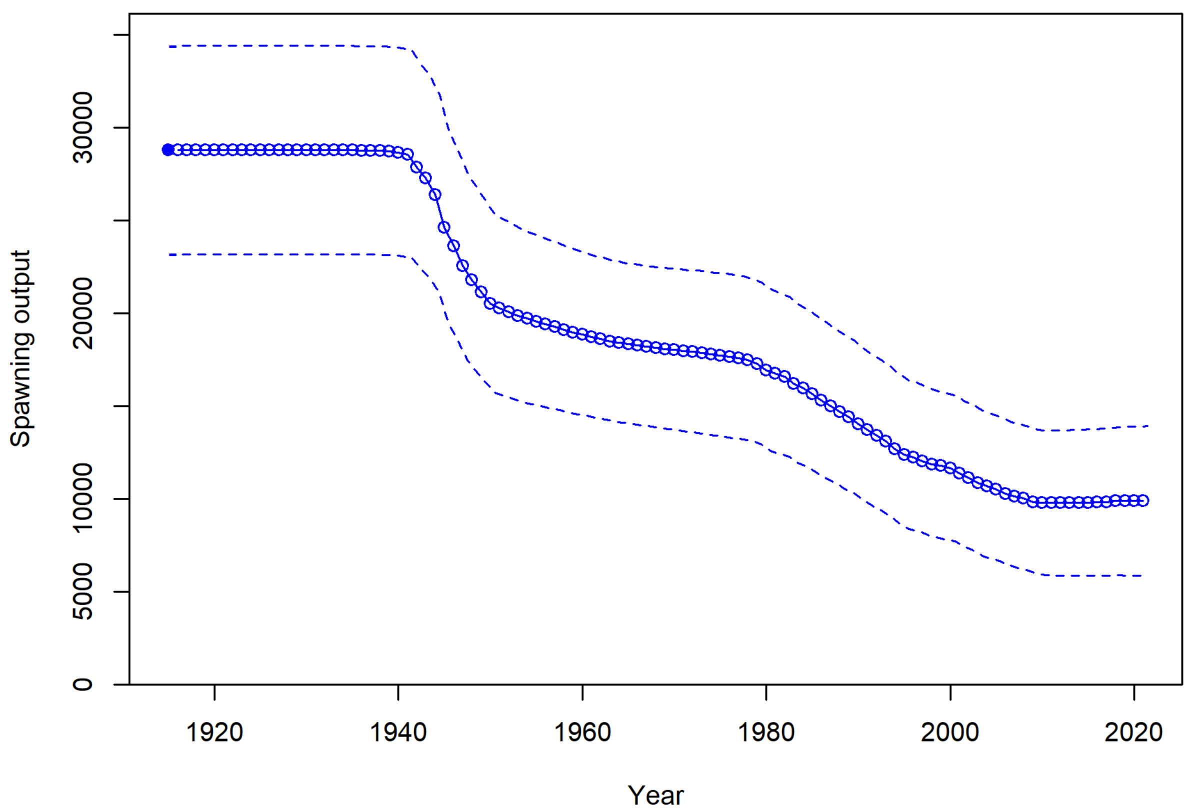

Figure ES-2. Time series of estimated spawning output (1,000s fish) of spiny dogfish for the base model (circles) with ~ 95 percent confidence interval (dashed lines).

Recruitment

The fecundity of dogfish in the Northeast Pacific Ocean has been well studied, with pregnant females having relatively few pups per litter (5 to 15), and with relatively little variability among individuals. Unlike fish producing millions of eggs, the low fecundity of dogfish suggests both low productivity in general and a more direct connection between spawning output and recruitment than for many species. Time series of estimated recruitment (in 1,000s of pups) are shown in Figure ES-3 and recent trends are presented in Table ES-2.

In the assessment, therefore, the spawner-recruit relationship was modeled using a functional form which allows a more explicit modeling of pre-recruit survival between the stage during which embryos can be counted in pregnant females to their recruitment as age 0 dogfish. The recruits were taken deterministically from the stock-recruit curve since the relatively large size of dogfish pups at birth (20-30cm) suggest that variability in recruitment would be lower than for a species with a larval stage, which is subject to higher mortality rates.

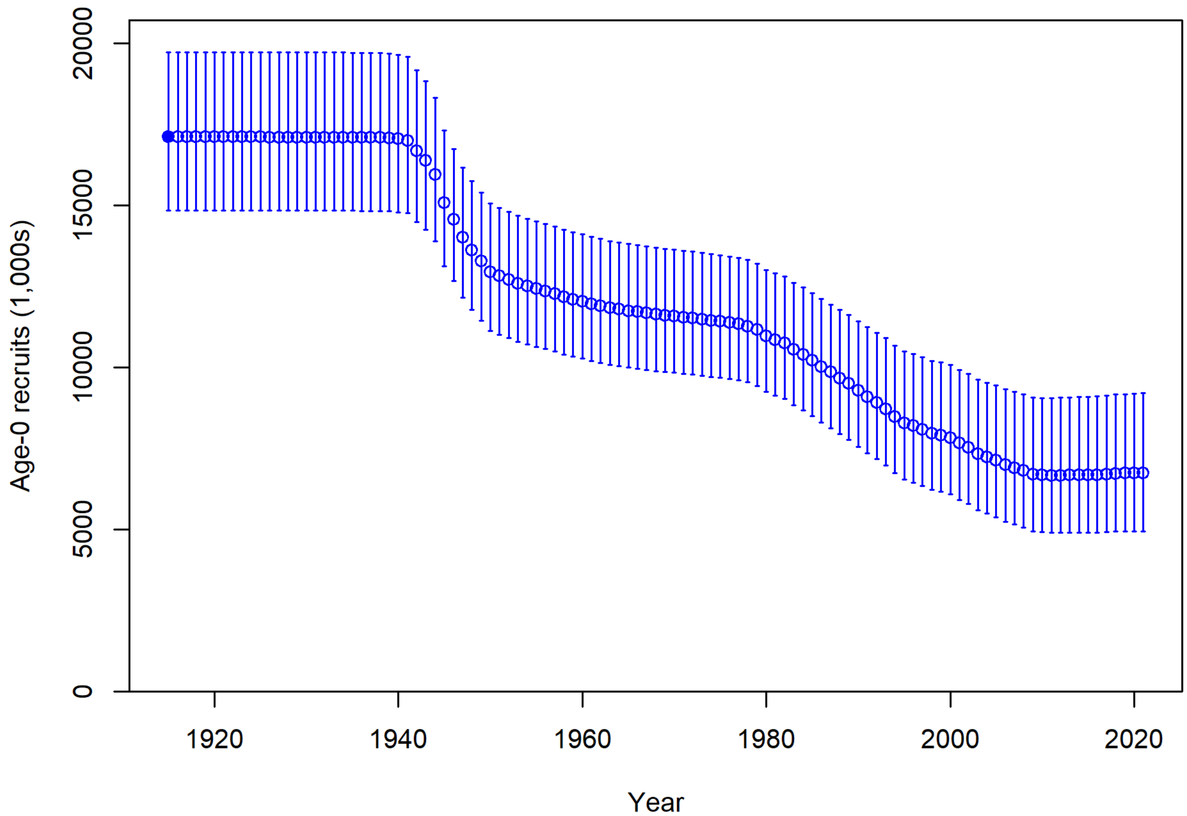

Figure ES-3. Time series of estimated recruitment (1,000s pups) for the base model (circles) with approximate 95 confidence intervals (vertical lines).

Exploitation status

The assessment shows that the stock of spiny dogfish off the continental U.S. Pacific Coast is currently at 34% of its unexploited level (Table ES-2, Figure ES-4). This is above the overfished threshold of $SB_{25\%}$ but below the management target of $SB_{40\%}$ of unfished spawning output. The Spawning Potential Ratio (SPR) used for setting the OFL is 50 percent. Through the history, the assessment estimates that spiny dogfish was fished at a rate that exceeded the relative SPR target in multiple periods, most notably during Vitamin A fishery, but also in 2018 (Table ES-3, Figures ES-5 and ES-6). Equilibrium yield curve for spiny dogfish from the assessment model is shown in Figure ES-7.

Table ES-3. Recent trends in estimated spawning potential ratio (SPR) and exploitation rate for spiny dogfish.

Year	1-SPR (%)	Interval	Exploitation Rate	Interval
2009	41.7	31.35–52.06	0.0136	0.0098–0.0174
2010	37.49	27.61–47.38	0.013	0.0093–0.0166
2011	46.32	34.47–58.17	0.019	0.0135–0.0244
2012	29.56	21.09–38.02	0.0094	0.0066–0.0121
2013	27.3	19.31–35.29	0.0076	0.0054–0.0099
2014	26.18	18.41–33.95	0.0073	0.0052–0.0095
2015	26.88	18.72–35.04	0.0083	0.0058–0.0107
2016	28.37	19.83–36.90	0.0093	0.0065–0.0121
2017	18.75	12.65–24.86	0.0058	0.0040–0.0075
2018	52.24	38.76–65.72	0.0228	0.0159–0.0298
2019	47.37	34.21–60.52	0.0196	0.0135–0.0257
2020	28.22	19.26–37.18	0.0089	0.0061–0.0118

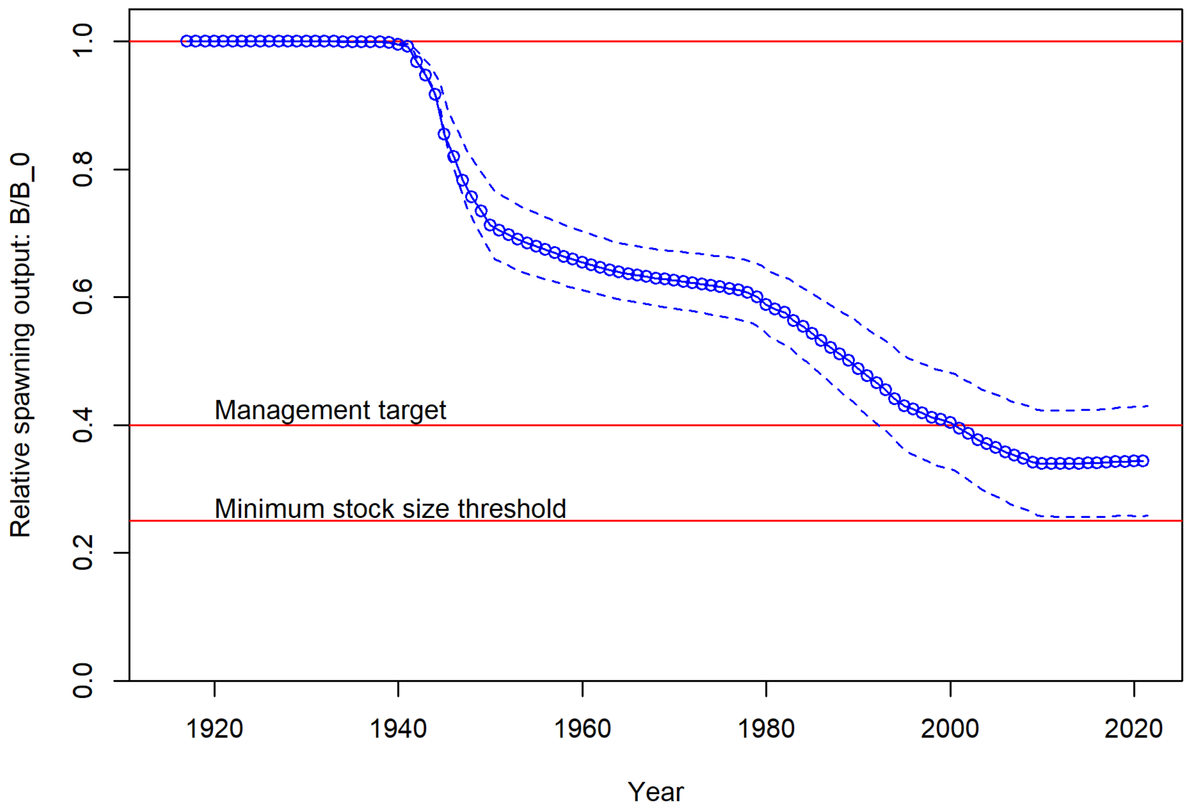

Figure ES-4. Estimated relative spawning output with approximate 95 percent asymptotic confidence intervals (dashed lines) for the base model.

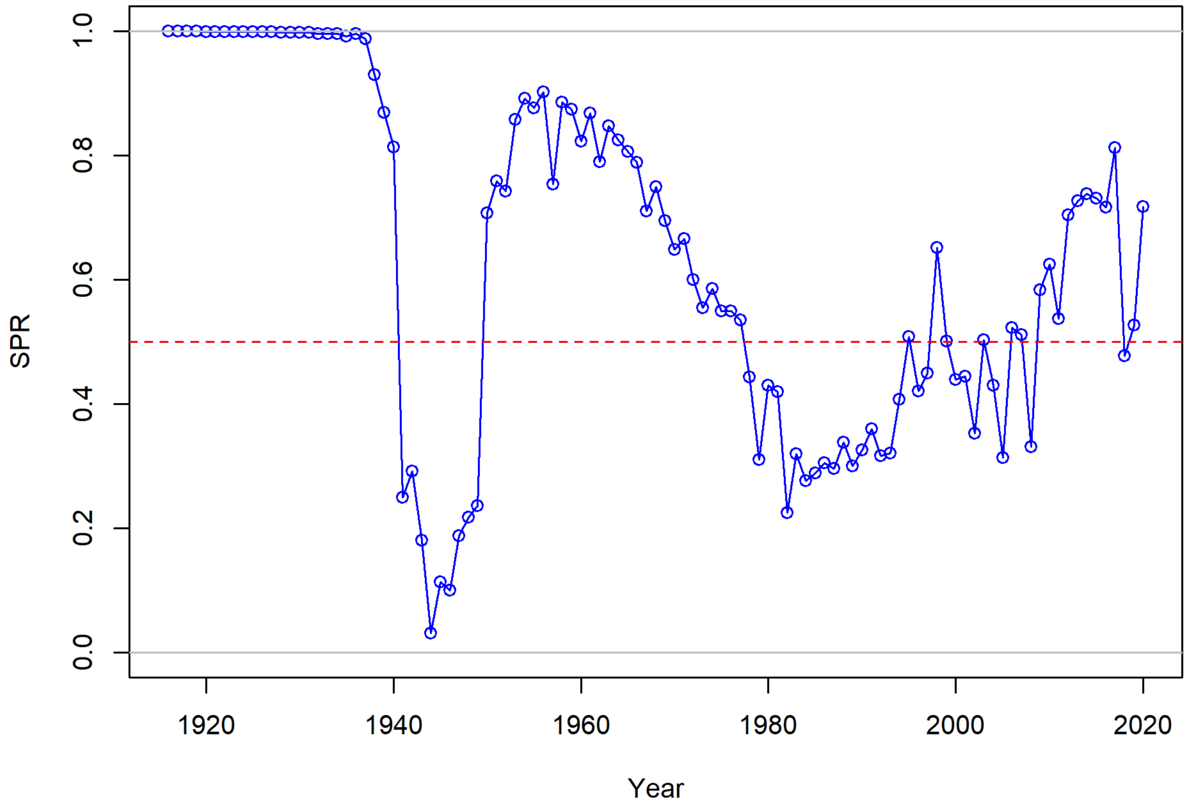

Figure ES-5. Time series of estimated spawning potential ratio (SPR) of spiny dogfish with SPR target of 0.5. Values below target reflect harvest that exceeded current overfishing proxy.

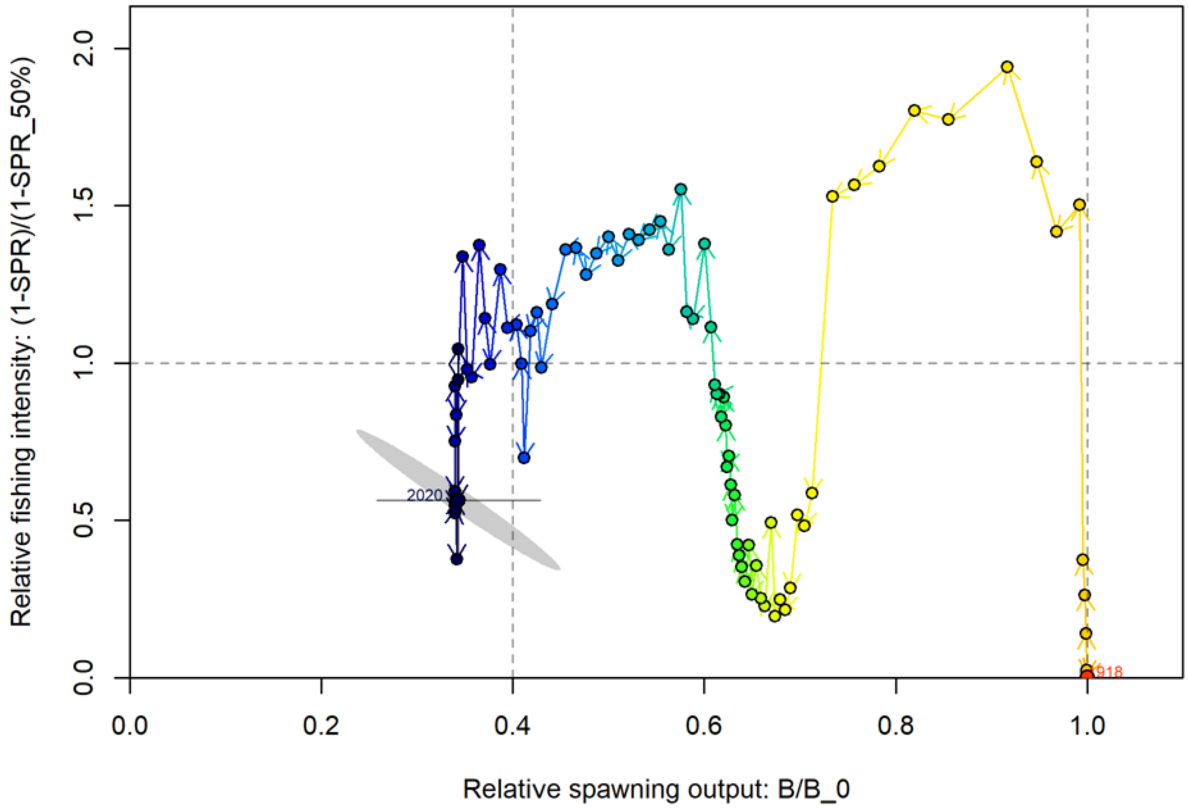

Figure ES-6. Phase plot of estimated relative (1-SPR) vs. relative spawning output for the base model. fishing intensity is (1-SPR) divided by 0.5 (1 minus the SPR target, which is 0.5). Relative spawning output is the annual spawning output divided by the spawning output corresponding to 40 percent of the unfished spawning output. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities: -0.982.

Reference points

Reference points from the assessment model are summarized in Table ES-4, while summary of recent trends in estimated spiny dogfish exploitation and stock level are shown in Table ES-8.

Unfished spawning stock output for spiny dogfish is estimated to be 28,778 thousands of pups (95% confidence interval: 24,676–32,880). The stock is declared overfished if the current spawning output is estimated to be below 25% of unfished level. The management target for spiny dogfish is defined as 40% of the unfished spawning output ($SB_{40\%}$), which is estimated by the model to be 11,511 thousand of fish (95% confidence interval: 9,870–13,152), which corresponds to an exploitation rate of 0.003.

This harvest rate provides an equilibrium yield of 318 mt at $SB_{40\%}$ (95% confidence interval: 269–367 mt). The model estimate of maximum sustainable yield (MSY) is 329 mt (95% confidence interval: 278–381 mt). Equilibrium yield curve for spiny dogfish from the assessment model is shown in Figure ES-7. The estimated spawning stock output at MSY is 14,164 thousands of pups (95% confidence interval: 12,185–16,143). The exploitation rate corresponding to the estimated SPR_{MSY} of F90% is 0.003.

Because of the extremely low productivity and other reproductive characteristics of the stock, fishing at the target of SPR 50% does not appear sustainable and is expected to reduce the spawning output of spiny dogfish over the long term to zero. Conversely, fishing at a rate that would maintain spawning output near 40% of the unfished level would require a target SPR of about 88% as estimated by the assessment model. The Council's Scientific and Statistical Committee should consider the appropriateness of using the current proxy harvest rate for spiny dogfish.

Table ES-4. Summary of spiny dogfish reference points from the assessment model.

	Estimate	Interval
Unfished Spawning Output (1000s of pups)	28,778	24,676–32,880
Unfished Age 1+ Biomass (mt)	227,235	200,637–253,833
Unfished Recruitment (R0) (1000s pups)	17,099	14,662–19,536
Spawning Output (2021) (1000s of pups)	9,895	5,864–13,926
Fraction Unfished (2021)	0.34	0.26–0.43
Reference Points Based $SB_{40\%}$		
Proxy Spawning Output $SB_{40\%}$	11,511	9,870–13,152
SPR Resulting in $SB_{40\%}$	0.883	0.883–0.883
Exploitation Rate Resulting in $SB_{40\%}$	0.003	0.003–0.004
Yield with SPR Based On $SB_{40\%}$ (mt)	318	269–367
Reference Points Based on SPR Proxy for MSY		
Proxy Spawning Output (SPR50)	NA	NA
SPR50	50	NA
Exploitation Rate Corresponding to SPR50	0.019	0.016–0.021
Yield with SPR50 at SB SPR (mt)	NA	NA
Reference Points Based on Estimated MSY Values		
Spawning Output at MSY (SB MSY)	14,164	12,185–16,143
SPR MSY	0.9	0.899–0.900
Exploitation Rate Corresponding to SPR MSY	0.003	0.002–0.003
MSY (mt)	329	278–381

Management performance

Recent management guidelines along with recent trends in catch (mt) for spiny dogfish are shown in Table ES-5.

Spiny dogfish on the west coast of the United States was managed under the Other Fish complex since implementation of the Groundfish Fishery Management Plan (FMP) in 1982 and managed with stock-specific harvest specifications beginning in 2015.

In 2005, a reduction in the acceptable biological catch (ABC) of the Other Fish complex was instituted due to removal of the California substock of cabezon from the complex. The same year, a 50% precautionary optimum yield (OY) reduction was implemented to accommodate uncertainty associated with managing unassessed stocks. In 2006, a trip limit for spiny dogfish was imposed for U.S. west coast waters, which varied between 100,000 and 200,000 lbs per two months for all gears. In 2009, another ABC reduction was implemented due to removal of longnose skate from the Other Fish complex and the 50% OY reduction was maintained.

In 2011, a reduction in the overfishing limit (OFL) was implemented due to removal of the Oregon substock of cabezon from the Other Fish complex. A 50% precautionary reduction of the annual catch limit (ACL) was maintained and a scientific uncertainty buffer was specified as an ABC of 7,742 mt under the Amendment 23 framework. The trawl trip limit was reduced to 60,000 lbs/2 months in 2011 to accommodate incidental bycatch.

In 2015, spiny dogfish were removed from the Other Fish complex and have been managed with stock-specific harvest specifications since then. Avoidance of spiny dogfish bycatch was encouraged in the trawl fishery and the industry adopted proactive measures to reduce their incidental take.

Table ES-5. Management guidelines, recent trends in landings and estimated total catch (mt) for spiny dogfish, in metric tons.

Year	**OFL**		**ABC/ACL**		**Catch**
	Other Fish a/	Spiny Dogfish	Other Fish a/	Spiny Dogfish	
2011	11,148	2,200	5,574	1,100	1,636.27
2012	11,150	2,200	5,575	1,100	798.94
2013	6,832	2,980	4,697	2,044	646.53
2014	6,802	2,950	4,717	2,024	618.92
2015	NA	2,523	NA	2,101	698.91
2016	NA	2,503	NA	2,085	781
2017	NA	2,514	NA	2,094	481.99
2018	NA	2,500	NA	2,083	1,907.51
2019	NA	2,486	NA	2,071	1,609.72
2020	NA	2,472	NA	2,059	721.44

a/ Spiny dogfish have been managed with stock-specific harvest specifications since 2015.

Ecosystem considerations

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to a lack of relevant data that could contribute ecosystem-related quantitative information for the assessment.

Unresolved problems and major uncertainties

Approximate asymptotic confidence intervals were estimated within the model for key parameters and management quantities and reported throughout the assessment. To explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in key model assumptions, a variety of sensitivity runs were performed, including runs with different assumptions regarding fishery removals, life-history parameters, shape of selectivity curves, stock-recruitment parameters, and many others. Uncertainty in natural mortality, survey catchability, stock-recruit parameters and the unfished recruitment level was also explored through likelihood profile analysis. Additionally, a retrospective analysis was conducted where the model was run after successively removing data from recent years, one year at a time.

In this assessment, the WCGBT Survey catchability coefficient was one of the major sources of uncertainty. Even though the base model was able to estimate a reasonable value the WCGBT Survey catchability, consistent with what we know about spiny dogfish latitudinal, depth and vertical availability to the survey, the likelihood profile indicated that the model has little information for this parameter. Therefore, to aid in exploring the base model, the WCGBT Survey catchability coefficient was fixed at the estimated value for model diagnostics.

Spiny dogfish is a transboundary stock, and there are high densities of dogfish close to the U.S.-Canada border, at the mouth of the Strait of Juan de Fuca which connects the outside coastal waters with the inside waters of Puget Sound and the Strait of Georgia. Limiting the assessment area to the U.S. West Coast coastal waters does not allow for including a full range of spatial and temporal dynamics for the species, and therefore results may possess additional uncertainty associated with not looking at the full scope of stock's distribution.

Scientific uncertainty

The Sigma values associated with the 2021 OFL (calculated from the normal approximation and converted to the log-standard deviation of a lognormal distribution) is 0.19, well below the minimum 1.0 value associated with Category 2, the most likely classification for this assessment.

Decision table

The primary axis of uncertainty used in the decision table (Table ES-7) was West Coast Groundfish Bottom Trawl Survey (WCGBT Survey) catchability (q). WCGBT Survey q in the assessment model was estimated to be q=0.586 and then fixed at the estimated value. To define alternative states of nature, we followed Terms of Reference and used the 12.5% and 87.5% quantiles of the likelihood profile of WCGBTS q (the value of 0.66 reflects the chi square distribution with one degree of freedom). Therefore, the models with q = 0.9 and q = 0.3 were used as the low and high states of nature, respectively.

Twelve-year forecasts for each state of nature were calculated for two catch scenarios. Both scenarios assumed full ACL catches for the 2021 and 2022, which are 1,621 mt and 1,585 mt, respectively. The low catch scenario assumed P* of 0.4 with 65% of ACL taken and the high catch scenario was P* of 0.4 with full ACL taken for years between 2023 and 2032.

Projected Landings, OFLs and Time-varying ACLs

Potential OFLs projected by the model are shown in Table ES-6. These values are based on an SPR target of 50%, a P* of 0.4, and a time-varying Category 2 Sigma which creates the buffer shown in the right-hand column. The OFL and ACL values for 2021 and 2022 are the current harvest specifications (also shown in Table ES-5) while the total mortality for 2021 and 2022 represent full ACL catch.

Table ES-6. Projections of landings, total mortality, OFL, and ACL values.

Year	Projected dead catch (mt),	OFL (mt)	ACL (mt)	Buffer
2021	1,621	1,452	*1,621*	1
2022	1,585	1,419	*1,585*	1
2023	1,001	1,387	1,001	0.762
2024	970	1,370	970	0.747
2025	941	1,354	941	0.733
2026	913	1,339	913	0.719
2027	887	1,325	887	0.706
2028	862	1,313	862	0.693
2029	839	1,302	839	0.68
2030	816	1,292	816	0.667
2031	794	1,283	794	0.654
2032	774	1,276	774	0.642

Research and data needs

In this assessment, several critical assumptions were made based on limited supporting data and research. There are several research and data needs which, if satisfied, could improve the assessment. These research and data needs include:

1) Continue all ongoing data streams used in this assessment. Continued sampling of lengths and ages from the landed catch and lengths and discard rates from the fishery will be very valuable for the years ahead. Also, a longer fishery independen index from a continued WCGBT Survey with associated compositions of length and age-at-length will improve understanding of dynamics of the stock.

2) Continue to refine historical catch estimates. A considerable uncertainty remains in the historic discard amounts, prior to the commencement of the West Coast Groundfish Observer Program. There is also the need to improve estimates of discard mortality. These issues are relevant for other West Coast stock assessments as well.

3) The ageing method for dogfish requires further research. The current assessment was able to estimate growth parameters for females and females, but understanding of maximum age especially for females continue to be uncertain. More research is needed on the topic of unreadable annuli that are missing due to wear on the spines of older dogfish. The efforts should be devoted to both improving current ageing techniques based on dogfish spines and developing new methods using other age structures. Ideally, an alternative method of ageing dogfish that does not rely on the estimation of ages missing from worn spines may be necessary. Improvement in ageing would contribute to better understanding of spiny dogfish longevity and help estimating natural mortality within the assessment model.

4) Poorly informed parameters, such as natural mortality and stock-recruit parameters will benefit from meta-analytical approaches until there is enough data to estimate them internal to the model.

5) There are high densities of dogfish close to the U.S.-Canada border, at the mouth of the Strait of Juan de Fuca which connects the outside coastal waters with the inside waters of Puget Sound and the Strait of Georgia. This distribution, combined with potential seasonal or directed movement patterns for dogfish suggest that U.S. and Canada should explore the possibility of a joint stock assessment in future years.

Most of the research needs listed above entail investigations that need to take place outside of the routine assessment cycle and require additional resources to be completed.

Table ES-7: 12-year projections for alternate states of nature defined based on WCGBT Survey catchability. Columns range over low, mid, and high state of nature, and rows range over different assumptions of catch levels.

			States of nature					
			Low state: q=0.9		Base model: q=0.59		High state: q=0.3	
Management decision	Year	Catch (mt)	Spawning output (1,000s fish)	Depletion	Spawning output (1,000s fish)	Depletion	Spawning output (1,000s fish)	Depletion
Full ACL for 2021 and 2022; P*0.4 with 65% of ACL taken after that	2021	1,621	6,703	0.263	9,895	0.344	20,067	0.513
	2022	1,585	6,672	0.261	9,876	0.343	20,068	0.513
	2023	655	6,636	0.260	9,854	0.342	20,066	0.513
	2024	635	6,638	0.260	9,868	0.343	20,100	0.514
	2025	616	6,637	0.260	9,879	0.343	20,130	0.515
	2026	598	6,634	0.260	9,888	0.344	20,158	0.515
	2027	581	6,628	0.260	9,893	0.344	20,182	0.516
	2028	565	6,620	0.259	9,896	0.344	20,202	0.517
	2029	549	6,608	0.259	9,895	0.344	20,219	0.517
	2030	535	6,594	0.258	9,892	0.344	20,232	0.517
	2031	520	6,578	0.258	9,885	0.343	20,241	0.517
	2032	507	6,559	0.257	9,875	0.343	20,246	0.518
Full ACL for 2021 and 2022; P*0.4 with full ACL taken after that	2021	1,621	6,703	0.263	9,895	0.344	20,067	0.513
	2022	1,585	6,672	0.261	9,876	0.343	20,068	0.513
	2023	1,001	6,636	0.260	9,854	0.342	20,066	0.513
	2024	970	6,629	0.260	9,859	0.343	20,092	0.514
	2025	941	6,618	0.259	9,861	0.343	20,114	0.514
	2026	913	6,604	0.259	9,860	0.343	20,132	0.515
	2027	887	6,587	0.258	9,855	0.342	20,147	0.515
	2028	862	6,566	0.257	9,847	0.342	20,157	0.515
	2029	839	6,541	0.256	9,834	0.342	20,162	0.515
	2030	816	6,513	0.255	9,817	0.341	20,164	0.516
	2031	794	6,482	0.254	9,797	0.340	20,160	0.515
	2032	774	6,447	0.253	9,773	0.340	20,152	0.515

Table ES-8. Summary of recent trends in estimated spiny dogfish exploitation and stock level from the assessment model.

Quantity	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
OFL Other Fish a/	11,148	11,150	6,832	6,802	NA	NA	NA	NA	NA	NA	NA
OFL Spiny Dogfish	*2,200*	*2,200*	*2,980*	*2,950*	2,523	2,503	2,514	2,500	2,486	2,472	2,479
ACL Other Fish a/	5,574	5,575	4,697	4,717	NA	NA	NA	NA	NA	NA	NA
ACL Spiny Dogfish	*1,100*	*1,100*	*2,044*	*2,024*	2,101	2,085	2,094	2,083	2,071	2,059	1,621
Total Catch	1636.269	798.94388	646.52739	618.91734	698.90689	781.000162	481.99312	1907.51277	1609.71551	721.43709	NA
1-SPR	0.46	0.3	0.27	0.26	0.27	0.28	0.19	0.52	0.47	0.28	NA
Exploitation Rate	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	NA
Age 1+ Biomass (mt)	86,333	85,152	84,795	84,574	84,362	84,052	83,642	83,519	81,951	80,684	227,212
Spawning Output	9,768	9,763	9,774	9,773	9,785	9,799	9,825	9,865	9,867	9,876	9,895
Interval	5,860–13,677	5,845–13,681	5,845–13,702	5,833–13,714	5,832–13,737	5,833–13,765	5,846–13,804	5,872–13,858	5,861–13,873	5,857–13,895	5,864–13,926
Recruits	6,660	6,657	6,663	6,663	6,670	6,679	6,696	6,721	6,723	6,728	6,740
Interval	4,605–8,715	4,596–8,717	4,599–8,728	4,593–8,733	4,595–8,746	4,598–8,761	4,609–8,782	4,630–8,812	4,624–8,821	4,622–8,833	4,628–8,851
Fraction Unfished	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Interval	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4

a/ Spiny dogfish have been managed with stock-specific harvest specifications since 2015.

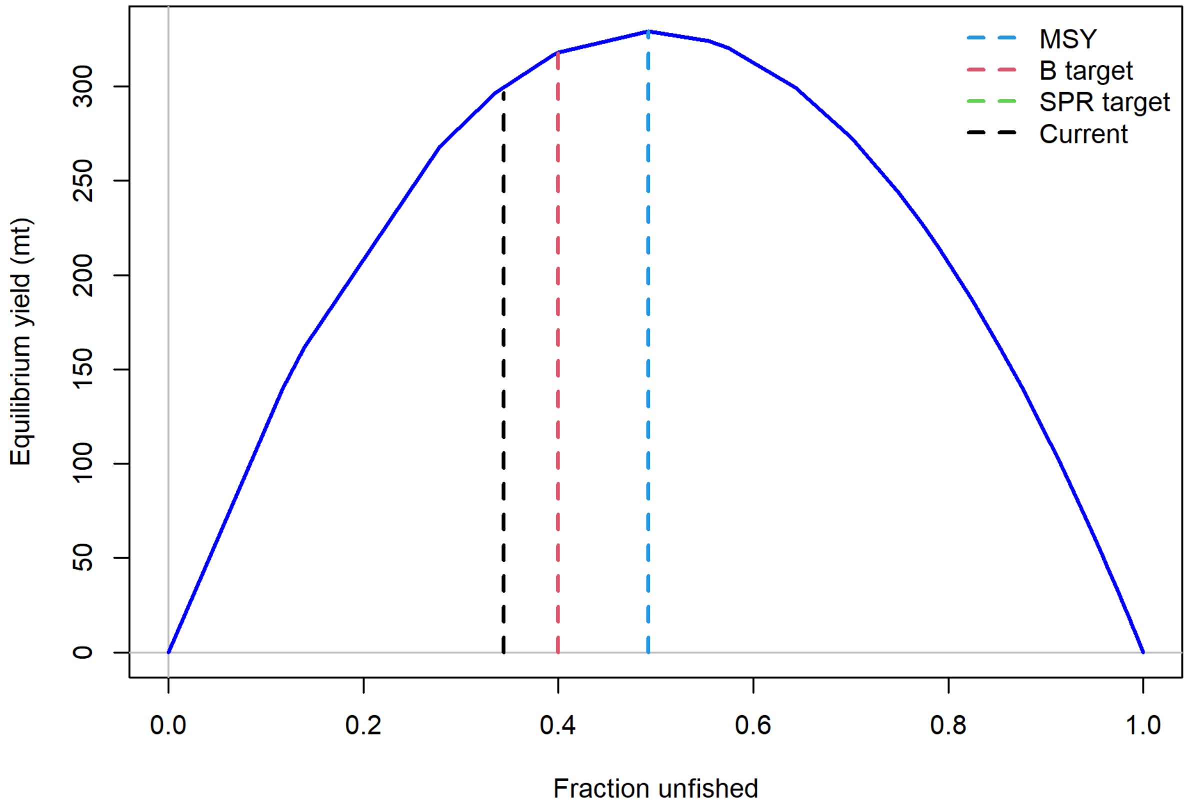

Figure ES-7. Equilibrium yield curve for spiny dogfish from the assessment model.