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IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

FIRST JUDICIAL DISTRICT AT SITKA

SITKA TRIBE OF ALASKA, Plaintiff, v. STATE OF ALASKA, DEPARTMENT OF FISH AND GAME, and the ALASKA BOARD OF FISHERIES, Defendants, and SOUTHEAST HERRING CONSERVATION ALLIANCE, Defendant-Intervenor.	Case No. 1SI-18-00212CI

STA'S OPPOSITION TO THE STATE'S & SHCA'S CROSS-MOTIONS FOR SUMMARY JUDGMENT & REPLY IN SUPPORT OF STA'S CROSS-MOTION FOR SUMMARY JUDGMENT RE: CONSTITUTIONAL CLAIMS

I. INTRODUCTION

The Alaska Department of Fish & Game ("ADF&G") grounds its arguments on a remarkable and completely unsupportable premise that Sitka Sound herring "are not just fine, but are flourishing."[1] If that were true, the 2019 and 2020 commercial fishing

[1] State Mem. at 4.

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seasons would not have been cancelled.[2] Without any commercial fishing for the past two years,[3] the numbers of Sitka Sound herring may be "smack-dab in the middle of long-term abundance back to at least 1925,"[4] but *abundance* does not account for the *quality* of the herring. As Justice Jay Rabinowitz aptly observed: "Quality as well as quantity of available resources must be considered in determining whether sustained yield requirements have been met."[5]

Here, it is an undisputed fact that herring roe quality is equally as important as the quantity of herring for both the commercial and subsistence fisheries.[6] Young, undersized herring, which comprised 83 percent of the forecasted 2020 population, are poor in quality and not desirable by commercial or subsistence fishermen.[7] There was no commercial fishery in 2019 or 2020 because there were not enough older, large

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2 *See* ADFG 3077.

3 The 2018 commercial fishing season also closed early because processors "found the fish too small for market standards." Emily Kwong, *Sitka Herring Fishery Closes Early, 8,300 tons short of quota*, Alaska Public Media (Apr. 4, 2018), https://www.alaskapublic.org/2018/04/04/sitka-herring-fishery-closes-early-8300-tons-short-of-quota. "Early closures also happened in 2016, 2013, and 2012." *Id*.

4 Deposition of Dr. Sherri Dressel at 105 (Oct. 29, 2019) [*hereinafter* Dressel Dep.].

5 *Southeast Alaska Conservation Council, Inc. v. State*, 665 P.2d 544, 557 (Alaska 1983) (Rabinowitz, J., dissenting).

6 *See, e.g.,* 5 AAC 27.195(b) ("[T]he department shall consider the *quality and quantity* of herring spawn on branches, kelp, and seaweed, and herring sac roe when making management decisions regarding the subsistence herring spawn and commercial sac roe fisheries in [Sitka Sound]." (emphasis added)); BOF 5112 (statement of Board Member Umphenour) ("Another big, important thing that was discussed was the quality of the product that the harvesters harvest."); *see also* ADFG 2481-82, 2660, 2640, 3077.

7 *See* ADFG 3077.

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herring with marketable sac roe.[8] Similarly, subsistence harvesters were unable to harvest the amount of herring spawn on branches necessary for subsistence uses in 11 of the 15 years between 2005 to 2019, despite increased efforts over the same time period.[9] The connection between the lack of older, larger herring and the decline in quality harvests is understood, both in traditional ecological knowledge and peer-reviewed science.[10]

The lack of *quality* herring has already resulted in significant economic, cultural, and health impacts to Alaskans.[11] Although ADF&G characterizes the size of the herring population as an "historic abundance"[12] (a characterization that is not undisputed),[13] STA tribal citizens have seen first-hand their traditional harvesting areas,

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8 *Id*.

9 ADFG 2960; *see* Affidavit of Harvey Kitka at ¶¶ 13-15 (Jan. 12, 2019) ["Kitka Aff."].

10 *See* Kitka Aff. ¶ 18; *See* Alec D. MacCall et al., *A Heuristic Model of Socially Learned Migration Behaviour Exhibits Distinctive Spatial and Reproductive Dynamics*, ICES J. of Marine Science (2018) (available at ADFG 2572-82) (describing the "Go With the Older Fish" theory in which migratory paths of herring follow the older, larger fish).

11 *See* Kitka Aff. ¶ 20 ("People are unable to eat as much herring as in the past, which is unfortunate since they have a high nutritional value."); Affidavit of John Woodruff at ¶ 9 (Jan. 24, 2019) (submitted in support of SHCA's Opposition to STA's Motion for Preliminary Injunction) ("The question has been posed to me, what would be the effect on Icicle if the Sitka herring sac roe fishery was closed for the 2019 season? It would constitute a *major and significant disruption to our business*, with potentially large economic impact." (emphasis added)).

12 State Mem. at 4.

13 *Compare id*., *with* ADFG 2153 (describing historical herring populations that were once "so numerous around Sitka in February and March that the water became milky from eggs and milt and it was easy to catch herring with a rake"), BOF 3778 ("[T]he threshold has not been updated with new data in 20 years and recent research in British Columbia (BC) and elsewhere suggest that the method to determine harvest rates and threshold levels may need to be reevaluated to better avoid states of low biomass and low productivity and to allow

which have been used for countless generations, become devoid of herring spawn.[14] It is incredible for ADF&G to describe the herring population as "fine" much less use it as proof that their actions cannot be questioned.

This lawsuit is not an academic exercise.[15] STA has demonstrated that ADF&G withheld important scientific information regarding the herring population and harvests from the Board of Fisheries, which is tasked with adopting regulations governing the commercial and subsistence fisheries. ADF&G does not dispute the fact that it did not provide data and analyses from the 2017 and 2018 subsistence harvests to the Board. ADF&G points out that the withheld reports were labeled "drafts" and were supposedly not finalized,[16] but ADF&G violates its constitutional duties when it fails to make relevant information available to the Board, even if the information is preliminary. It is the Board's task, and not ADF&G's, to weigh *all* of the available information and make policy decisions that govern the fishery.

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populations to recover from such states."), ADFG 2833 ("A re-analysis is also need[ed] to avoid a 'shifting baseline' in which herring biomass is constrained by managing the spawning stock at a relatively low level of abundance."), Kitka Aff. ¶ 6 ("Historically in my lifetime, the herring spawned all over Sitka Sound. It was a beautiful sight to watch the herring arrive, covering the entire Sound.").

14 *See* Kitka Aff. ¶ 20 ("The continuing decline of the herring population, and continuing inability to successfully harvest roe in traditional and accessible areas, has forced some people to stop harvesting eggs.").

15 *See* Order Re: Cross Motions for Partial Summary Judgment at 12 (Mar. 31, 2020) ("[B]ased on the undisputed record before the court, ADFG's implementation of 5 AAC 27.195(a) is unlawful.").

16 State Mem. at 33 n. 77.

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Recently, STA learned that in addition to failing to provide the Board with subsistence harvest reports in either draft or final form,[17] ADF&G also did not disclose an independent scientific assessment recommending changes to the existing (and still current) herring harvest control rule—a formula established by the Board in regulation that sets the commercial harvest limit.[18] The only way for STA to be sure that there are no other studies, reports, and data that ADF&G has refused to make public or provide to the Board is for this Court to recognize that ADF&G has a constitutional duty to apply principles of management intended to sustain the yield of Sitka Sound herring, including using the best available information. The only relief available to STA is a judgment from this Court declaring that ADF&G must provide the best available information regarding the Sitka Sound herring population to the Board.

II. ARGUMENTS

A. The Best Available Information Requirement is an Objective Standard that Courts Apply Routinely When Reviewing Agency Actions.

ADF&G and SHCA fundamentally mischaracterize the well-established best available information requirement.[19] STA's memorandum explained that the requirement is an objective standard that simply prevents agencies from ignoring

[17] *See infra* Part II.C.2 (discussing the "Martell Report").

[18] *See* 5 AAC 27.160(g).

[19] *See* State Mem. at 24-25; SHCA Mem. at 25-26.

relevant information.[20] "An agency complies with the best available information standard as long as it does not ignore available studies, even if it disagrees with or discredits them."[21] When applying that objective standard the court's only task is to determine whether ADF&G failed to provide relevant information to the Board. The narrow inquiry does not present any of the threshold jurisprudential problems raised by ADF&G and SCHA.[22]

In misconstruing the requirement, ADF&G and SHCA rely on the false narrative that judicial review of whether an agency used the "best available information" is a subjective analysis that would compel courts to make policy determinations about what is the "best" information. ADF&G and SHCA then erroneously conclude that STA's claim is "nonjusticiable" because "[e]very dispute over the scientific validity of a particular body of data would present a constitutional question."[23] In other words, ADF&G and SHCA erroneously assert that reviewing whether ADF&G provided the Board with the best available information would require the court to determine what information is "best"—"an undertaking that is simply not manageable."[24] That might be the case if that were the correct application of the requirement, but it is not.

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20 *See* STA Mem. at 27-30.

21 *Id*. at 28 (quoting *San Luis & Delta-Mendota Water Auth. v. Locke*, 776 F.3d 971, 995 (9th Cir. 2014)).

22 *See* State Mem. at 16-21; SHCA Mem. at 26.

23 State Mem. at 21; *see also* SHCA Mem. at 26.

24 State Mem. at 25.

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"Best available information" simply means that an agency may not ignore or omit information that may be relevant to its decision. The concept of best available information, also referred to as the "best available science" or "best available scientific information ('BASI')," is a commonly recognized principle of sustained yield management.[25] It is axiomatic that science-based natural resource management requires managers and biologists to consider all of the relevant information.[26] Otherwise, management decisions could easily be driven by selected studies or data that support a preferred policy or flawed outcome—a result that reflects an inherent "bias" in

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[25] *See, e.g.*, Byrce E. Esch et al., *Using Best Available Science Information: Determining Best and Available*, Journal of Forestry 116(5):473-80 (2018) ("The use of 'the best available scientific information' (often referred to as BASI) is advised or mandated in public land and resource management by state, federal, and international environmental laws, policies, and regulations.") (available at https://www.researchgate.net/profile/Tzeidle_Wasserman/-publication/327738915_Using_Best_Available_Science_Information_Determining_Best_and_Available/links/5cba0496299bf1209771a911/Using-Best-Available-Science-Information-Determining-Best-and-Available.pdf); P.J. Sullivan et al., *Defining and Implementing Best Available Science for Fisheries and Environmental Science, Policy, and Management*, Fisheries 21(9):460-65 (2006) ("The best available science can be defined and acquired for any resource or environmental issue, including the most controversial ones, so that fully informed decisions are possible.") (available at https://digitalcommons.library-.umaine.edu/cgi/viewcontent.cgi?article=1029&context=sms_facpub).

[26] *See, e.g.*, Susah Charnley et al., *Evaluating the Best Available Social Science for Natural Resource Management Decision-Making, Environmental Science & Policy*, 73:80-88 (2017) ("Inherent in the concept of available science is that it is physically and conceptually accessible to the user, and directly relevant to a management issue of concern.") (available at https://www.fs.fed.us/pnw/pubs/journals/pnw_2017_charnley003.pdf).

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management decisions.[27] Alaska's Framers explicitly disavowed that kind of non-scientific, results-oriented natural resource management.[28]

Judicial review under the best available information requirement involves an objective standard that does not require courts to decide what particular information is subjectively the "best."[29] Instead, the court's focus is limited to identifying whether there is relevant information that the agency ignored or did not consider. Courts routinely review agency decisions using that standard.

For example, in *Alaska Center for the Environment v. Rue*, the Alaska Supreme Court concluded that the Commissioner of ADF&G failed to incorporate "available scientific information" that was relevant to the Commissioner's decision not to list Cook Inlet belugas as an endangered species.[30] In *Alaska Center for the Environment*,

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27 STA intended the term "bias" to refer to ADF&G selectively deciding which scientific information would be available for the Board's consideration. *See* STA Mem. at 26-27 (the "Sustained Yield and Common Use Clauses require ADF&G to fully, and without bias, provide the Board with the best available information"). ADF&G is inexplicably confused by this simple principle. *See* State Mem. at 18 ("The first issue is 'what does bias mean?' "). "Bias" means a "prejudice" or "predilection," Black's Law Dictionary (11th ed. 2019), as in ADF&G is "biased" in favor of maintaining the regulatory status quo, and therefore, it attempts to only provide information to the Board that supports leaving the current regulations in place.

28 *See Native Vill. of Elim v. State*, 990 P.2d 1, 7 (Alaska 1999) ("Yet the term 'sustained yield principle' is used in connection with management of such resources. When so used it denotes *conscious application insofar as practicable of principles of management* intended to sustain the yield of the resources being managed." (emphasis added) (quoting Papers of the Alaska Constitutional Convention, 1955-1956, Folder 210, Terms)).

29 *San Luis & Delta-Mendota Water Auth.*, 776 F.3d at 995 ("An agency complies with the best available science standard as long as it does not ignore available studies, even if it disagrees with or discredits them.").

30 95 P.3d 924, 932 (Alaska 2004).

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the Court affirmed the ultimate decision not to list belugas, but in reviewing whether the Commissioner properly exercised his "full range of discretion," the Court determined that the Commissioner ignored "abundant data" and information that was relevant to the decision. The Court expressly directed the Commissioner to take a "hard look at *all relevant scientific information submitted or available*" at the time of the next review of the belugas' status.[31]

Although *Alaska Center for the Environment* involved ADF&G's statutory obligations, and not constitutional duties, that case demonstrates that courts can effectively apply the best available information requirement when reviewing ADF&G's disclosures to the Board. The question of whether ADF&G used the best available information is essentially the same as the "hard look" doctrine, which "consists primarily of ensuring that the agency has taken a hard look at the salient problems and has genuinely engaged in reasoned decision making."[32]

Importantly, the requirement to provide the Board with the best available information is not new to ADF&G. In *Stepovak-Shumagin Set Net Association ("SSSNA") v. State, Board of Fisheries*,[33] the State's representations to the Alaska Supreme Court acknowledged ADF&G's role in providing "the best available

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[31] *Id*. at 933 (emphasis added).

[32] *Id*. at 926 (quoting *Interior Alaska Airboat Ass'n v. State*, 18 P.3d 686, 690 (Alaska 2001)).

[33] 886 P.2d 632 (Alaska 1994).

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information" to the Board.[34] "The record confirms that the Board considered *the best available information from the department*, from the public, and from the advisory committees, took a hard look at the issues presented, and made a sound and reasoned decision by adopting the regulation."[35] In *SSSNA*, the Court concluded that the Board did not act arbitrarily or capriciously by adopting a regulation delaying a commercial salmon fishery opening.[36] In reaching its decision, the Court recognized that Board members "relied" on "information presented by ADF&G to assist them in formulating their own conclusions regarding the proposals," which the State represented was, in fact, "the best available information."[37]

ADF&G's and SHCA's central premise that "it is simply not manageable"[38] for courts to apply the best available information requirement is also disproven by the thousands of federal court decisions that have applied precisely that standard of judicial review. As STA's memorandum explained, the requirement that agencies use the best available information is a common and explicit feature in federal statutes.[39] "In deciding what is 'best available' the [agency] is required to seek out and consider all

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34 Brief of Appellee, *SSSNA v. State*, S-05679, 1994 WL 16483119 at * 18; *see id*. at * 6 ("One function of the Board is to evaluate the best information that is currently available").

35 *Id*. at *23 (emphasis added).

36 *SSSNA*, 886 P.2d at 648.

37 *Id*. at 641.

38 State Mem. at 25; *see* SHCA Mem. at 23-26.

39 STA Mem. at 28-29; *see also* Esch et al., *supra* note 25 (recognizing that the best available information requirement is ubiquitous in environmental law).

existing scientific data."[40] A large body of federal court decisions have fully developed and outlined manageable standards of review for the widely accepted principle of management that requires agencies to consider the best available information.[41] STA is only asking this Court to apply that well-established requirement in the context of ADF&G's presentation of information to the Board.

B. ADF&G Has an Independent Duty Under the Sustained Yield and Common Use Clauses to Provide the Board with the Best Available Information.

The merits of STA's constitutional claims are barely addressed by either ADF&G or SHCA. The defendants never explicitly disclaim the fact that ADF&G has a constitutional duty to provide the Board with the best available information. Instead, they suggest that STA lacks a cause of action to even bring its claims.[42] According to SHCA, the "flexibility of the sustained yield principle, and its status as a guiding principle, likewise do not suggest that the framers impliedly intended to create an actionable constitutional duty that ADF&G and the Board use [best available information] in fisheries management and decision-making."[43] Lost on SHCA is the

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[40] *Miccosukee Tribe of Indians of Fla. v. U.S.*, 566 F.3d 1257, 1265 (11th Cir. 2016).

[41] *See, e.g.*, *San Luis & Delta-Mendota Water Auth.*, 776 F.3d at 995; *San Luis & Delta-Mendota Water Auth. v. Jewell*, 747 F.3d 581, 602 (9th Cir. 2014); *Kern Cnty. Farm Bureau v. Allen*, 450 F.3d 1072, 1080 (9th Cir. 2006); *Conner v. Burford*, 848 F.2d 1441, 1454 (9th Cir. 1988); *Native Vill. of Point Hope v. Salazar*, 730 F. Supp.2d 1009, 1016-19 (D. Alaska 2010).

[42] *See* State Mem. at 19-20; SHCA Mem. at 23-26.

[43] SHCA Mem. at 21.

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fact that the Alaska Supreme Court has already held that the Board must use the best available information in its decision-making.[44] Here, requiring ADF&G to provide best available information to the Board is consistent with the Framers' intent that the Sustained Yield Clause should "play a meaningful role in resource management."[45]

STA merely asks this Court to recognize that the Board cannot fulfill its own duties to use the best available information unless ADF&G provides that information to the Board. There is no plausible argument for why the Sustained Yield and Common Use Clauses do not apply to ADF&G. It would be groundbreaking for this Court to conclude that ADF&G is somehow exempt from Article VIII of the Alaska Constitution, or that the "conscious application" of "principles of management intended to sustain the yield of the resources being managed" does not include using the best available information to make those decisions.

Rather than address the merits of STA's constitutional claims, ADF&G and SCHA focus on threshold issues that they erroneously contend render STA's claims "not justiciable."[46] First, according to ADF&G, there can be no Sustained Yield Clause violation unless "the fishery is being managed at an unsustainable level."[47] Neither logic nor precedent support that proposition. The Alaska Supreme Court has never

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44 *See Native Vill. of Elim*, 990 P.2d at 8.

45 *Id*. at 7 (quoting Papers of the Alaska Constitutional Convention, 1955-1956, Folder 210, Terms).

46 State Mem. at 20; SHCA Mem. at 23.

47 State Mem. at 9.

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required plaintiffs to show that a fish or game population is currently at an unsustainable level before raising a Sustained Yield claim. The purpose of the Sustained Yield Clause would easily be undermined if plaintiffs had to wait until after the population is at an unsustainable level before challenging actions by ADF&G that threaten the continued sustainability of the population.

But even if establishing that the "fishery is being managed at an unsustainable level" is a prerequisite for a Sustained Yield Clause violation, that showing has been satisfied here.[48] It is an undisputed fact that the *quality* of Sitka Sound herring is not managed at a sustainable level. There has not been enough quality herring for the commercial or subsistence fisheries since at least 2018—the last year that there was a commercial fishery.[49] STA submits that it is beyond dispute that the *quality* of herring is currently at an unsustainable level, but if the Court agrees with ADF&G that the *abundance* of the herring population is a material fact, the question of sustainability must be decided based on the evidence presented at trial. ADF&G has admitted that the current metrics used to determine historical abundance, including "pristine biomass," are out-of-date and inaccurate,[50] and STA has pointed out credible evidence that ADF&G's herring management suffers from "shifting baseline syndrome" in which the

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48 *See Southeast Alaska Conservation Council*, 665 P.2d at 557 (Rabinowitz, J., dissenting) ("Quality as well as quantity of the available resources must be considered in determining whether sustained yield requirements have been met.").

49 *See* ADFG 3077.

50 *See* BOF 3778.

population is managed "at a relatively low level of abundance" compared to historical patterns (pre-Western settlement).[51]

Second, ADF&G invokes *Mesiar v. Heckman* to support its argument that STA's constitutional claims would "create new constitutional requirements (and causes of action)."[52] But ADF&G's reliance on *Mesiar* is misplaced. *Mesiar* involved a tort claim alleging that an ADF&G employee acted negligently in collecting fishery data.[53] The Alaska Supreme Court concluded that there was no actionable duty of care owed by ADF&G to individual resource users.[54] *Mesiar* does not have anything to say about whether Article VIII of the Alaska Constitution permits a cause of action against ADF&G for its failure to consciously apply "principles of management intended to sustain the yield of the resources being managed."[55]

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51 *See* ADFG 2833; Affidavit of Dr. Gregory T. Ruggerone at ¶ 13 (Jan. 14, 2019) (submitted in support of STA's Motion for Preliminary Injunction) ("Available data indicate the harvest threshold that triggers the commercial fishery has likely been set too low (25,000 tons) and the harvest rate too high; a new analysis is needed to estimate the harvest threshold based on updated estimates of unfished biomass and other considerations identified below. This is why the Sitka Sound herring fishery is consider[ed] to be impacted by a 'shifting baseline.' In other words, a high harvest rate on a relatively small population inhibits the ability of the population to rapidly recover from population declines associated with ocean conditions and harvest, *and the population becomes constrained to a relatively low abundance (i.e., new low baseline*)." (emphasis added)).

52 State Mem. at 20 (citing *Mesiar v. Heckman*, 964 P.2d 445, 450 (Alaska 1998).

53 *Mesiar*, 964 P.2d at 448.

54 *Id*. at 452 ("We conclude that the relationship between Heckman and ADF&G does not support an actionable duty.").

55 *Native Vill. of Elim*, 990 P.2d at 7 (quoting Papers of the Alaska Constitutional Convention, 1955-1956, Folder 210, Terms).

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ADF&G cites no cases or other authorities supporting its position that the manner in which ADF&G implements its Article VIII duties is somehow beyond judicial review. On the contrary, the Alaska Supreme Court has already declined to rule, as ADF&G and SHCA argue here, that the Sustained Yield Clause does not support an implied cause of action.[56] In *Native Village of Elim v. State*, the Court addressed the merits of a Sustained Yield claim, concluding that the Board's regulations applied sustained yield principles appropriately.[57] The Court did not share ADF&G's concern that reviewing Sustained Yield Clause claims on their merits would raise "the specter of endless litigation."[58]

Third, ADF&G invokes the political question doctrine in a flawed effort to convince this Court not to reach the merits of STA's claims.[59] Once again, ADF&G begins its argument from the faulty premise that the best available information requirement is a subjective standard that would be unmanageable for a court to apply.[60] But ADF&G ignores the fact that the well-established best available information requirement is an objective standard and is routinely applied in federal courts without

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[56] *Id*. at 5 ("Elim contends that the Board failed to properly apply the sustained yield clause in managing the False Pass fishery . . . .").

[57] *Id*. at 8 ("Here the record supports the conclusion that the False Pass fishery management plan applies the sustained yield principle 'insofar as practical.' ").

[58] State Mem. at 19.

[59] *Id*. at 22-23 (citing *Baker v. Carr*, 369 U.S. 186, 210 (1962)).

[60] *Id*. at 23.

running afoul of the political question doctrine.[61] Here, there is no question that the Court can rule on ADF&G's constitutional duties—a purely legal question—without implicating the political question doctrine. Moreover, the Court can find a clear violation of those constitutional duties based on ADF&G's withholding of relevant information from the Board. Thus, none of the factors outlined in *Baker v. Carr* for identifying political questions apply to the narrow questions raised by STA.

C. ADF&G Withheld Relevant Information Regarding Sitka Sound Herring from the Board.

1. The 2017 and 2018 Subsistence Harvest Reports

ADF&G does not dispute the fact that it withheld important information regarding subsistence harvests from the Board.[62] In its memorandum, ADF&G admits that it did not provide the Board with the 2017 and 2018 subsistence harvest reports, which included data and analysis demonstrating that subsistence harvests were well below the amount necessary for subsistence established by the Board: "The reports are in the ADFG record because they are documents produced by ADFG that have not been presented to the Board."[63]

ADF&G attempts to justify its failure to provide those subsistence reports to the Board in two ways. First, ADF&G insists that the subsistence harvest reports were not relevant to the Board's consideration of the agenda change requests ("ACRs") at the

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[61] *See supra* note 41.

[62] *See* State Mem. at 33.

[63] *Id*. at 33 n. 75.

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October 2018 and 2019 Board work sessions.[64] Importantly, ADF&G offers no explanation for why the 2017 subsistence harvest report was not provided to the Board before the January 2018 regular meeting.[65] At that meeting, the Board considered proposals to amend the commercial and subsistence fishing regulations, including the regulation setting the amount necessary for subsistence.[66] It defies logic to conclude that a subsistence harvest report from the previous year was irrelevant to the Board's decisions regarding those proposals—ADF&G submitted the 2016 subsistence harvest report, which was not the most recent year for which ADF&G had subsistence data.[67] The Board (and the public) should have had the benefit of the 2017 subsistence harvest report at the January 2018 meeting. Thus, ADF&G violated its constitutional duties by withholding the best available information regarding the 2017 subsistence harvest.

As for the Board's October 2018 and 2019 work sessions, both the 2017 and 2018 subsistence harvest reports were absolutely relevant to the Board's consideration of the ACRs. Both of the ACRs focused on the fact that subsistence harvesters were not meeting even the minimum range of the amount necessary for subsistence.[68] The ACRs

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[64] *Id*. at 38 ("In the context of the work sessions, the Tribe's focus on [the amount necessary for subsistence ("ANS")] in its memorandum is misplaced, since consideration of ANS appears nowhere within ACR criteria.").

[65] *See id*. at 1-41. ADF&G explains that the 2017 report "was not published until October 2019 and the 2018 report published in March 2020," *id*. at 33, but no actual reasons for the delay are provided.

[66] *See* BOF 3739-41.

[67] BOF 3856-3902.

[68] *See* BOF 4675 (2018's "ACR 10"); ADFG 2832 (2019's "ACR 4").

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requested that the Board amend the commercial fishing regulations to provide a reasonable opportunity to harvest the amount necessary for subsistence.[69] The Board has an explicit statutory duty to ensure that its regulations provide a reasonable opportunity for subsistence,[70] which the Legislature has declared to be the priority consumptive use for Alaska's fisheries.[71]

ADF&G argues that the ACRs did not meet the Board's criteria for accepting proposals outside of the normal three-year cycle in which the Board reviews regulations.[72] But ADF&G's analysis ignores the fact that the Board decides whether to accept an ACR, not ADF&G. The Board has wide discretion to consider an ACR that is aimed at addressing subsistence needs, regardless of whether ADF&G thinks that ACRs should be limited to conservation concerns. The ACR policy adopted by the Board provides that it will "not accept an agenda change request that is predominantly allocative in nature *in the absence of new information that is found by the board to be compelling*."[73] By withholding the subsistence harvest reports from the previous fishing seasons, ADF&G ensured that the Board would not have relevant new information, and

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[69] *See* BOF 4675; ADFG 2832.

[70] AS 16.05.258(b)(1) (directing the Board to "provide a reasonable opportunity for subsistence uses").

[71] Ch. 1, § 1(c)(1), SSSLA 1992 ("[S]ubsistence uses of Alaska's fish and game resources are given the highest preference, in order to accommodate and perpetuate those uses.").

[72] State Mem. at 37.

[73] 5 AAC 39.999(a)(2) (emphasis added).

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consequently, the Board would not have the opportunity to determine on its own whether the new information was sufficiently compelling to grant the ACRs.

The main thrust of ADF&G's argument appears to be that subsistence harvest reports have nothing to do with managing the fishery for sustained yield.[74] ADF&G is flabbergasted that subsistence harvest information could be relevant to the Board's consideration of commercial fishing regulations (or sustained yield) despite the fact that the Board explicitly directed ADF&G to consider subsistence when managing the commercial fishery.[75] Importantly, it is not ADF&G's role to decide what the Board should consider. The Legislature delegated policy-making authority to the Board, not ADF&G.[76] Thus, it is vital that ADF&G provide the best available information to the Board (and the public), so the Board can decide for itself how to use the information. There is no way to know for sure how the Board would have weighed the information contained in the 2017 and 2018 subsistence harvest reports or whether the Board would have found the data and analysis in the reports compelling if ADF&G had not withheld that information.

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74 *See* State Mem. at 39.

75 *See* 5 AAC 27.195(a) ("In managing the commercial sac roe fishery . . . the department shall . . . (2) distribute the commercial harvest by fishing time and area if the department determines that it is necessary to ensure that subsistence users have a reasonable opportunity to harvest the amount of herring spawn necessary for subsistence uses as specified in 5 AAC 01.716(b).").

76 *See Peninsula Marketing Ass'n v. Rosier*, 890 P.2d 567, 572 (Alaska 1995) (noting that the Board "is directed to adopt regulations establishing open and closed seasons and areas for the taking of fish and setting . . . harvest levels." (citing AS 16.05.251(1) & (3)).

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Second, according to ADF&G the 2017 and 2018 subsistence harvest reports were "drafts" and were not available in time to be provided to the Board.[77] ADF&G argues that it had "no duty to expedite its reports to inform the Board" of the results of the 2017 and 2018 subsistence harvests.[78] At the outset, it's unclear what ADF&G means by "expedite." The 2017 subsistence season ended in April 2017. ADF&G had more than seven months to finalize the harvest report before the January 2018 Board meeting, but the final report was not published until October 2019—more than two years after the season ended.[79] In contrast, ADF&G had no problems collecting and analyzing data from the 2017 commercial harvest, which was presented in a published report at the Board's January 2018 meeting.[80]

Regardless, STA is not asking this Court to micromanage ADF&G's personnel or set deadlines for ADF&G's reports. Instead, consistent with its constitutional duty to provide the Board with the best available information, ADF&G could have simply presented the draft reports or preliminary data and analyses to the Board. Preliminary data, even with caveats about its reliability, can be valuable to the Board's deliberations

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77 State Mem. at 33.

78 *Id*. at n. 77.

79 *Id*. at 33; ADFG 2711.

80 BOF 3841 (providing data and analysis from the 2017 commercial fishing season).

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on proposals, especially when the Board has no other sources for the same information.[81]

ADF&G already recognizes that "preliminary data" can be provided to the Board in some situations. Dr. Sherri Dressel explained that, in her expert opinion, the "best available information" does not have to be perfect or answer every question investigated.[82] Dr. Dressel acknowledged that ADF&G provides "preliminary data" to the Board when it "seems really important and it's extremely timely . . . and urgent."[83]

Dr. Dressel's stance on preliminary data is consistent with the general rule for best available information, which holds that an agency complies with its duties "as long as it does not ignore available studies, even if it disagrees with or discredits them."[84] The D.C. federal district court explained that when an agency fails to make its own data available to the public—even when the agency "chose not to review the data"—it undermines the public's ability to meaningfully participate in the decision-making process: "[Interested] parties, by not having the data underlying the report, were

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81 STA and the public would have no way to present data or analysis that ADF&G has labeled as a "draft" and not made public, let alone know what data or analyses ADF&G possesses.

82 Dressel Dep. at 58.

83 *Id*. at 98.

84 *San Luis & Delta-Mendota Water Auth*., 776 F.3d at 995.

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deprived of important and material information from which they could make meaningful analysis in order to provide their views."[85]

Here, ADF&G withheld the 2017 and 2018 subsistence harvest reports from the Board without any plausible explanation or justification. By deciding what information to provide the Board, ADF&G acted as the gatekeeper for information that was considered by the Board. Although the public, including STA, have some ability to submit information to the Board, STA does not have access to the most critical information regarding the fishery—the data, analysis, and reports produced by ADF&G's experts, who are the primary advisors to the Board.[86] This Court should conclude that ADF&G's decisions to withhold subsistence harvest reports from the Board was a violation of ADF&G's constitutional duties to provide the Board with the best available information.

2. The Martell Report

SHCA raises a new issue in its memorandum: ADF&G also failed to provide the Board with a completed independent analysis of the model used to calculate the threshold and estimate the annual returning biomass of herring.[87] SHCA claims that "ADF&G is aware of the need to update its analysis of the threshold, but the results of

[85] *Endangered Species Comm. of Bldg. Indus. Assn' of S. Cal. v. Babbitt*, 852 F. Supp. 32, 37 (D.D.C. 1994) (holding agency was required to make available raw data underlying report which it relied on in decision-making).

[86] *See* STA Mem. at 26 (citing studies demonstrating that the Board is most inclined to follow ADF&G's advice).

[87] SHCA Mem. at 8.

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that work were not available for purposes of Board meetings in the period January 2018 through October 2019."[88] That assertion is plainly contradicted by the evidence; ADF&G had a completed, finalized report that was withheld from the Board.

An independent analysis of ADF&G's herring model was conducted by a scientist, Dr. Steve Martell from the University of British Columbia,[89] and the results of his analysis were documented in a written report, known as the "Martell Report."[90] STA had been aware that ADF&G commissioned Dr. Martell to conduct an independent analysis of the model but was informed by Dr. Dressel that the reports were "drafts" and that "[t]hey are not yet there"—meaning, not yet ready to be released to the public.[91] STA obtained the Martell Report from the State in September 2020,[92] after STA filed its opening summary judgment memorandum, and it facially disproves SHCA's claim that the report was "not available for purposes of Board meetings" between January 2018 and October 2019—the Martell Report is dated December 16, 2016.[93]

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88 *Id.*

89 Dressel Dep. at 87.

90 *See* Affidavit of Andrew Erickson (Oct. 23, 2020).

91 Dressel Dep. at 86.

92 Attached as Exhibit 1. STA notes that Dr. Martell's written conclusions are found on pages 1 to 6 and 46 to 48 of the report. The remaining pages consist of equations, charts, graphs, and other technical material supporting the recommendations.

93 Exhibit 1 at 1.

The Martell Report is important for two reasons. First, it calls into question ADF&G's representations to the Board in October 2019. ADF&G explained to the Board that the "model and analysis are currently in development and review and results are not yet available."[94] That appears to be erroneous because the Martell Report is dated December 16, 2016, and is the final, complete report that was delivered to ADF&G.[95]

Second, and most importantly, the Martell Report provided ADF&G with not only an analysis of the current model, but precise instructions for how to improve that model. As Dr. Martell explained, his report "describe[s] a technical description of the proposed model changes, and provide[s] both the equations and the AD Model Builder template code to document how the equations are actually implemented in the code."[96] Thus, ADF&G had the tools it needed to implement the recommended changes to the model, but apparently ADF&G never informed the Board about that fact. Nor did ADF&G ever, to the best of STA's understanding, provide the Martell Report to the Board or the public.

Under Alaska's system of fishery management, and the constitutional sustained yield mandate,[97] ADF&G must be required to present all relevant information to the

94 ADFG 2957.

95 *See* Exhibit 1. Nothing in the Martell Report indicates that it is a draft.

96 Exhibit 1 at 4.

97 *See Rosier*, 890 P.2d at 572.

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Board, and not act as a gatekeeper for important information. ADF&G should not be permitted to continue operating as a "black box," in which only information that it chooses to provide to the Board is considered and becomes part of the Board's administrative record. As this case demonstrates, it is nearly impossible to know what information ADF&G has until ADF&G produces it. ADF&G did not even include the Martell Report in its initial disclosures or administrative record in this case—and yet, the Martell Report is clearly relevant to STA's claims that the Sitka Sound herring population is not currently being managed for sustained yield. It is inconceivable that an independent, expert report analyzing flaws in ADF&G's current biological model, *and* providing specific tools to fix that model, could be considered irrelevant to STA's claims.[98]

STA is not asking this Court to review ADF&G's scientific determinations or complex biological models. Nor is STA asking this Court to direct the Board or ADF&G to take any specific action based on any specific information. The question before the Court is much simpler: did ADF&G withhold relevant scientific information from the Board in violation of its constitutional duties to consciously apply principles that are intended to sustain the yield of the Sitka Sound herring fishery? The answer is yes. It is indisputable that the Martell Report was part of the body of scientific evidence

[98] *See Noffke v. Perez*, 178 P.3d 1141, 1150 (Alaska 2008) ("In general, our rules favor 'a system of liberal pretrial discovery.' Alaska Civil Rule 26 provides that '[p]arties may obtain discovery regarding any matter not privileged which is relevant to the subject matter involved in the pending action. . . .") (affirming superior court award of discovery sanctions).

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that constitutes the best available information and ADF&G withheld that information from the Board.[99] STA's proposed relief asks this Court for a declaration that ADF&G has a constitutional duty to provide the Board with the best available information. Such a declaration will ensure that in the future the Board has access to *all* of the information that it needs to engage in reasoned decision-making.

D. STA's Constitutional Claims Are Not Moot.

Finally, SHCA contends that STA's constitutional claims against ADF&G became moot when STA dismissed different claims against the Board.[100] ADF&G does not join that meritless argument, perhaps because it correctly recognizes that STA's previous claims against the Board are irrelevant to the issues here. This Court must focus its analysis on STA's present constitutional claims against ADF&G, which remain a live and justiciable controversy.

"A claim is moot if it has lost its character as a present, live controversy, or if the plaintiffs would not be entitled to relief even if they were to prevail."[101] STA explained that ADF&G violated its constitutional duties in the past by withholding information from the Board between January 2018 and October 2019, but ADF&G's

99 *See* Exhibit 1 (dated December 16, 2016); *but see* ADFG 2957 ("[T]he model and analysis are currently in development and review and results are not yet available") (ADF&G's October 2019 comments submitted to the Board).

100 *See* SHCA Mem. at 18-19.

101 *Vanek v. State, Bd. of Fisheries*, 193 P.3d 283, 287 (Alaska 2008).

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constitutional violations are ongoing and have continued to this day.[102] ADF&G has yet to provide the Board with important scientific information regarding the Sitka Sound herring fishery or publish that information so that the public may present it to the Board. As this round of summary judgment motions makes clear, the controversy over ADF&G's constitutional duties is very much alive and well. This isn't a situation where the underlying regulation has been changed or the unlawful agency action is wholly in the past.[103]

Even if STA's constitutional claims are primarily focused on ADF&G's past conduct, the claims fall under the public interest exception to the mootness doctrine.[104] The public interest exception applies when (1) the disputed issues are capable or repetition, (2) the mootness doctrine would allow the issues to repeatedly circumvent judicial review, and (3) "the issues presented are so important to the public interest as to justify overriding the mootness doctrine."[105] Each of those factors is satisfied in this case. First, ADF&G's failure to present all of the relevant information to the Board is not only capable of repetition but almost certain to recur (particularly if ADF&G is not

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102 *See* STA Mem. at 37-38.

103 *Cf. Ahtna Tene Nene v. State, Dep't of Fish & Game*, 288 P.3d 452, 457-58 (Alaska 2012) (concluding that appeal was moot because the originally challenged regulation was changed and no longer in effect).

104 *See State, Dep't of Nat. Resources v. Greenpeace, Inc.*, 96 P.3d 1056, 1063 (Alaska 2004) ("We conclude that this appeal as to the constitutionality of the procedure followed in lifting the stay satisfies the public interest exception to the mootness doctrine.").

105 *Hayes v. Charney*, 693 P.2d 831, 834 (Alaska 1985).

clearly informed by a court of the constitutional obligations that ADF&G is currently denying). ADF&G argues that it has no duty to provide all information regarding particular fisheries to the Board.[106] ADF&G's pattern of selecting information that supports its desired outcomes will continue at future Board meetings unless this Court clarifies that ADF&G's constitutional duty to manage fisheries according to principles of sustained yield requires ADF&G to provide the best available information to the Board.

Second, the mootness doctrine, if applied, would repeatedly allow the question of ADF&G's constitutional duties to circumvent judicial review. A plaintiff could only challenge ADF&G's failure to provide the best available information to the Board after the fact, and the information that was withheld would almost certainly be unknown to potential plaintiffs until well after the Board's decisions have been finalized. In this case, STA only became aware of relevant information that was not included in the Board's administrative record through discovery—a process that is not normally available to plaintiffs challenging specific ADF&G decisions or Board actions.[107]

Third, the issues presented here are sufficiently important that mootness should not prevent the court from clarifying ADF&G's constitutional duties. As the Alaska Supreme Court has recognized when applying the public interest exception, "[n]atural

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[106] State Mem. at 16.

[107] *See* Order Re: Motion to Quash Notice of Depositions of Lauren Sill, Kyle Hebert, and Dr. Sherri Dressel (Oct. 7, 2019).

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resources are of prime importance to the public."[108] Whether ADF&G has constitutional duties to provide the Board with all relevant information necessary for the Board to make informed, rational decisions governing Alaska's fisheries is a vital question that must be answered before the next Board meeting in 2021.

The relief STA seeks is a declaratory judgment clarifying ADF&G's constitutional obligations going forward. STA is entitled to declaratory relief even if no injunctive or other administrative relief (such as vacating a regulation) is requested or warranted.[109] Without a declaratory judgment from this Court, it is all but certain that ADF&G will continue to withhold relevant information from the Board and the public, including at the Board's upcoming meeting regarding Sitka Sound herring regulations.

III. CONCLUSION

For the foregoing reasons, this Court should conclude that Article VIII of the Alaska Constitution requires ADF&G to provide the best available information to the Board. ADF&G violated its constitutional duties by failing to provide the best available information to the Board regarding the Sitka Sound herring fishery.

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108 *Greenpeace*, 96 P.3d at 1062.

109 *See State v. American Civil Liberties Union of Alaska*, 204 P.3d 364, 368 (Alaska 2009) (citing AS 22.10.020(b)).

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Dated this 23rd day of October 2020, at Anchorage, Alaska.

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Cheri Woods

Age-structured model for Alaska herring stocks

Steve Martell

December 16, 2016

Executive Summary

This document describes the proposed changes that have been made to the Age-structured assessment model for Alaska herring stocks.

The objective of this project was to review and modify the existing AD Model Builder Code for the Age-structured model for Alaska herring stocks (version 0.1 Jan 2015). The overarching objective of the modifications are: to improve numerical stability, ease of use, general flexibility for alternative structural assumptions, and estimation of observation and process error variance to better quantify uncertainty. The following list of bullets summarizes the proposed changes that have been implemented to date:

- Modifications to the Input Data File. Users can now specify estimates of observation error for each annual observation for: catch, egg surveys, mile milt days, and composition data.
- Modifications to the Control file. Changes to the control file now allow users to estimate or fix parameters, change the phase of estimation, set initial parameter values, apply informative priors of various statistical distributions, all without having to recompile the code. This permits rapid exploration (even automated) of alternative hypotheses and structural assumptions that are repeatable.
- Added controls for the addition of time varying natural mortality rates, blocks of time-varying maturity, a flexible system from implementing a wide variety of selectivity options including time-varying blocks, or continuous non-parametric functions (i.e., cubic splines). The control file is also structured so it can expand with new model features, or custom outputs, that develop in the future.
- Custom command line options were added to the code. Two options were added to permit rapid simulation testing (`-sim` option), and automate the procedures of conducting retrospective analysis without having to make any potentially dangerous modifications to input files (the `-retro` option).
- Many of the previous routines in the current version of the stock assessment model have been broken down into smaller functions. This both reduces the amount of redundant code that currently exists and makes the code easier to read and understand by humans.
- The model has 5 major components:

1. Inputs (includes data and controls that specifies model structure).
2. Population dynamics: a collection of sub-models that relate to the biology (e.g., natural mortality, maturity, stock-recruitment).
3. Observation dynamics: a collection of sub-models that relate how fishing mortality interacts with population model (e.g., fisheries selectivity, fishing mortality, predicted egg abundance index, predicted composition data).
4. Statistical criterion: the objective function that relates estimated model parameters to differences between observed and predicted variables.
5. Outputs: including and not limited to parameter estimates, convergence criterion, derived management quantities and residuals.

- There are a few structural differences being proposed in this model that relate to how selectivity is modeled, the observation error assumed in the composition data, and variance terms that relate to both process error and observation error.
  - To avoid breaking the derivative chain in calculating the objective function and its gradient, use of the max function to re-scale the selectivities should be avoided. Often you can get away with it in very simple models where selectivity is very well informed, but can soon become problematic when your jointly estimating additional parameters that are confounded with selectivity (e.g., time-varying natural mortality). To do so, the proposed change rescales the selectivity vector for ages such that it has a mean of 1.
  - The previous generation used a least-square estimator for the age-composition proportions. The proposed changes implemented in this model assume the age-proportion data are logistic-normal, and these data are weighted by the conditional maximum likelihood estimate of the variance (i.e., objectively weighted). Alternatives likelihood formulations are also easily implemented in future iterations.
  - Lastly, each catch and survey observation in the input data file also has an associated log standard error associated with it (approximately the coefficient of variation). In cases where it is possible to estimate a standard error in the data using bootstrap procedures, the inter-annual variation in observation error can now be specified. In addition, the process error term permits recruitment variation around a stock-recruitment relationship. Currently the Ricker model is implemented, with the option to implement the Beverton-Holt model annotated in the code.
- Additional elements were also introduced in the objective function calculation to improve the overall estimation robustness. These include penalties that are only implemented in the initial phases to set up initial gradients that will get key population parameters in the “ball park”. These penalties can then be relaxed (or set = 0) in the terminal phases.
- Of significant difference is the use of informative prior distributions (or sometimes less informative) for population parameters including: natural mortality, initial recruitment, average recruitment, unfished recruitment, steepness of the stock recruitment relationship, and the variance in the recruitment deviations (process

error). The only option for including priors in the previous generation was to fix a parameter value (which implies the variance is 0, or very informative). For example, having the option to estimate natural mortality where the prior mean is set at the original fixed value and assume some arbitrary CV can often reduce model confounding in cases where there are one-way trips in the relative abundance data. Comparing the marginal posterior density and prior density will shed light on how informative the data are about the parameters.

- Model selection criterion can also be evaluated using Deviance Information Criterion (DIC). This criterion is calculated using the posterior sample values generated from one of AD Model Builders built-in sampling routines (e.g., The Metropolis Hastings Algorithm).

Lastly, a few R-scripts have been developed for the purposes of conducting simulation-estimation experiments for self-testing to examine for potential bias in the estimators, and exploring options for correcting any such bias.

An example assessment using the data for the 2015 Sitka herring stock is provided in this document. This example is not meant to be used as a comparison with other assessments for this stock. The intent of the example is to be illustrative. Finally, the scope of this project focused on the aforementioned points above, and primarily focuses on data weighting and estimation of uncertainty. There are many other graphical methods that could be explored to further communicate levels of uncertainty to fisheries managers, and I would refer you to the work of Dr. Ian Stewart at the Intl. Pacific Halibut Commission on communicating uncertainty to decision makers.

1 Acknowledgments

I greatly appreciate the feedback from the State of Alaska scientists who participated in the training workshop in Juneau Alaska, July 27-29, 2016. A special thank you to Dr. Sherri Dressel for organizing this workshop and inviting me to bid on this contract.

Contents

2 Introduction

This document describes the structural differences between the Age-structured model for Alaska herring (programmed by Pete Hulson, pete.hulson@noaa.gov). The original model was written in Excel, and translated to the AD Model Builder template language. The objective function was a simple weighted least-squares estimator that made numerous simplifying assumptions about the error structure in the data. The objective for the next generation of stock assessment models for Alaska herring stocks is to use a more modern statistical approach to fitting models to data collected from fisheries dependent and independent sources.

In this document we first decompose the original source code to understand how the various observations are related to structural assumptions in the model, and how these data are weighted when estimating model parameters. Next we describe a technical description of the proposed model changes, and provide both the equations and the AD Model Builder template code to document how the equations are actually implemented in the code. A simple example of a simulation-estimation experiment exploring estimation performance (i.e., precision and bias) is explained from both an observation and mixed observation-process error model. Following, a simple example of fitting the model to the Sitka herring stock using the example Sitka data and control files that are available in the code repository.

Having both the equations and the code serve a dual purpose, first it provides model documentation and second allows for new programmers to learn more about the language itself and implement changes to accommodate alternative structural assumptions. The model code is intended to be a living document, and I would encourage developers to use use the code repository, create branches and add or modify the existing code to tailor the model for specific applications or research projects.

3 Model deconstruction

This section is intended to serve three purposes: 1) to document the model structure given the code in model.tpl, 2) to detail proposed changes to the model code to improve overall numerical stability, and 3) provide a statistical approach that is amenable to maximum likelihood and Bayesian methods.

3.1 Model Structure

Table 1 begins with the objective function that is being minimized in the original Alaska herring model programmed by Pete Hulson. There are four components defined in (T1.1), where three of the four components are scaled by user defined coefficients λ. The first component is the commercial age-composition data (QC), the second is the spawning biomass age-composition (QS), the third is egg deposition data (WQE), and finally the fourth component is a penalty on the recruitment deviations from the underlying Ricker stock-recruitment model (QR).

For the commercial age-composition data, observation errors in the age-proportions are assumed to be normal (T1.2), where the predicted proportion-at-age (T1.3) is a function of the numbers-at-age (T1.4) and selectivity (T1.5). Note that in (T1.4) that the function is not continuous. In this case the selectivity curve is rescaled to have a maximum value of 1.0. The `max` operation in the denominator of this function breaks the derivative chain in AD Model Builder and can result in numerical problems during parameter optimization associated with corrupt derivative information.

The same normal error distribution is also assumed for the age-proportions in the spawner catch composition samples (T1.6). In this case, the age proportions are based on the mature numbers-at-age at the time of spawning, where the fishery removals are first subtracted from the mature numbers-at-age (T1.7). Note that this further assumes that all removals (i.e., fisheries selectivity) only harvests sexually mature fish. This assumption is inconsistent with (T1.4), where a different logistic curve is assumed for fisheries selectivity.

The catch-at-age data is internally derived in the model (T1.9) conditional on the numbers-at-age and the estimated selectivity. The model further assumes the total catch (in short tons) is measured without error. This is also referred to as conditioning the model on catch.

The residual sum of squares for the egg deposition survey is given by (T1.10). In this case the observation errors are assumed to be log-normal, and each year's observation is weighted by the inverse variance of sampling observation errors (φ_i).

Table 1: Decomposition of the objective function based on the source code provided in `model.tpl`. The objective function f is what AD Model Builder is trying to minimize. Note that $\dot{}$ represents mature state variables (e.g., mature weight-at-age $\dot{w}_j$)

Objective function		
$f = \lambda_C QC + \lambda_S QS + WQE + \lambda_R QR$		(T1.1)
Commercial catch proportion-at-age		
$QC = \sum_i \sum_j (\hat{Q}_{i,j} - Q_{i,j})^2$	$\hat{Q}_{i,j}$ observed proportions-at-age	(T1.2)
$Q_{i,j} = \frac{V_{i,j}}{\sum_j V_{i,j}}$	$Q_{i,j}$ predicted proportion-at-age	(T1.3)
$V_{i,j} = N_{i,j} \frac{S_{i,j}}{\max(S_{i,j})}$	$V_{i,j}$ vulnerable numbers-at-age	(T1.4)
$S_{i,j} = \frac{1}{1 + \exp(-g_i(j - a_i))}$	$S_{i,j}$ Selectivity in year i for age j	(T1.5)
Spawn proportion-at-age		
$QS = \sum_i \sum_j (\hat{O}_{i,j} - O_{i,j})^2$	$\hat{O}_{i,j}$ observed proportion-at-age	(T1.6)
$O_{i,j} = \frac{\dot{N}_{i,j}}{\sum_j \dot{N}_{i,j}}$	$O_{i,j}$ predicted proportion mature-at-age	(T1.7)
$\dot{N}_{i,j} = N_{i,j} M_{i,j} - C_{i,j}$	$\dot{N}_{ij}$ Number-at-age at spawning	(T1.8)
$C_{i,j} = \frac{\hat{c}_i Q_{i,j}}{\sum_j Q_{i,j} w_j}$	$\hat{c}_i$ observed catch, w_j weight-at-age	(T1.9)
Egg deposition survey		
$WQE = \sum_i \varphi_i \left[\ln(\hat{y}_i) - \ln(y_i)\right]^2$	$\hat{y}_i$ observed egg deposition, φ_i weight	(T1.10)
$y_i = 0.5 \sum_j O_{i,j} (\rho_i \dot{w}_{i,j} - \alpha_i)$	ρ_i and α_i fecundity-weight regression	(T1.11)
Penalized recruitment deviations		
$QR = \sum_i^{(I-k)} \left[\ln\left(N_{i+k,k}\right) - \ln\left(f(\dot{N}_{i,j})\right)\right]^2$	$N_{i+k,k}$ number of age k recruits	(T1.12)
$f(\dot{N}_{i,j}) = a\dot{B}_i \exp(-b\dot{B}_i)$	Ricker stock-recruitment	(T1.13)
$\dot{B}_i = \sum_j \dot{N}_{i,j} \dot{w}_j$	$\dot{B}_i$ mature biomass at spawning	(T1.14)

4 Technical description of the proposed model changes

4.1 Input Data

The best resource for looking at the input data is the html file that describes the input data. There are 7 major sections to the data file.

1. Model dimensions.
2. Fecundity regression coefficients.
3. Total Annual Catch.
4. Empirical Weight-at-age (spawn and commercial).
5. Age-composition (spawn and commercial).
6. Egg deposition data.
7. Mile milt days.

These are the same data inputs that were used in the ASA model; however, there have a been a number of significant changes to the input data file. The most significant change is the addition of the log standard error for each catch, egg deposition, and spawn survey observation.

4.2 Control file

There are also significant changes to the control file. In fact, it's a completely different control file than what was used in the ASA model. Again, the best resource for looking at the specific contents of the control file is the control file itself.

To highlight some of the major changes, the control file now consists of a design matrix for controlling the leading model parameters; specifically, the bounds and phases in which these parameters are estimated. There is a block for time-varying maturity, a block for time-varying natural mortality rate deviations, a block for selectivity, where the user can choose among alternative parametric and non-parametric selectivity curves. Lastly, there is a vector of other miscellaneous model controls for, *inter Alia*, re-scaling catch, conditioning the model on catch or effort.

4.3 Age-schedule information

Empirical weight-at-age data are part of the input data file. Maturity-at-age is assumed to follow a logistic function with age, where the parameters of the logistic function are estimated within the model.

4.3.1 Maturity-at-age

For the maturity-at-age, the HAM assumes that age-specific maturity follows a logistic relationship, where the estimated parameters define the age-at-50% maturity and the standard deviation, for each unique block period (the block periods are user defined).

The source code for the TPL file is as follows:

```
FUNCTION void initializeMaturitySchedules()
  int iyr = mod_syr;
  int jyr = 0;
  mat.initialize();

  for(int h = 1; h <= nMatBlocks; h++) {
    dvariable mat_a50 = mat_params(h,1);
    dvariable mat_a95 = mat_params(h,2);

    jyr = (h != nMatBlocks) ? nMatBlockYear(h) : nMatBlockYear(h)-retro_yrs;

    // fill maturity array using logistic function
    do{
      mat(iyr++) = plogis95(age,mat_a50,mat_a95);
    } while(iyr <= jyr);
  }
```

where `plogis` is a built in ADMB function for the logistic:

$$f(x) = (1 + \exp(-(x - \mu)/\sigma))^{-1}$$

where μ and σ are the location and scale parameters that are estimated.

4.3.2 Natural mortality

Natural mortality is both age- and time-specific. At the time of writing, there is no code that allows for age-dependent natural mortality, but this option is easily added as a feature to the HAM.

The source code for the TPL file is as follows:

```
FUNCTION void calcNaturalMortality()

  int iyr = mod_syr;
  int jyr;
  Mij.initialize();
  switch(mort_type) {
    case 1: // constant M within block.
      for(int h = 1; h <= nMortBlocks; h++){
        dvariable mi = mfexp(log_natural_mortality + log_m_devs(h));

        jyr = h != nMortBlocks?nMortBlockYear(h):nMortBlockYear(h)-retro_yrs;
        // fill mortality array by block
        do{
          Mij(iyr++) = mi;
```

```
      } while(iyr <= jyr);
    }
  break;
  case 2: // cubic spline
    dvector iiyr = dvector((nMortBlockYear - mod_syr)/(mod_nyr-mod_syr));
    dvector jjyr(mod_syr,mod_nyr);
    jjyr.fill_seqadd(0,double(1.0/(mod_nyr-mod_syr)));
    dvar_vector mi = log_natural_mortality + log_m_devs;
    vcubic_spline_function cubic_spline_m(iiyr,mi);
    dvar_vector mtmp = cubic_spline_m(jjyr);
    for(int i=mod_syr; i <= mod_nyr; i++)
    {
      Mij(i) = mfexp(mtmp(i));
    }
  break;
}
```

where the Matrix $M_{i,j}$ is the instantaneous natural mortality rate for year i and age j. At this point the code just fills each row of the matrix with the same annual natural mortality rate (i.e., age-independent). This is where you would want to modify the code to allow for age-dependent natural mortality rates.

4.3.3 Selectivity

Currently only the logistic selectivity option is implemented. But the source code is structured such that alternative parametric and non-parametric functions can be easily added to the source code using a switch statement.

The source code for the TPL file is as follows:

```
FUNCTION void calcSelectivity()
  /**
    - Loop over each of the selectivity block/pattern
    - Determine which selectivity type is being used.
    - get parameters from log_slx_pars
    - calculate the age-dependent selectivity pattern
    - fill selectivty array for that block.
    - selectivity is scaled to have a mean = 1 across all ages.
  */
  dvariable p1,p2;
  dvar_vector slx(sage,nage);
  log_slx.initialize();



  for(int h = 1; h <= nSlxBlks; h++){

    switch(nSelType(h)){
      case 1: //logistic
        p1  = mfexp(log_slx_pars(h,1,1));
        p2  = mfexp(log_slx_pars(h,1,2));
        slx = plogis(age,p1,p2) + TINY;
```

```
      break;
    }

    int jyr = h != nSlxBlks ? nslx_nyr(h):nslx_nyr(h)-retro_yrs;
    for(int i = nslx_syr(h); i <= jyr; i++){
      log_slx(i) = log(slx) - log(mean(slx));
    }
  }
  Sij.sub(mod_syr,mod_nyr) = mfexp(log_slx);
```

The matrix $S_{i,j}$ is the relative selectivity for age j in year i. Additional functions for computing the vector `slx` can be new cases (e.g. case 2: // coefficients).

In this model, selectivity is parameterized to have a mean value of 1.0. The reason for this particular parameterization is to ensure the objective function remains continuous and differentiable. In each year, the vector of age-specific selectivity coefficients is scaled to have a mean value of 1.0, rather than have an asymptote of 1.0. This is accomplished, in log-space, by subtracting the mean from the vector of age-specific selectivities. This avoids having to use the max function; the use of the max function can lead to a discontinuity in the objective function which result in non-convergence. The trade-off for this numerical stability is that the interpretation of fishing mortality rates changes. The estimator is calculating the average-age-specific fishing mortality rate. The fully-selected fishing mortality rate is more commonly used metric, and this is easily accommodated post-estimation by re-scaling the vector of fishing mortality rates by the maximum age-specific selectivity in each year.

Note that the trends in the mean fishing mortality rates already integrates the changes in selectivity over time. These estimates of F probably better reflect the measure of fishing effort (i.e., mile-hours fished). Whereas, asymptotic estimates reflect the trends in fishing mortality rates for "fully recruited" cohorts and are less likely to reflect fishing intensity.

4.4 Fishing mortality

If the model is conditioned on effort, then a routine that calculates the age-specific fishing mortality rate is invoked. In this routine, a vector of fishing mortality rate parameters, in log-space, is estimated, and the age-specific fishing mortality rate is the product of the fishing rate and age-specific selectivity. The source code for this routine is as follows:

```
FUNCTION void calcFishingMortalitiy()
  /**
    - Calculate Fishing mortality, and then Zij = Mij + Fij
    */

  for(int i = mod_syr; i <= mod_nyr; i++) {
    Fij(i) = exp(log_ft_pars(i)) * Sij(i);
  }
```

If the model is conditioned on catch (i.e., the method the ASA model uses), then there is a resulting difference equation which has the potential to result in negative numbers-at-age, which results in negative infinity in log-space. To guard against this, a simple solution might be to use a max function to ensure that a positive number is returned. However, this is yet another occurrence where the objective function is discontinuous and subject to non-convergence issues. AD Model Builder has a function `posfun` that can be used to ensure the objective function remains continuous and differentiable.

4.5 Population dynamics

Estimated parameters for the population dynamics model include the initial abundance of ages 3-9+ for the initial year, abundance of age-3 recruits each year, and the natural mortality rate. In the original parameterization of the model, these initial recruitments and the vector of initial numbers-at-age result in creating $(N + A - 1)$ scaling parameters. To reduce the potential confounding with other global scaling parameters, updates to the model code include estimation of two recruitment scaling parameters, and two vectors that represent deviations from the mean. This modification reduces the potential for parameter confounding among the many parameters that affect global scaling (i.e., catchability coefficients, natural mortality rates, average recruitment or unfished biomass).

4.5.1 Initial state variables.

In this routine, the objective is to set the initial values for the numbers-at-age matrix $N_{i,j}$. Specifically, the row dimensions of the matrix are from the start year to the terminal year + 1, the column dimensions are the ages. This routine first calculates the survivorship to age j based on natural mortality rates, then initializes the first row of $N_{i,j}$ matrix using the average initial recruitment and deviations around that average recruitment multiplied by the survivorship at age j. The source code also includes the Taylor series for the plus group:

```
FUNCTION void initializeStateVariables()
  /**
    - Set initial values for numbers-at-age matrix in first year
      and sage recruits for all years.
    */
  Nij.initialize();

  // initialize first row of numbers-at-age matrix
  // lx is a vector of survivorship (probability of surviving to age j)
  dvar_vector lx(sage,nage);

  for(int j = sage; j <= nage; j++){

    lx(j) = exp(-Mij(mod_syr,j)*(j-sage));
    if( j==nage ) lx(j) /= (1.0-exp(-Mij(mod_syr,j)));


    if( j > sage ){
      Nij(mod_syr)(j) = mfexp(log_rinit + log_rinit_devs(j)) * lx(j);
    }
  }
```

```
// iniitialize first column of numbers-at-age matrix
for(int i = mod_syr; i <= mod_nyr + 1; i++){
  Nij(i,sage) = mfexp(log_rbar + log_rbar_devs(i));
}
```

The survivorship calculation `lx` corresponds to (T2.2) in Table 2, and the numbers-at-age in the initial year and age-3 recruits corresponds to (T2.3) and (T2.4), respectively.

4.5.2 Update state variables

In this routine, the numbers-at-age are propagated in time, where the-age specific survival rate is partitioned into two periods: a fishing period, and a period of natural mortality. The ASA model currently in use for Sitka Sound herring assumes a pulse fishery. At the start of each time step, the model first calculates the predicted catch-at-age in numbers in year i. This is done by first converting the catch-in-weight to catch-in-numbers using the predicted average weight of the catch. This corresponds to the `wbar` variable in the following code chunk (note the dependency on predicted proportions-at-age):

```
FUNCTION void updateStateVariables()
  /**
  - Update the numbers-at-age conditional on the catch-at-age.
  - Assume a pulse fishery.
  - step 1 calculate a vector of vulnerable-numbers-at-age
  - step 2 calculate vulnerable proportions-at-age.
  - step 3 calc average weight of catch (wbar) conditional on Qij.
  - step 4 calc catch-at-age | catch in biomass Cij = Ct/wbar * Qij.
  - step 5 condition on Ft or else condition on observed catch.
  - step 6 update numbers-at-age (using a very dangerous difference eqn.)

  Nov 30, 2016
  - added options for simulation model:
    - b_simulation_flag is true, then condition model on catch & S-R curve.

  */

  Qij.initialize();
  Cij.initialize();
  Pij.initialize();
  dvariable wbar;   // average weight of the catch.
  dvar_vector vj(sage,nage);
  //dvar_vector pj(sage,nage);
  dvar_vector sj(sage,nage);


  for(int i = mod_syr; i <= mod_nyr; i++){
```

```
    // step 1.
    vj = elem_prod(Nij(i),Sij(i));

    // step 2.
    Qij(i) = vj / sum(vj);

    // ADF&G's approach.
    if( !dMiscCont(2) ) {
      // step 3.
      dvector wa = data_cm_waa(i)(sage,nage);
      wbar = wa * Qij(i);

      // step 4.
      Cij(i) = data_catch(i,2) / wbar * Qij(i);
      // should use posfun here
      Pij(i) = posfun(Nij(i) - Cij(i),0.01,fpen);

      // step 6. update numbers at age
      sj = mfexp(-Mij(i));
      Nij(i+1)(sage+1,nage) =++ elem_prod(Pij(i)(sage,nage-1),
                                          sj(sage,nage-1));
      Nij(i+1)(nage) += Pij(i,nage) * sj(nage);
    }
    // step 5.
    // Condition on Ft
    else {
      // add flexibility here for Popes approx, or different seasons
      Pij(i) = elem_prod( Nij(i), exp(-Fij(i)) );
      Cij(i) = elem_prod( Nij(i), 1.-exp(-Fij(i)));

      // the following assumes fishery is at the start of the year.
      dvar_vector zi = Mij(i) + Fij(i);
      Nij(i+1)(sage+1,nage) = ++ elem_prod(Nij(i)(sage,nage-1),
                                           mfexp(-zi(sage,nage-1)));
      Nij(i+1)(nage) += Nij(i,nage) * mfexp(-zi(nage));
    }
  }
```

Once the catch-at-age data is calculated, the pulse fishery proceeds by subtracting the C_{ij} from the $N_{i,j}$. The last two steps correspond to step 4 in the annotated code chunk. The last steps the survive the remaining numbers-at-age using the natural mortality rate in year i. Then finally, update the numbers-at-age j to $j+1$ in year i to year $i+1$, including the plus group for the terminal age-group.

4.5.3 Stock-recruitment & Spawning stock biomass

The spawning stock biomass (after roe-fishery removal) is the product of the remaining numbers-at-age, the maturity-at-age, and the weight-at-age from spawn samples. The equation is defined in (T2.10) in Table 2. Note that the lag between spawning biomass and age-3 recruits is taken into account.

The stock recruitment relationship assumes that recruitment follows a Ricker type. The form of the Ricker model is as follows

$$R_i = s_o B_i \exp(-\beta B_i + \epsilon_i)$$

where the parameter s_o is the slope at the origin (or maximum number of recruits per spawning unit), and β defines slope of $\ln(R_i/B_i)$ versus the independent variable B_i. These two parameters are derived from the leading parameters the unfished recruitment R_0 and the steepness of the stock recruitment relationship as defined by (Mace and Doonan, 1988).

The source code for the stock-recruitment relationship is well annotated and describes some of the derivations:

```
FUNCTION void calcSpawningStockRecruitment()
  /**
  The functional form of the stock recruitment model follows that of a
  Ricker model, where R = so * SSB * exp(-beta * SSB).  The two parameters
  so and beta where previously estimated as free parameters in the old
  herring model.  Herein this fucntion I derive so and beta from the
  leading parameters Ro and reck; Ro is the unfished sage recruits, and reck
  is the recruitment compensation parameter, or the relative improvement in
  juvenile survival rates as the spawning stock SSB tends to 0. Simply a
  multiple of the replacement line Ro/Bo.

  At issue here is time varying maturity and time-varying natural mortality.
  When either of these two variables are assumed to change over time, then
  the underlying stock recruitment relationship will also change. This
  results in a non-stationary distribution.  For the purposes of this
  assessment model, I use the average mortality and maturity schedules to
  derive the spawning boimass per recruit, which is ultimately used in
  deriving the parameters for the stock recruitment relationship.
    */

  /*
    Spoke to Sherri about this. Agreed to change the equation to prevent
    substracting immature fish from the numbers before calculating SSB.
  */
  for(int i = mod_syr; i <= mod_nyr; i++){
    //Oij(i) = elem_prod(mat(i),Nij(i));
    //ssb(i) = (Oij(i) - Cij(i)) * data_sp_waa(i)(sage,nage);

    Oij(i) = elem_prod(mat(i),Nij(i)-Cij(i));
    ssb(i) = Oij(i) * data_sp_waa(i)(sage,nage);
  }


  // average natural mortality
  dvar_vector mbar(sage,nage);
  int n = Mij.rowmax() - Mij.rowmin() + 1;
  mbar  = colsum(Mij)/n;

  // average maturity
```

```
  dvar_vector mat_bar(sage,nage);
  mat_bar = colsum(mat)/n;


  // unfished spawning biomass per recruit
  dvar_vector lx(sage,nage);
  lx(sage) = 1.0;
  for(int j = sage + 1; j <= nage; j++){
    lx(j) = lx(j-1) * mfexp(-mbar(j-1));
    if(j == nage){
      lx(j) /= 1.0 - mfexp(-mbar(j));
    }
  }
  dvariable phie = lx * elem_prod(avg_sp_waa,mat_bar);

  // Ricker stock-recruitment function
  // so = reck/phiE; where reck > 1.0
  // beta = log(reck)/(ro * phiE)

  // Beverton Holt use:
  // beta = (reck - 1.0)/(ro *phiE)
  ro   = mfexp(log_ro);
  reck = mfexp(log_reck) + 1.0;
  so   = reck/phie;
  beta = log(reck) / (ro * phie);

  spawners = ssb(mod_syr,mod_nyr-sage+1).shift(rec_syr);
  recruits = elem_prod( so*spawners , mfexp(-beta*spawners) );
  resd_rec = log(column(Nij,sage)(rec_syr,mod_nyr+1)+TINY)
           - log(recruits+TINY);
```

There is an issue with regards to calculating reference points in cases where there is non-stationarity (i.e., any time varying parameters such as natural mortality, maturity etc.). At what period should be used to define the average weight-at-age for spawning herring? What period should be used for calculating the average maturity? All of these are subjective decisions, and based on my experience will have little impact on the overall fit to the data, but could have major implications for harvest policy changes.

4.6 Observation models

4.6.1 Age composition

The predicted age-composition is based on the vulnerable proportions at age $Q_{i,j}$ in (T2.5). The residual difference is used to compute the negative log likelihood in the objective function. The code for the age composition residual calculation is as follows:

```
FUNCTION void calcAgeCompResiduals()
  /**
  - Commercial catch-age comp residuals
  - Spawning survey catch-age comp residuals.
```

```
*/

resd_cm_comp.initialize();
resd_sp_comp.initialize();
for(int i = mod_syr; i <= mod_nyr; i++){

  // commercial age-comp prediction
  pred_cm_comp(i) = Qij(i);
  if( data_cm_comp(i,sage) >= 0 ){
    resd_cm_comp(i) = data_cm_comp(i)(sage,nage) - pred_cm_comp(i);
  }

  // spawning age-comp prediction
  pred_sp_comp(i) = (Oij(i)+TINY) / sum(Oij(i)+TINY);
  if( data_sp_comp(i,sage) >= 0 ){
    resd_sp_comp(i) = data_sp_comp(i)(sage,nage) - pred_sp_comp(i);
  }
}
```

Note that both the residual difference between the commercial and spawning samples are calculated in this routine. If there are missing data for a given year (denoted by a -9.0 in the data file), then the residual difference is set to 0 for that year and there is no contribution to the negative log likelihood.

4.6.2 Egg deposition

The observation model for the egg deposition data treats these observations as estimates of absolute abundance. Therefore, there is no associated scaling parameter that is estimated. The observation errors in the egg deposition data are assumed to be log-normal. The predicted age-deposition data is based on the female (assuming a 50:50 sex ratio) mature numbers-at-age multiplied by the fecundity at age. The annotated source code is as follows:

```
FUNCTION void calcEggSurveyResiduals()
  /**
  - Observed egg data is in trillions of eggs
  - Predicted eggs is the mature female numbers-at-age multiplied
    by the fecundity-at-age, which comes from a regession of
    fecundity = slope * obs_sp_waa - intercept
  - Note Eij is the Fecundity-at-age j in year i.
  -
  */
  resd_egg_dep.initialize();
  for(int i = mod_syr; i <= mod_nyr; i++){
    pred_egg_dep(i) = (0.5 * Oij(i)) * Eij(i);
    if(data_egg_dep(i,2) > 0){
      resd_egg_dep(i) = log(data_egg_dep(i,2)) - log(pred_egg_dep(i));
    }
  }
```

4.6.3 Aerial surveys

The aerial survey index, or mile milt days, are treated as relative abundance data. The underlying assumption in this observation model is that the observation errors are log normal, and that the index is proportional to the spawning stock biomass. Note that the code does not estimate the coefficient, rather the conditional maximum likelihood estimate of the scaling coefficent is used (see Walters and Ludwig, 1994, for a full explanation). The annotated code follows:

```
FUNCTION void calcMiledaySurveyResiduals()
  /**
  - Assumed index from aerial survey is a relative abundance
  index. The slope of the regression ln(SSB) = q * ln(MileMilt) + 0
  is computed on the fly in case of missing data.
  - See Walters and Ludwig 1994 for more details.
  */
  resd_mileday.initialize();
  pred_mileday.initialize();
  int n = 1;
  dvar_vector zt(mod_syr,mod_nyr); zt.initialize();
  dvariable zbar = 0;
  for(int i = mod_syr; i <= mod_nyr; i++){
    if(data_mileday(i,2) > 0){
      zt(i) = log(data_mileday(i,2)) - log(ssb(i));
      zbar  = zt(i)/n + zbar *(n-1)/n;
      n++ ;
    }
  }
  pred_mileday = ssb * exp(zbar);
  resd_mileday = zt - zbar;
```

4.6.4 Predicted catch

In the case where the model is conditioned on effort and fitted to the catch time series data, the predicted catch is the sum of products between the catch-at-age in numbers and the observed weight-at-age in the commercial fishery. We further assume observation errors are log-normal. The source code follows:

```
FUNCTION void calcCatchResiduals()
  /**
  - Catch residuals assuming a lognormal error structure.
  */
  pred_catch.initialize();
  resd_catch.initialize();
  for(int i = mod_syr; i <= mod_nyr; i++) {
    if(data_catch(i,2) > 0) {
      pred_catch(i) = Cij(i) * data_cm_waa(i)(sage,nage);
      resd_catch(i) = log(data_catch(i,2)) - log(pred_catch(i));
    }
  }
```

4.7 Objective function

The objective function is organized into two sections, the first contains the negative log-likelihoods for the data given the model parameters. The second are a series of penalties, in the case of maximum likelihood estimation, prior density functions in the case of a Bayesian estimation.

4.7.1 Negative log-likelihoods

The negative log-likelihoods There are five 6 negative log-likelihoods functions in the objective function that correspond to the 5 different data elements and the residual process errors associated with a stock-recruitment relationship. Table 3 summarizes the available options currently implemented.

The source code for the negative loglikelihoods follows:

```
// 1. Negative loglikelihoods
nll.initialize();

// Mulitvariate logistic likelihood for composition data.
double sp_tau2;
double minp = 0.00;
int t1 = mod_syr;
int t2 = mod_nyr;
dmatrix d_sp_comp = trans(trans(data_sp_comp).sub(sage,nage)).sub(t1,t2);
nll(1) = dmvlogistic(d_sp_comp,pred_sp_comp,resd_sp_comp,sp_tau2,minp);

// Mulitvariate logistic likelihood for composition data.
double cm_tau2;
dmatrix d_cm_comp  = trans(trans(data_cm_comp).sub(sage,nage)).sub(t1,t2);
nll(2) = dmvlogistic(d_cm_comp,pred_cm_comp,resd_cm_comp,cm_tau2,minp);

// Negative loglikelihood for egg deposition data
dvector std_egg_dep = TINY + column(data_egg_dep,3)(t1,t2);
nll(3) = dnorm(resd_egg_dep,std_egg_dep);

// Negative loglikelihood for milt mile day
dvector std_mileday = TINY + column(data_mileday,3)(t1,t2);
nll(4) = dnorm(resd_mileday,std_mileday);

// Negative loglikelihood for stock-recruitment data
dvariable std_rec = log_sigma_r;
nll(5) = dnorm(resd_rec,std_rec);

// Negative loglikelihood for catch data
dvector std_catch = column(data_catch,3)(t1,t2);
nll(6) = dnorm(resd_catch,std_catch);
```

For the composition data, the multivariate logistic likelihood is currently implemented, as this is a self-scaling likelihood. A good reference for this particular likelihood and how it's implemented in AD Model Builder can be found in Schnute and Richards (1995). More recent work on the weighting of composition data is available in Francis (2011). The function `dmvlogistic` requires 5 arguments: the observed and predicted composition matrices, a matrix for returning the residuals, a variable for the conditional MLE of the variance of the observation errors, and a threshold value called `minp`. The multivariate logistic likelihood does not accommodate 0 observations for age proportions. Therefore there are two options for dealing with 0s: 1) add a small constant to all observed and predicted observations and re-normalize, or 2) pool the adjacent cohorts if the observed proportion is less than some minimum observed proportion. The first option is widely used in programs such as stock synthesis, and is akin to manufacturing data. If a particular cohort is relatively weak, and only partially selected, the sample size required to observe just one individual of a certain age in a given year could be infinitely large. Instead of adding a constant, option 2 pools the data such that the likelihood of ages, for example, 3-4 are evaluated jointly, rather than the likelihood of age-3 plus the likelihood of age-4. This pooling of the data and predictions does not require the addition of a constant that could potentially bias the result. A good practice that I've found is to just set `minp=0`, and then conduct sensitivity tests using where proportions less than 1% or 2% etc are pooled into the adjacent cohort.

In the case of the likelihoods for the egg deposition index, aerial surveys, and catch data, the function `dnorm` is used, where the arguments are the vector of residuals, and a vector of standard-deviations for each observation. Note that you can effectively turn individual years of data off by setting the `log.se` value to a large number (e.g., 5.0).

The current version of the source code will estimate an annual fishing mortality rate for each year (when the model is conditioned on effort only). This can become problematic in the case where the catch is 0 for a particular year. A technical point in cases where the catch is 0. In this case the MLE for the fishing mortality rate is also 0, but the derivative is undefined because the observed standard deviation is also 0. In such cases, estimates of the standard error for the fishing mortality rate in a year with 0 catch will be undefined. One option to explore for simulation studies (i.e., when using the -sim argument) is to modify the original data file and add a small, insignificant amount, of catch to ensure the simulation model generates some data, otherwise spurious results may occur in simulation studies.

4.7.2 Penalties

Currently the code for the penalties is as follows:

```
dmatrix d_sp_comp = trans(trans(data_sp_comp).sub(sage,nage)).sub(t1,t2);
nll(1) = dmvlogistic(d_sp_comp,pred_sp_comp,resd_sp_comp,sp_tau2,minp);

// Mulitvariate logistic likelihood for composition data.
double cm_tau2;
dmatrix d_cm_comp  = trans(trans(data_cm_comp).sub(sage,nage)).sub(t1,t2);
nll(2) = dmvlogistic(d_cm_comp,pred_cm_comp,resd_cm_comp,cm_tau2,minp);

// Negative loglikelihood for egg deposition data
dvector std_egg_dep = TINY + column(data_egg_dep,3)(t1,t2);
nll(3) = dnorm(resd_egg_dep,std_egg_dep);
```

```
// Negative loglikelihood for milt mile day
dvector std_mileday = TINY + column(data_mileday,3)(t1,t2);
nll(4) = dnorm(resd_mileday,std_mileday);

// Negative loglikelihood for stock-recruitment data
dvariable std_rec = log_sigma_r;
```

The penalties are implemented in a phased approach, where in the initial phases of parameter estimation, the penalties initially have small standard deviations. This increases the overall efficiency of the non-linear search routine to help resolve the overall scaling. Then in the terminal phase, these penalties are relaxed (increased variance) such that they provide little or no influence on the gradient structure. A similar strategy is also used with the recruitment deviation parameters.

5 Simulation example

Built into the assessment model code is a command line option that conducts a simulation experiment. In this experiment, the input parameter values are known, and simulated observations are generated with known error distributions. The model then proceeds to estimate the model parameters using built-in optimization procedures. Any potential biases can be detected by comparing the estimated values with the true values. This is best done using a Monte Carlo experiment where the distributions of estimated parameters are compared with the true values used in simulating the data.

For this simulation example, the data from the Sitka herring stock will be used. I first fit the model to the Sitka data to obtain the following parameter input file. Next, save this file as `ham.pin`, and by default the model will read these parameters when the application is first initialized. These parameters saved in the `ham.pin` file can be modified to specific values defined by the user.

```
# Number of parameters = 106  Objective function value = -1067.91  Maximum gradient component =
    0.000146673
# theta[1]:
-0.503402545573
# theta[2]:
4.19024390238
# theta[3]:
5.65105702886
# theta[4]:
6.34259911617
# theta[5]:
1.28108178211
# theta[6]:
0.614742804759
# log_rinit_devs:
 -0.369099857438 0.0432573918353 -0.232452148129 0.450637740947 0.107656872785
# log_rbar_devs:
 -1.71838525570 -1.67116045858 -0.785130704400 -2.32065685005 -2.43830223672 -3.16312286545 -1.59961940954
      -0.183637375474 1.32240176081 -0.137209104183 -1.28834862444 -0.411898580727 1.04415812632
     0.262636124152 -1.13914483251 -0.0891842359559 1.80064719129 -0.255869889506 -1.74476380697
     -1.03396568671 1.88568689495 -0.546576451091 -1.48967523844 -0.994032025259 0.524164900236
     0.347541168834 1.14799261913 1.19578236045 -0.221319825319 0.862572980916 1.10468337111
     0.751162194596 2.06816736234 0.159887259205 0.751872098920 0.987472284687 1.40415756341 1.64452226242
      1.40874746193 1.41059964860 0.330241657355 -0.0165228217769 1.04703009587 -1.94748796339
     1.22905663405 0.504830220587
# mat_params[1]:
 4.50000000000 7.00000000000
# log_m_devs:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# log_slx_pars[1]:
 1.09861228867 -0.693147180560
# log_slx_pars[2]:
```

```
 1.50743640058  -0.331659075481
# log_slx_pars[3]:
 1.77240606047  0.0107003869354
# log_ft_pars:
 -2.98070476911  -3.11738199477  -3.11884859564  -3.03984330553  -1.82381258039  -2.08980608571  -8.91395057202
     -4.69390362291  -3.29132526822  -2.76846814111  -2.71491299020  -2.30490013629  -2.16575297377
     -2.17788654497  -1.92424610026  -2.10886395022  -2.54065392177  -1.84657016221  -1.51265689328
     -2.50451696325  -3.26161715876  -2.52673542945  -1.85876833453  -2.47927928999  -2.90263367564
     -1.68711715035  -1.73349724696  -2.41633464261  -2.21695495405  -2.99506697086  -1.90955934394
     -2.10428618377  -2.71340347735  -2.38404572145  -2.38594313472  -2.52440253674  -2.37870137084
     -2.19838420627  -2.25348830854  -2.09952696950  -2.00882977224  -2.15518189265  -3.04941561245
     -1.69527908160  -2.08737142634
```

Next, run the model using the `-sim` flag using the number 1 as the random number seed. At the command line you can run:

```
./ham -sim 1
```

When you execute the above command, the following sequence summarizes the events that occur inside the simulation model:

1. Set random number seed for random variables.
2. Read in the model data.
3. Read in the initial parameter values from `ham.par`.
4. Run the simulation model:
   (a) Call the population dynamics subroutines.
   (b) Call the observation models to generate predicted observations.
   (c) Add random errors to the simulated observations.
   (d) Overwrite the input data in memory with the simulated data.
5. After the simulated data has been created, the model proceeds with its normal routines for conducting parameter estimation.
6. Simulated observations are printed to the report file.
7. Estimated parameters in the `ham.par` file should be comparable with the true parameter (`ham.pin`) values that were used in generating the simulated data.

This approach to simulation-estimation is called "self-testing" where both the same model is used to generate the data, as well as, in fitting the model to data. Arguably, this approach should generate exact parameter estimates in the case where data are generated with no simulated observation errors.

5.1 Observation error

For the purposes of demonstration, Figure 5.1 shows the results of conditioning the simulation model on the Stika herring data. In these simulation-estimation experiments, all of the simulations were conditioned on the same fishing mortality rates and recruitment vectors that were estimated from fitting the model to the Sitka data. The only difference between the 8 simulation models are the random numbers in the observation errors.

The simple test should result in estimates of spawning stock biomass and fishing mortality rates that fall within the 95% confidence interval that was used to generate the data. The results in Figures 5.1 and 5.1 indicate that this is in fact the case.

5.2 Mixed error

In a mixed error model, the model includes process errors in the form of deviations from average recruitment, and these are drawn from a normal distribution with a mean 0 and standard deviation equal to σ_R. When conducting simulations of this type, the model is conditioned on the instantaneous fishing mortality rates that are specified in the parameter input file (`ham.pin`) if the file exists in the current working directory. If a parameter input file does not exist, then the initial values specified in the control file are used for the leading model parameters and the annual instantaneous fishing mortality rates are set at a default value of 0.2 each year.

It's important to note here that the scaling parameters (initial recruitment and average recruitment) are sufficiently large such that the population is not driven to extinction based on the initial parameter values. Moreover, the current iteration of the simulation model generates recruits from an average recruitment and log-normal deviations. As such, the simulated data are not informative about the underlying stock-recruitment relationship. Additional modifications should be made to the simulation model, where the expected value of recruitment in each simulation year is a function of R_0 and the steepness (or slope at the origin) of the stock-recruitment relationship.

No mixed error simulations are shown in this technical document, but the same procedure as outlined in section 5.1 is used to conduct the simulation experiments.

6 Example Assessment: Sitka herring

For this example, the data from the Sitka herring stock were used in this assessment. This example is just that, an example. This is not intended to be used for any decision making purposes.

6.1 Input data

The catch data shown in Figure 3 are shown with the estimated 95% confidence intervals associated with the log standard error associated in the input data file. For this example the assessment model is conditioned on effort, which simply means a vector of fishing mortality rates are estimated by fitting the model to the observed catch. The previous assessment simply subtracted the catch, which implies the catch is known and assumed to have no measurement error.

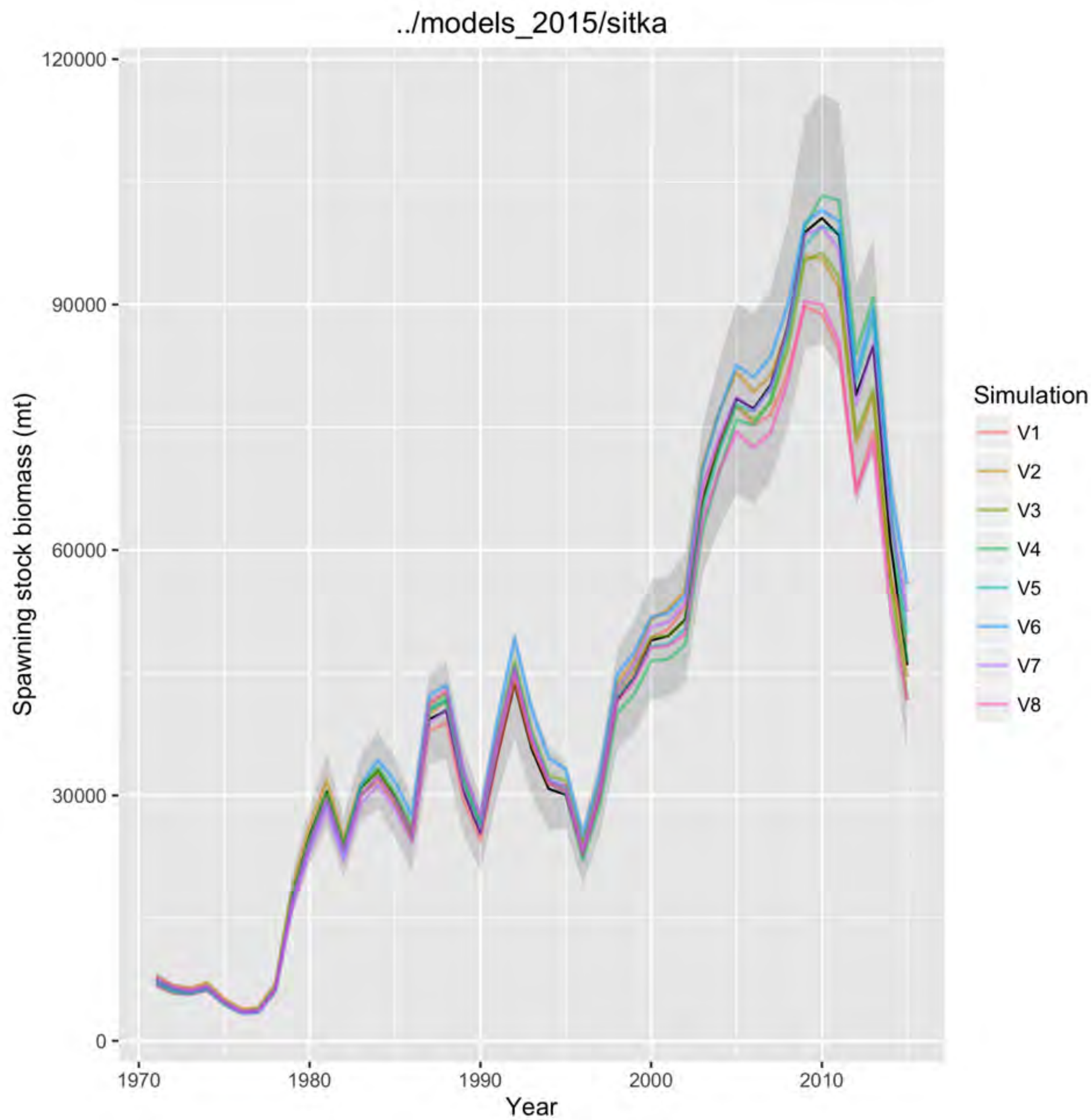

Figure 1: Estimates of spawning stock biomass where only the observation errors differ among simulations. Shaded region corresponds to the 95% credible interval for the true distribution of spawning biomass, and the colored lines correspond to estimates based on simulated observations in the egg survey and catch-age sampling.

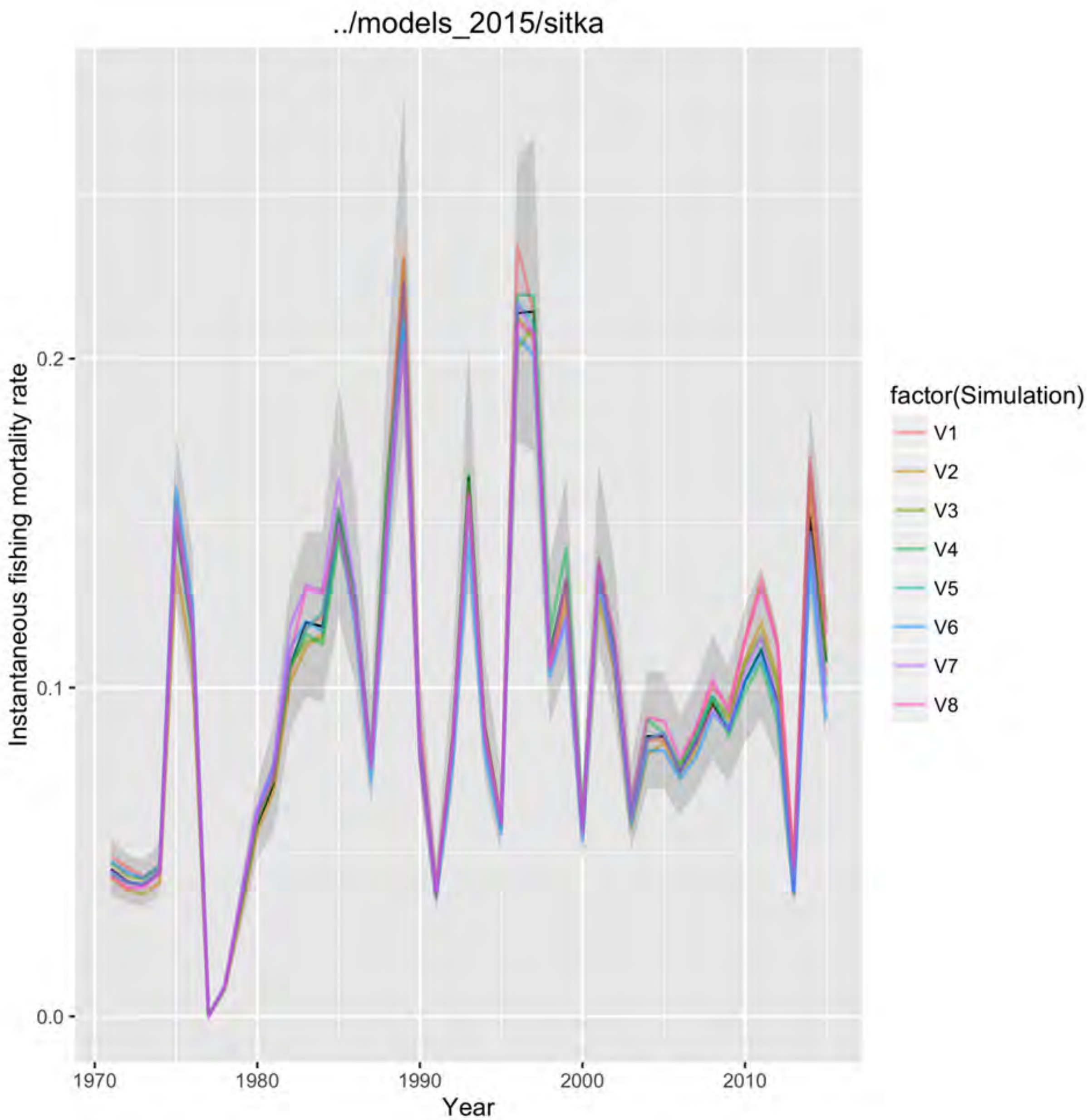

Figure 2: Estimates of the instantaneous fishing mortality rates where the only observation errors differ among simulations. Shaded region corresponds to the 95% credible interval for the true distribution of fishing mortality, and the colored lines correspond to estimates based on simulated observations in the egg survey and catch-age sampling.

The primary index for fitting this model is the survey egg deposition data. The time series for the Sitka herring stock is shown in Figure 4 and are plotted on a logarithmic scale. There has been nearly a 10-fold increase in this index between 1970's and the 2010's. Note that the model assumes a 50:50 sex ratio, and the data are scaled in trillions of eggs, assuming the catch is in metric tons.

The empirical weight-at-age data for the spawn survey are shown in Figure 5). The commercial weight-at-age data are shown in Figure 6. These are user input data and are used to convert numbers-at-age to weight-at-age.

Figures 7 and 8 are bubble plots showing the proportions-at-age in the age-composition data for the spawn survey samples and the commercial samples, respectively. Each distinct color represents a specific cohort over time, and the area of each circle is proportional to abundance.

Table 2: Notation and equations for population dynamics model.

Model parameters

$$\theta = \{\ln(M), \ln(\bar{R}), \ln(\ddot{R}), \ln(\alpha), \ln(\beta), \vec{\delta}\} \quad \text{(T2.1)}$$

Initial States ($i = 1980$)

$$\iota_j = \begin{cases} \exp(-M * (j - \min(j))) & \text{where } 3 \le j \le 7 \\ \dfrac{\exp(-M * (j - \min(j)))}{1 - \exp(-M)} & \text{where } j = 8 \end{cases} \quad \text{survivorship} \quad \text{(T2.2)}$$

$$N_{i,j} = \ddot{R} \exp(\delta_{i-j}) \iota_j \qquad i = 1980, \forall j \quad \text{initial numbers-at-age} \quad \text{(T2.3)}$$

$$N_{i,j} = \bar{R} \exp(\delta_i) \qquad \forall i, j = 3 \quad \text{age-3 recruits} \quad \text{(T2.4)}$$

Dynamic States ($i > 1980$)

$$Q_{i,j} = \frac{N_{i,j} S_{i,j}}{\sum_j N_{i,j} S_{i,j}} \quad \text{vulnerable proportions} \quad \text{(T2.5)}$$

$$\bar{w}_i = \sum_j w_j Q_{i,j} \quad \text{average weight of catch} \quad \text{(T2.6)}$$

$$C_{i,j} = \frac{\hat{c}_i Q_{i,j}}{\bar{w}_i} \qquad \text{where } \hat{c}_i \text{ is the observed catch (mt)} \quad C_{i,j} \text{ catch-at-age} \quad \text{(T2.7)}$$

$$\acute{N}_{i,j} = N_{i,j} \exp(-F_{i,j}) \quad \text{(T2.8)}$$

$$N_{i+1,j+1} = \acute{N}_{i,j} \exp(-M_{i,j}) \quad \text{(T2.9)}$$

Spawning stock biomass

$$B_i = \sum_j (N_{ij} - C_{ij}) \omega_{ij} w_j \quad \text{Spawning stock biomass} \quad \text{(T2.10)}$$

Stock-recruitment

Table 3: Data and types of likelihoods implemented

Data	normal	log-normal	multivariate-logistic	multinomial
Commercial Age-comps			X	
Spawn Survey Age-comps			X	
Egg deposition		X		
Aerial survey		X		
Catch		X		
Stock-Recruitment		X		

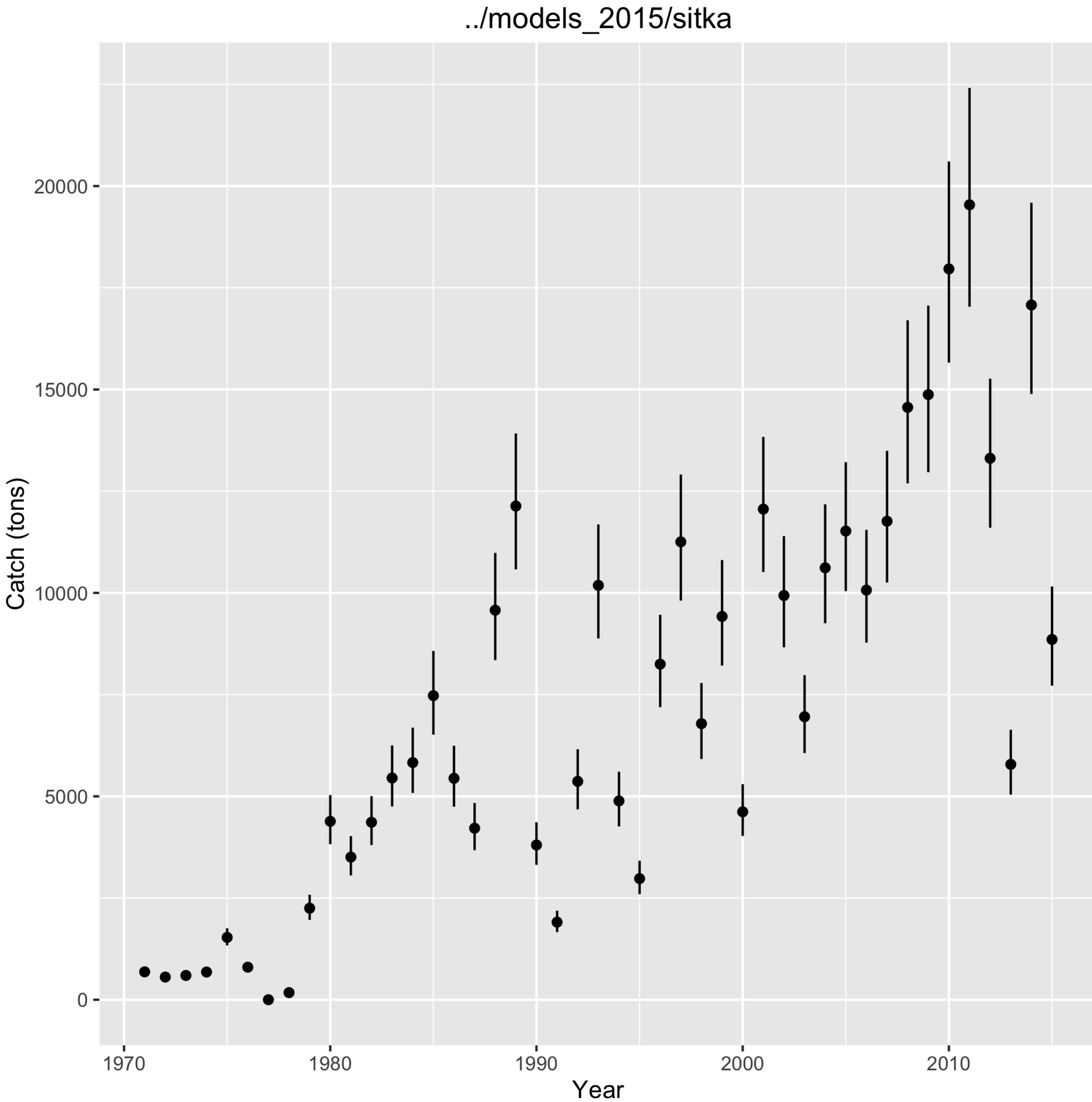

Figure 3: Herring removals from the Sitka stock. Error bars are based on the log standard error defined in the input data file.

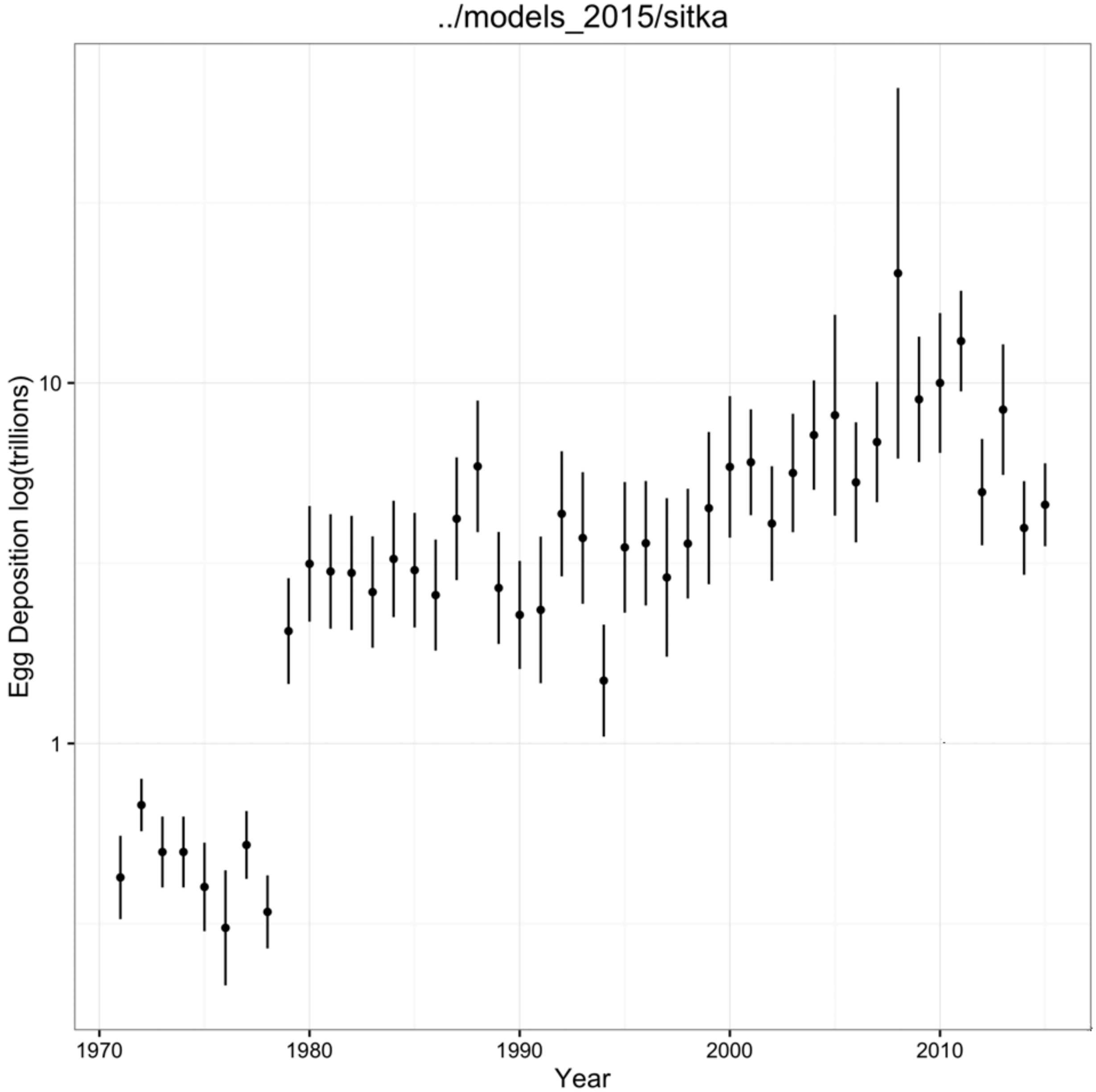

Figure 4: Egg survey index for Sitka herring. Note that these data are plotted on a log scale.

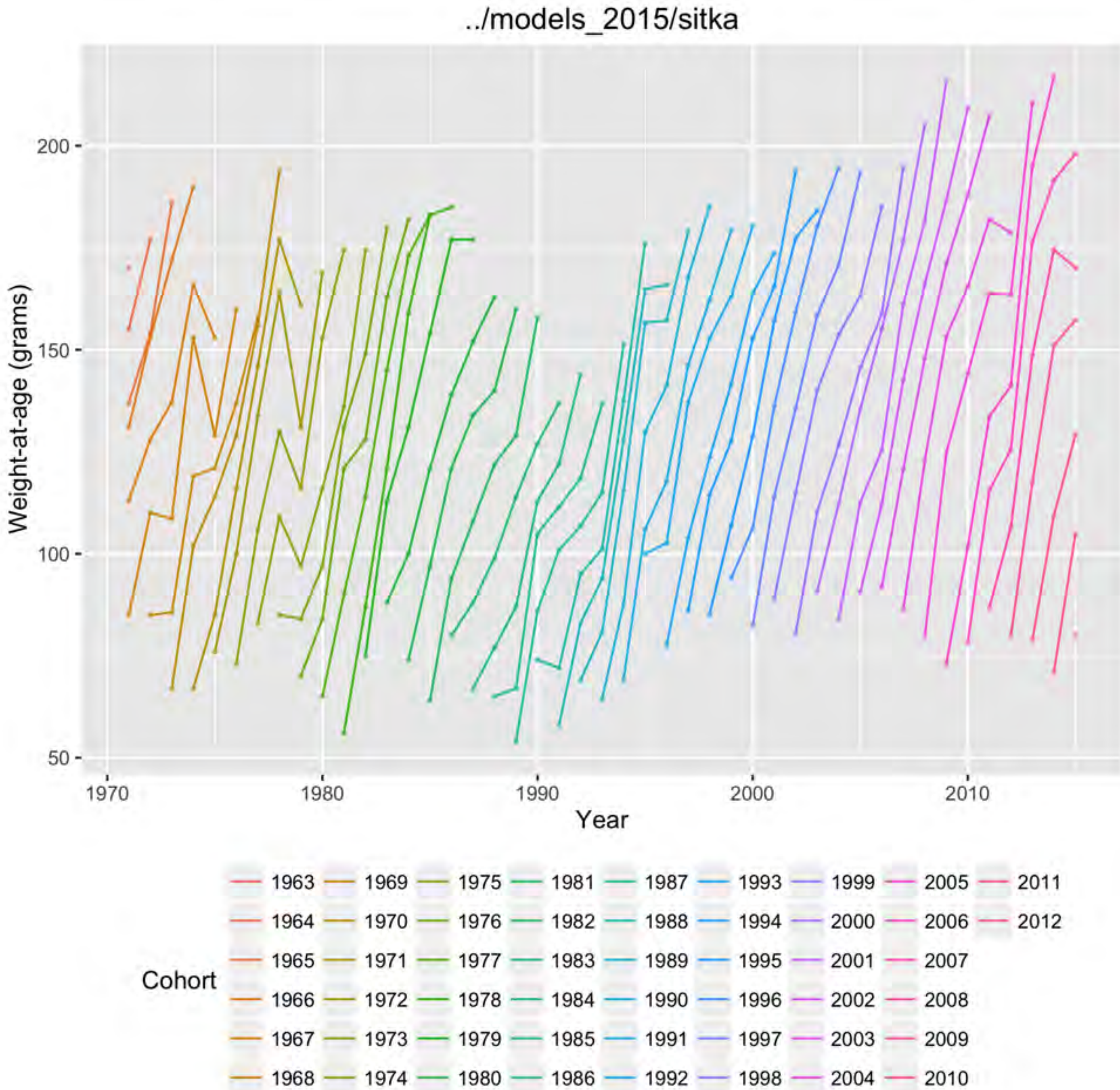

Figure 5: Empirical weight-at-age data for Sitka spawn survey.

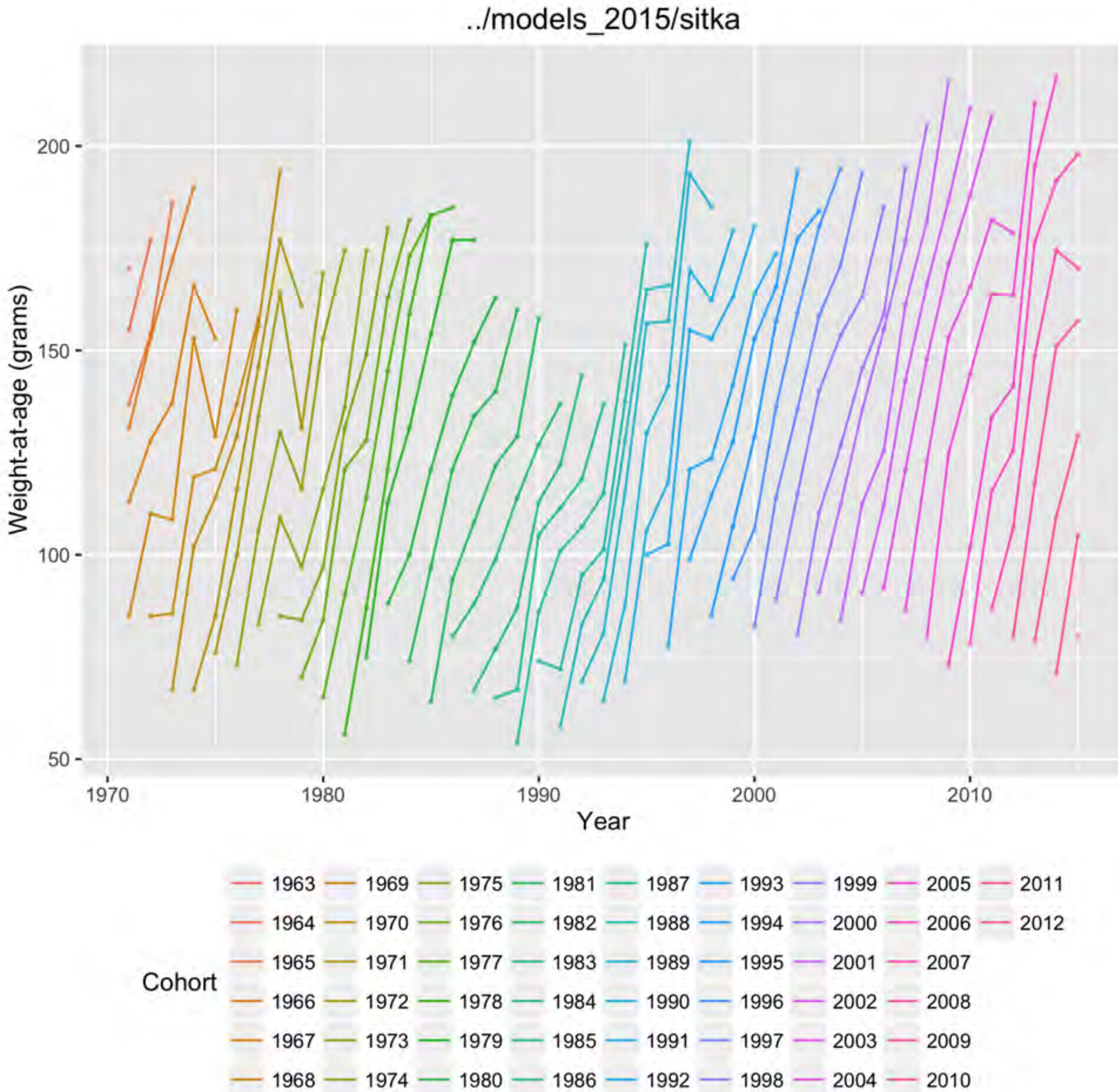

Figure 6: Empirical weight-at-age data for Sitka Commercial fishery samples.

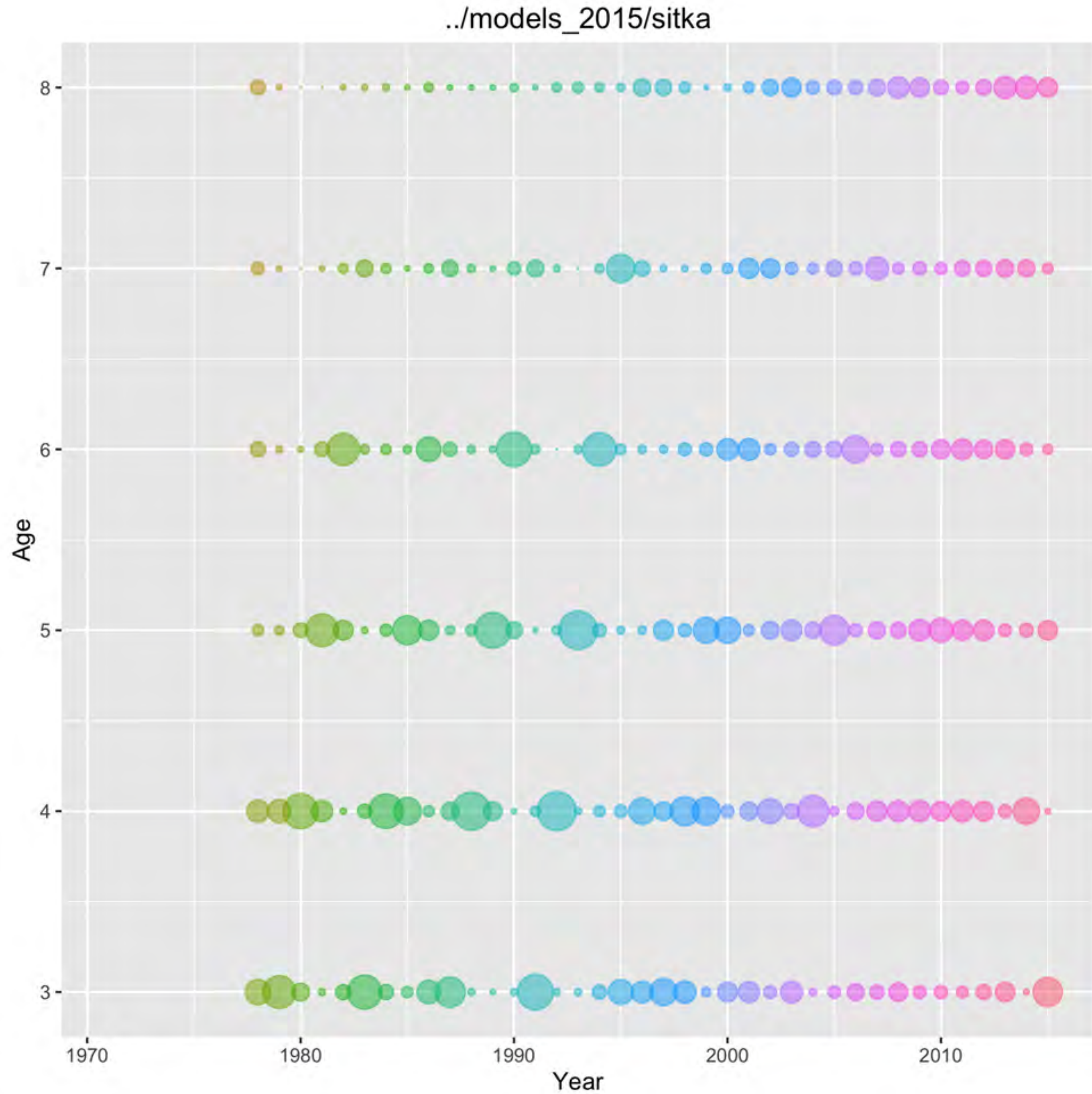

Figure 7: Age-proportions by year from the spawn survey samples.

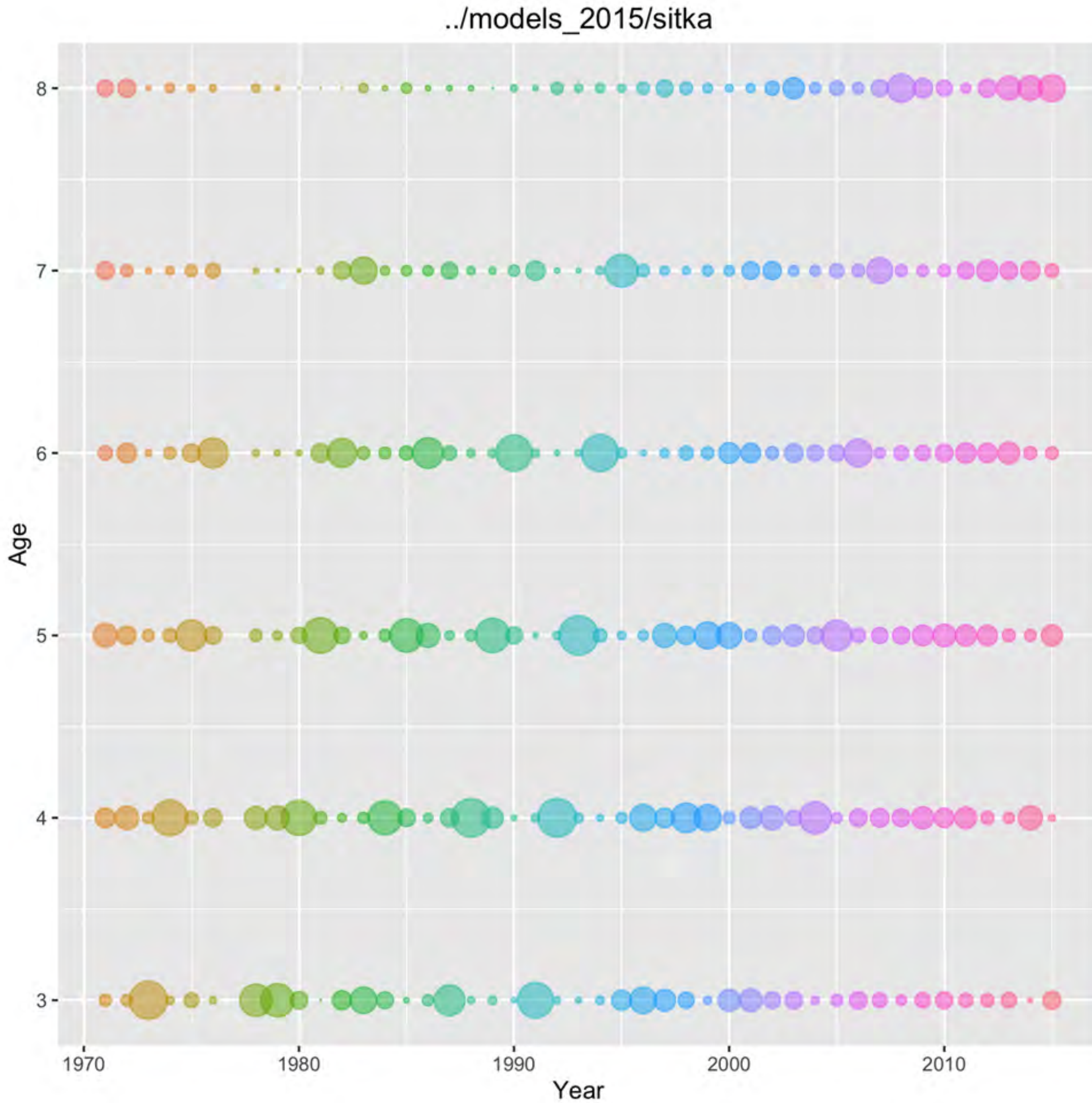

Figure 8: Age proportions by year from the commercial fishery samples.

6.2 Model outputs

Model output from the age-structured herring model are stored in a number of output files that are produced automatically by ADMB. The maximum likelihood estimates (MLE) of model parameters with standard deviations and correlations are found in the `ham.cor` file. User defined outputs are in the `ham.rep` file, and if you wish to add additional outputs that currently do not exist, these outputs can be added to the `REPORT_SECTION` of the tpl file and the code must be recompiled.

The following output figures were generated from a series of R-scripts (available on the project repository) that were developed during the course of model development.

Estimates of mature spawning stock biomass (male and female combined based on the maturity ogive) are shown in Figure 9, along with the approximate 95% confidence interval.

Estimates of the average annual instantaneous fishing mortality rates each year are shown in Figure 10. Recall that age-specific selectivity each year is scaled to have a mean value of 1.0 to ensure both parametric and non-parametric selectivity models remain continuous and differentiable. If asymptotic estimates of fishing mortality rates are desired, then the series shown in Fig. 10 is multiplied by the maximum selectivity each year.

Figure 11 compares the trends in the asymptotic fishing mortality rates versus the average fishing mortality rate. The trends in the asymptotic estimates of fishing mortality suggests that fishing mortality rates have been increasing in recent years, but this trend is associated with changes in selectivity, where younger age-classes are becoming less vulnerable to the gear. To examine this issue further you would look for changes in selectivity over time where older age-classes are more selected that younger age-classes.

Again, in this example the stock assessment model is conditioned on fishing effort. This means that a vector of annual fishing mortality rates are estimated by jointly fitting the model to the observed catch data (Figure 12). This differs significantly from the previous model version where the observed catch was assumed to be measured without error, and removed from the population using a difference equation.

The residual difference between the observed and predicted catch is shown in Figure 13. In this case the residuals appear to have a non-random pattern that emerges due to the minor differences between the trends in F associated with the catch and abundance index, and the trends in Z that are inferred from the age-composition data. Furthermore, the pattern changes from random from 1970-1979, to all negative from 1980 to 1999, and flips to positive from 2000 to 2015. These blocks also correspond to the selectivity blocks in the control file for the Sitka herring stock.

The primary information that the model is being fit to is the egg deposition index (Figure 14). The egg deposition survey data are treated as absolute abundance information. In other words there is no additional scaling parameter that is estimated for the purposes of comparing only trend information. These data provide information about population scaling, so units associated with catch, weight-at-age, and maturity, are critical.

The residuals for the egg deposition pattern are shown in Figure 15. The model is not able to fit the 1988, 1994, and 2008 survey data points (corresponding to the largest 3 residuals).

Another feature built into the assessment model is to jointly fit a stock-recruitment model to the estimated age-3 recruits and estimated spawning biomass. This could also be done outside the model, but the resulting estimates of uncertainty in reference points would be biased because uncertainty in the independent variable (spawning biomass) is not propagated. The residual fit to a Ricker stock-recruitment curve is shown in Figure 16.

Residual fits to the catch-at-age data for the spawn survey samples are shown in Figure 17. The area of each circle is proportional to the residual difference between the observed catch-at-age proportion and the predicted catch-at-age proportion. The residual patterns for the commercial age-composition proportions is shown in Figure 18. Ideally, the pattern of residuals would be completely random with respect to both age and time dimensions. Some patterns to watch out for that could be a sign of model-misspecification are blocks of residuals all of the same sign (+ve or -ve) that might be indicative of a change in behavior or a change in regulations that result in a behavioral change.

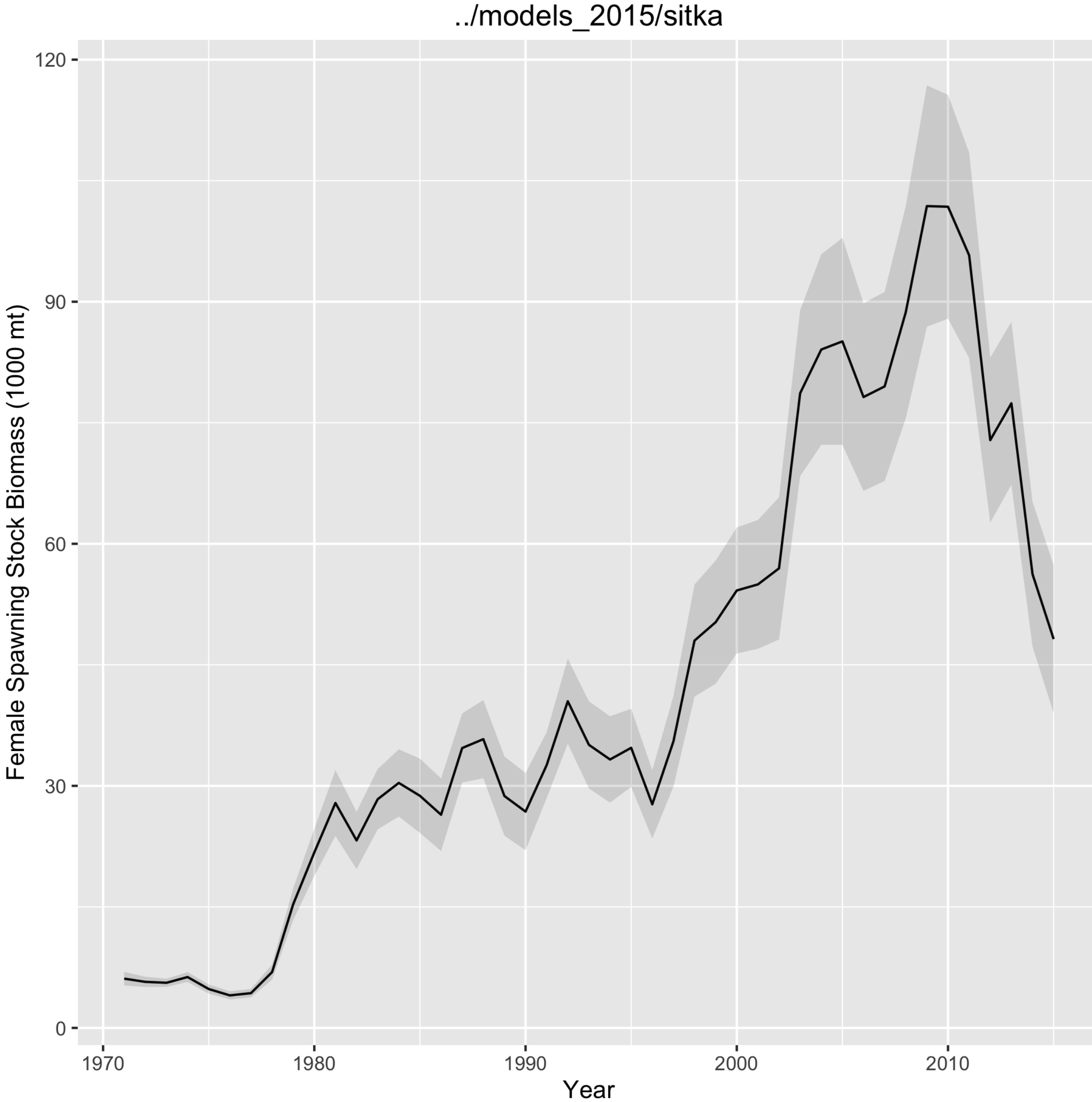

Figure 9: Estimates of mature spawning biomass at the time of spawning, (post-fishery) and the 95% confidence interval shown in the shaded region.

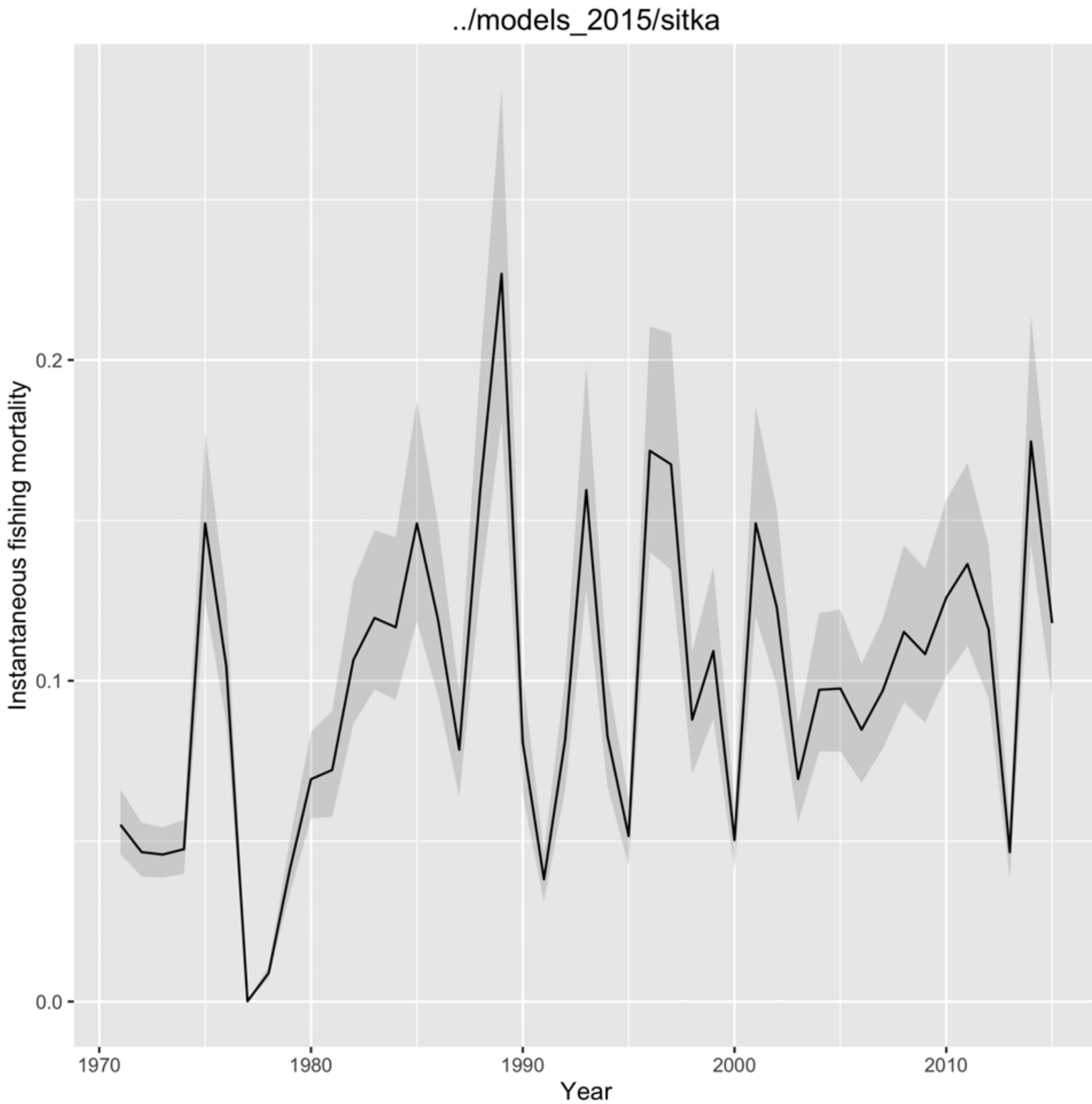

Figure 10: Estimates of the mean instantaneous fishing mortality rate with the 95% confidence interval.

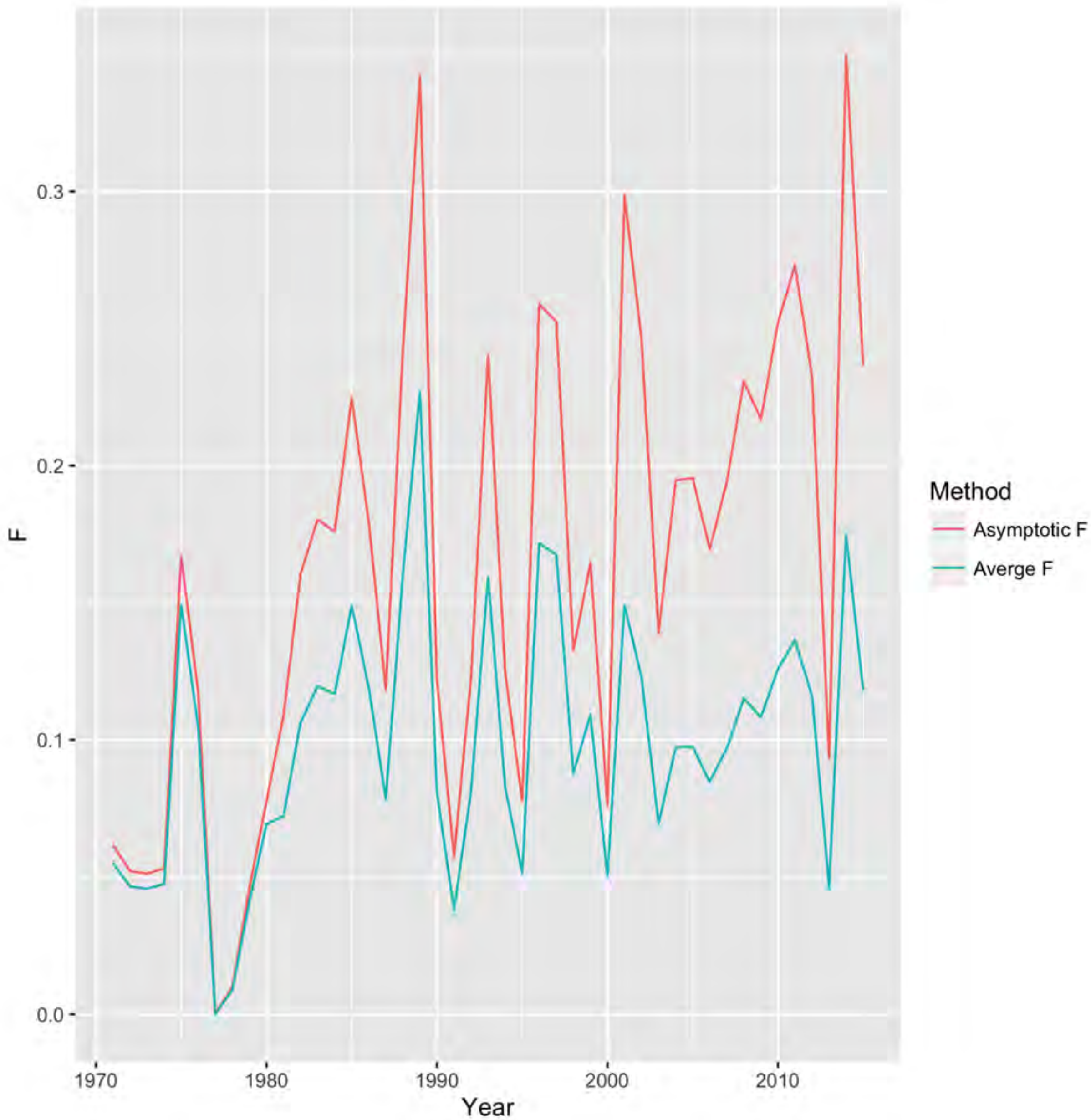

Figure 11: Trends in average age-specific fishing mortality rates versus the asymptotic trends in fishing mortality rate. The trends differ slightly due to changes in selectivity over time.

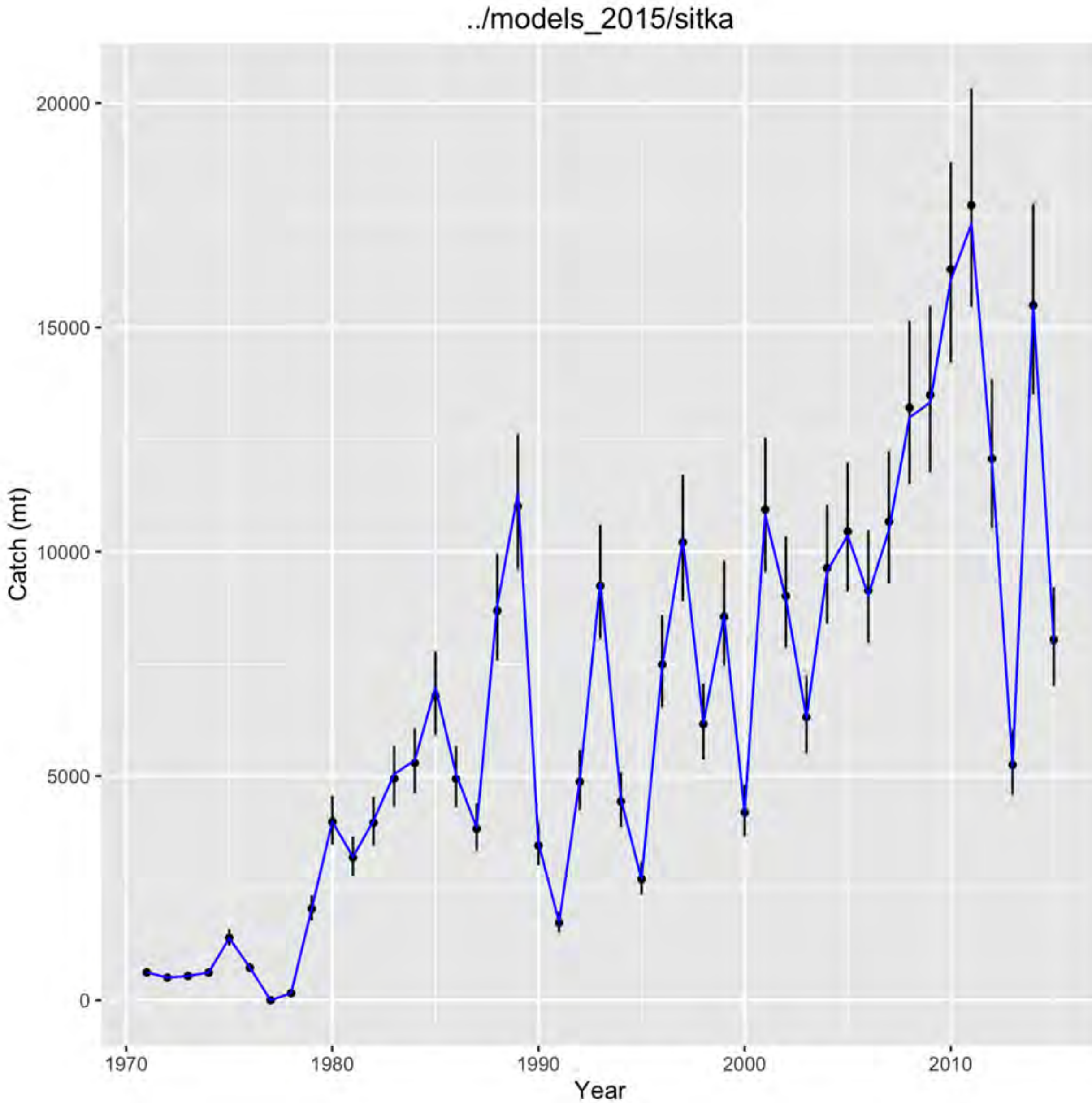

Figure 12: Observed and predicted catch in the Sitka herring fishery.

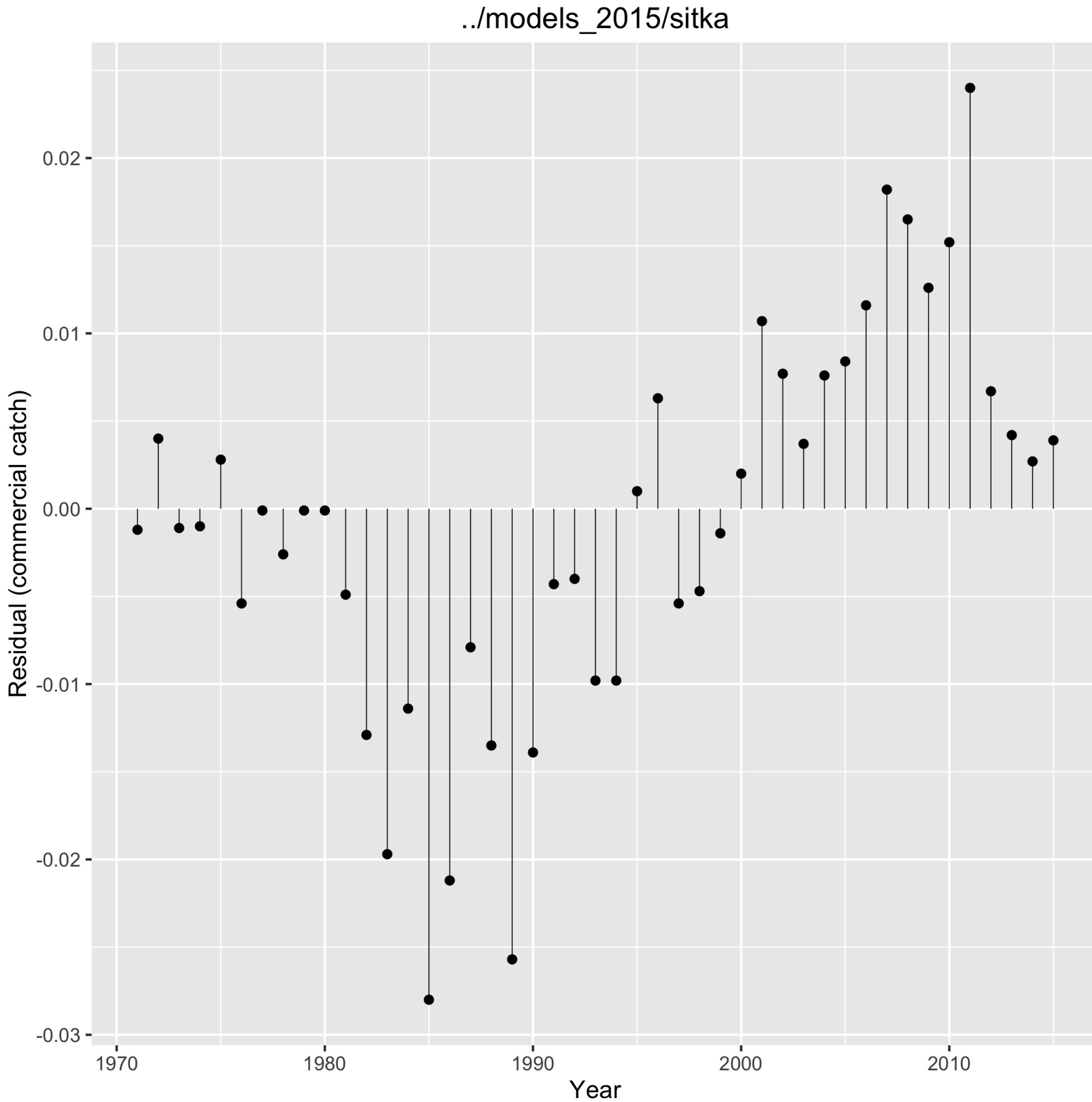

Figure 13: Residual fit to the commercial catch data.

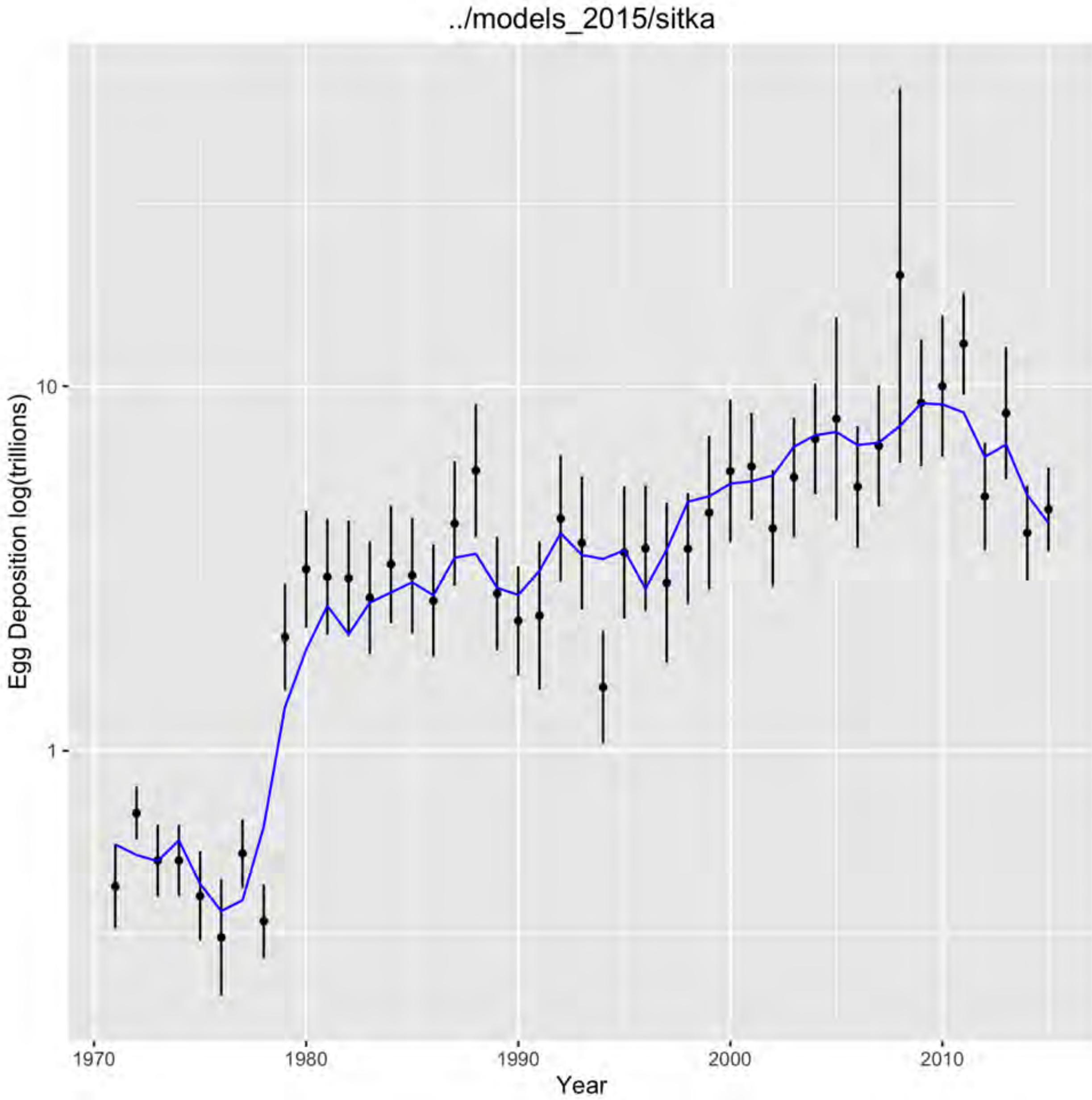

Figure 14: Fits to the egg survey index for Sitka herring. Note these data and predictions are plotted on a log scale.

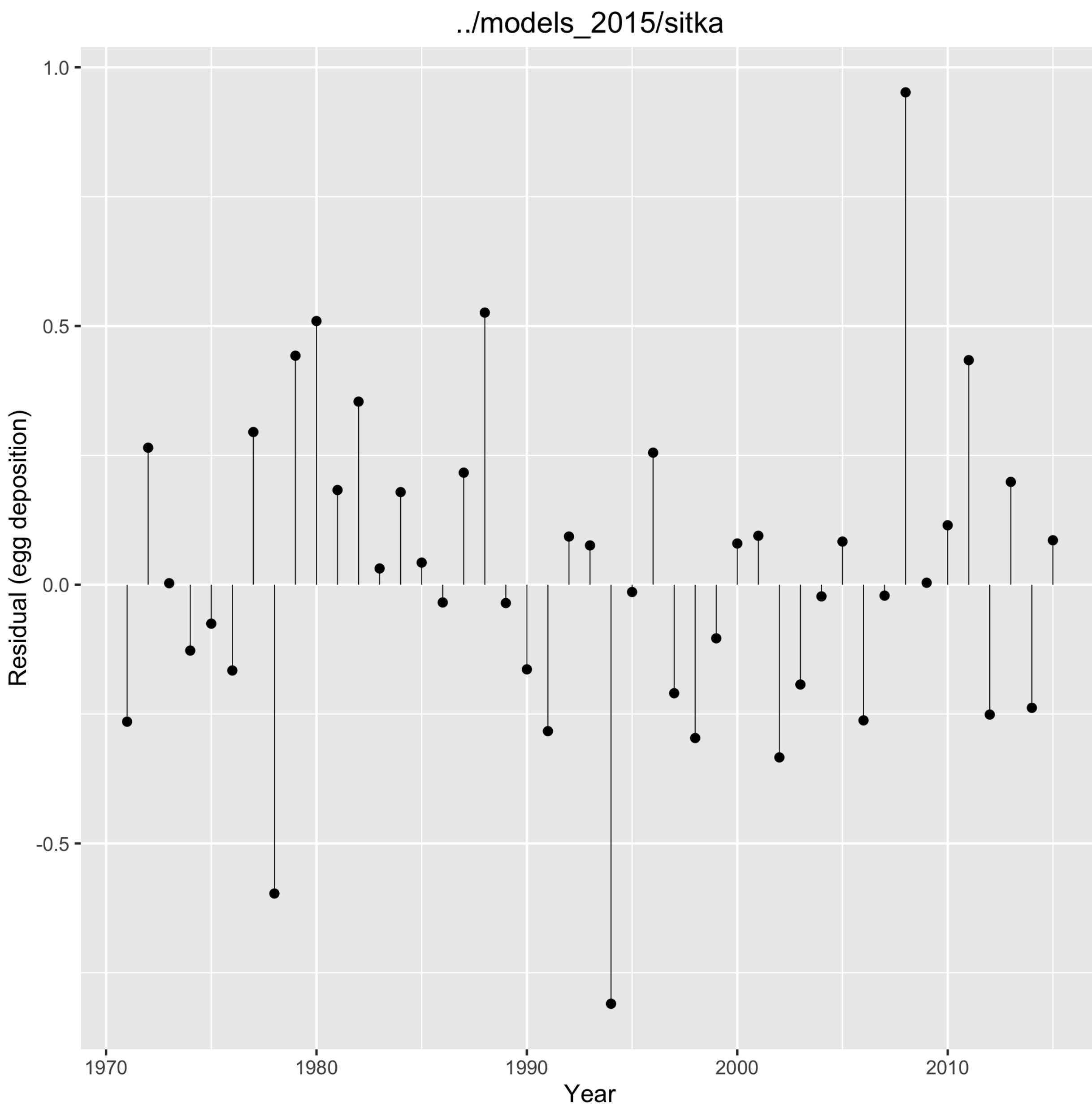

Figure 15: Residual fit to the egg deposition data.

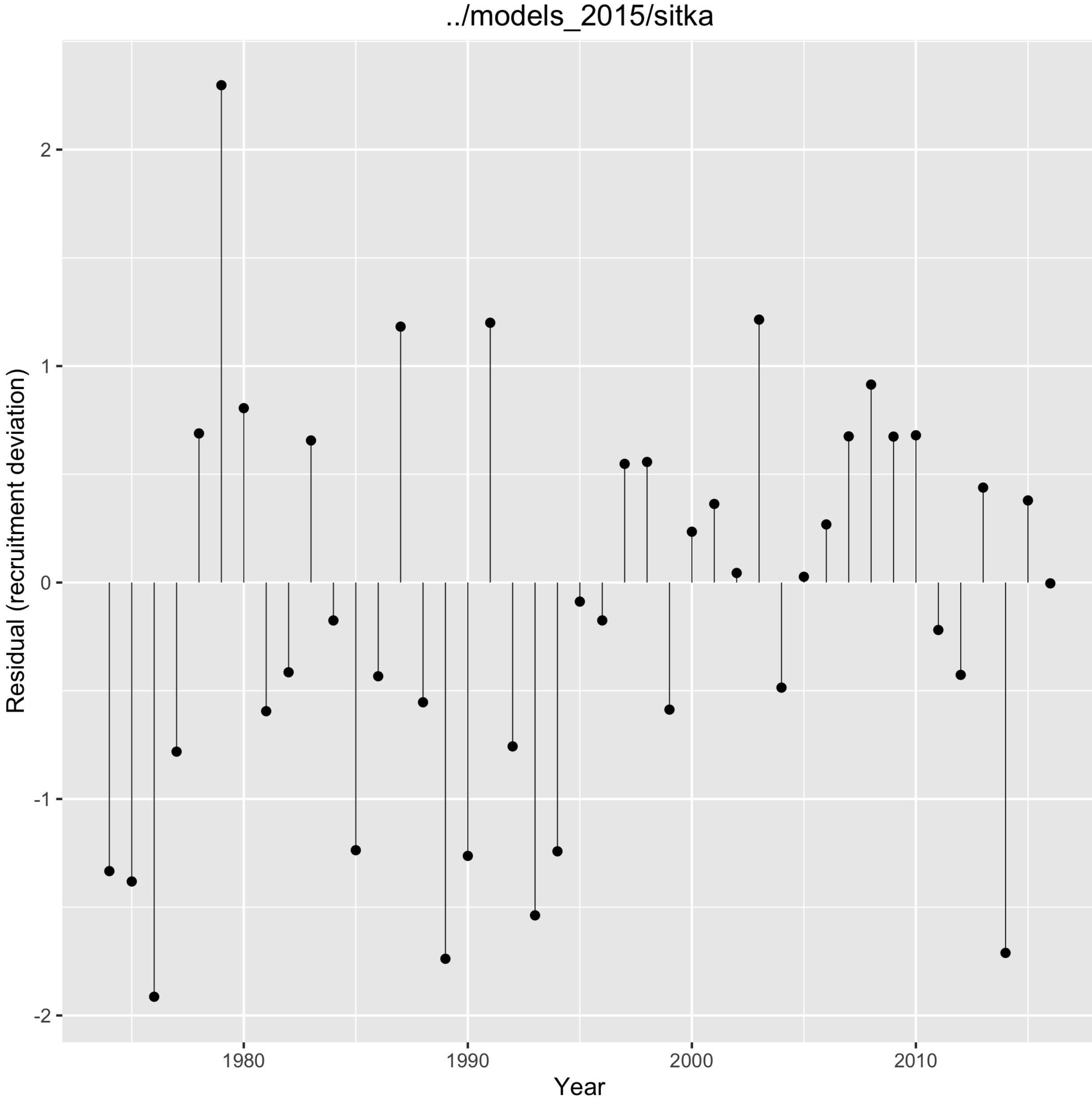

Figure 16: Residual deviations between the log of annual age-3 recruits and the Ricker stock recruitment relationship.

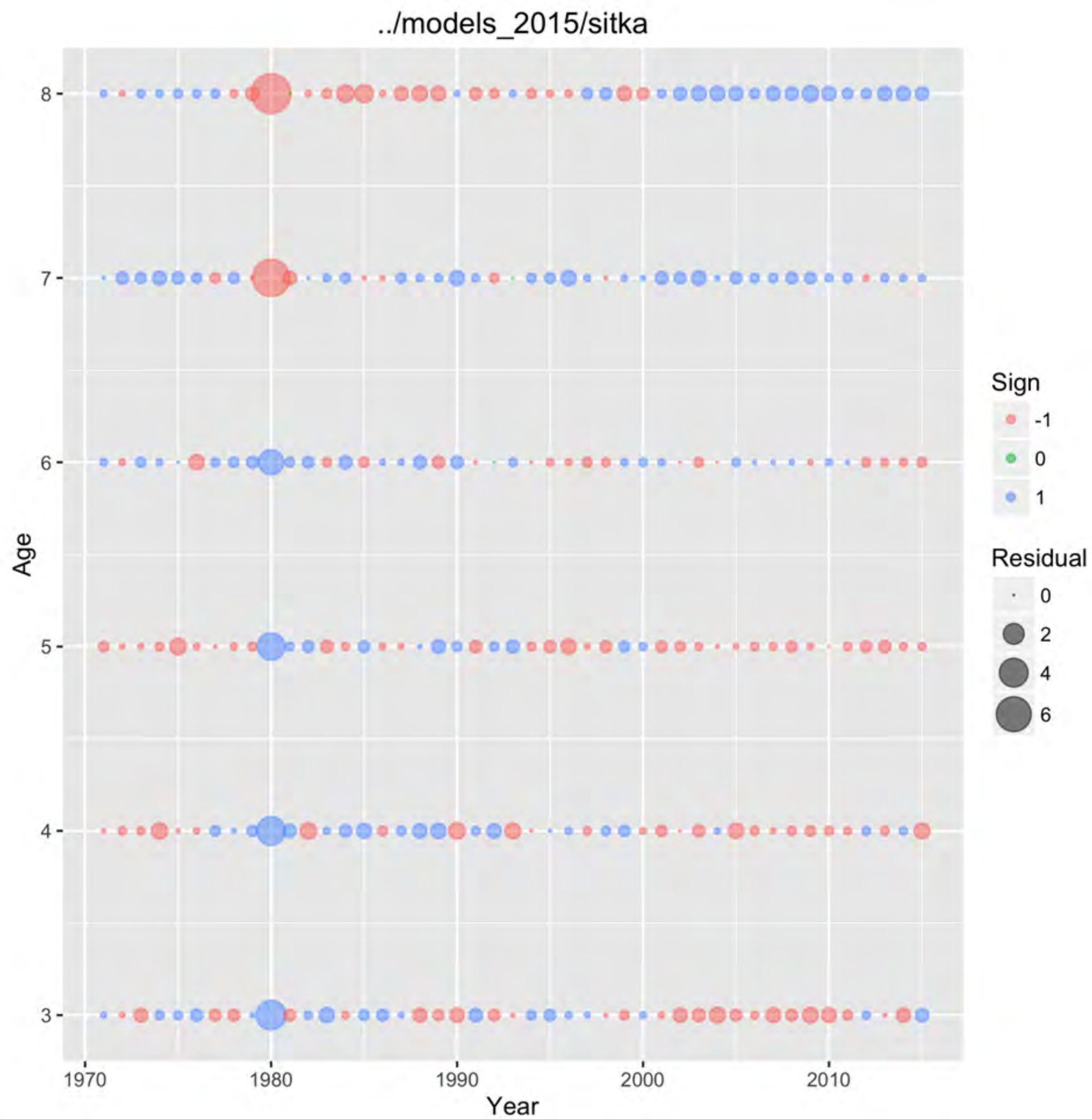

Figure 17: Residual fits to the spawn survey age composition data.

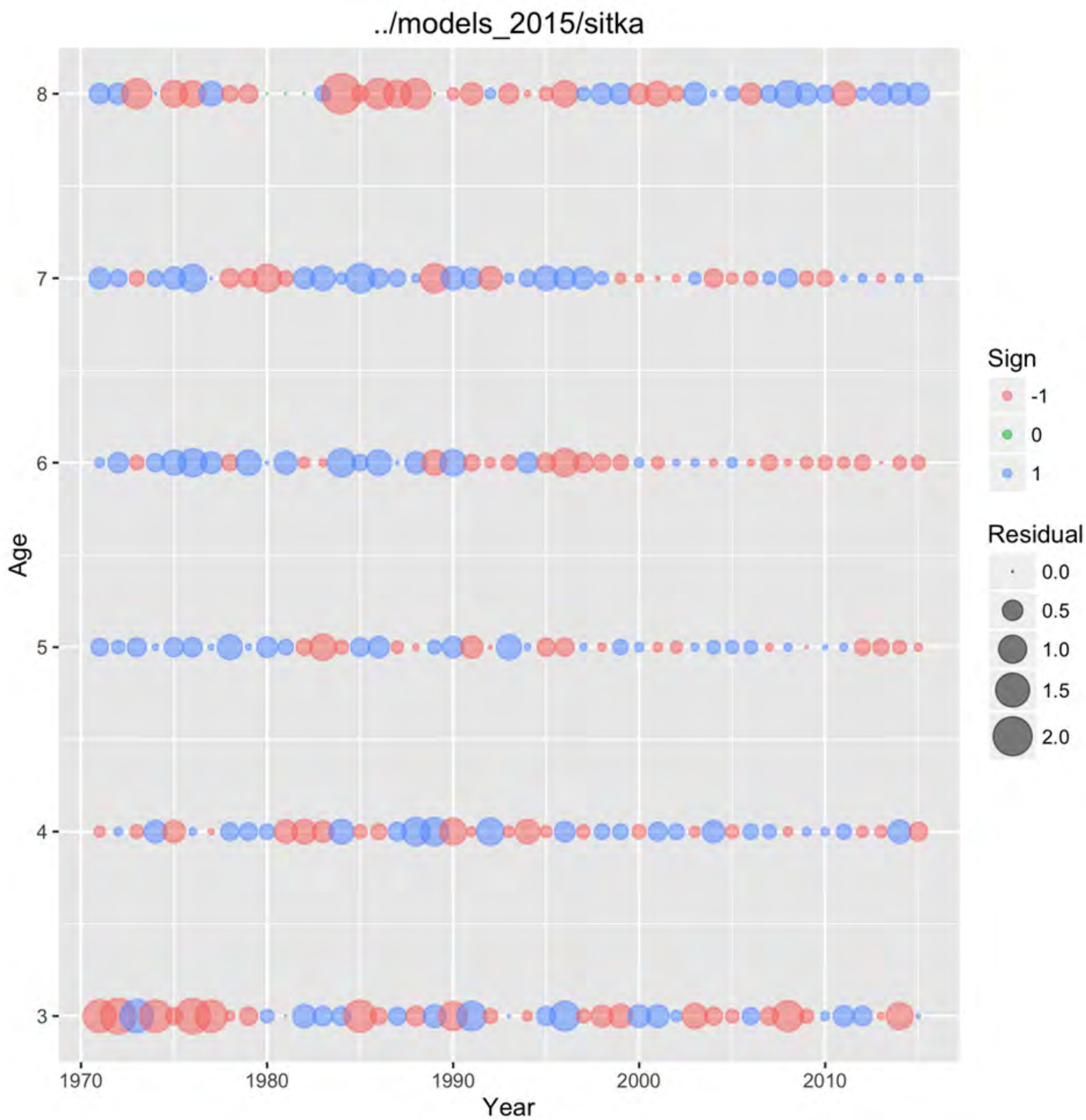

Figure 18: Residual fits to the commercial age composition data.

7 Summary

Although age-structured models tend to estimate dozens, if not 100s, of more parameters than the simple surplus production or biomass dynamics models, The key policy parameters that define stock productivity and scale (i.e., intrinsic rate of growth and carrying capacity) only involve 3 basic parameters, unfished stock size, natural mortality, and the steepness of the stock-recruitment relationship. Estimates of unfished biomass, or its analogue unfished recruitment, defines the population scaling. This parameter is primarily informed by the scale of the catch data. The natural mortality rate defines "residency", or the number of years and average individual will persist in the population and survive to contribute to future generations via spawning events. Trend information in composition data can jointly inform natural mortality rates in a stock assessment model, but these estimates are also conditional on structural assumptions about model selectivity. The steepness of the stock recruitment relationship is more related to population resilience, but in this case we are specifically referring to how strong the density-dependent juvenile survival rate from egg to age-3 recruit is. The stronger the compensatory response is, the more resilient the stock is to the effects of fishing.

If reliable estimates of unfished stock size, natural mortality rates, and the steepness of the stock recruitment relationship can be obtained from the age-structured assessment model, then fisheries reference points can easily be developed conditional on assumptions about fisheries selectivity. The code herein readily provides the means to calculate MSY or SPR-based reference points. Furthermore, uncertainty in these reference points can also be quantified by either sampling from the joint posterior distribution and computing a distribution for MSY, or FMSY. Or use the delta method to obtain asymptotic estimates of uncertainty using the inverse of the Hessian matrix (e.g., an `sdreport_number` in ADMB).

A number of significant changes were introduced into this new code, with the primary goals of: improving numerical stability, providing a more modern statistical framework for quantifying uncertainty, and changes to the data input and control files to allow for rapid exploration of alternative model structures without having to recompile the code, or have several versions of the code, that are all prone to programmer errors. I've also tried to provide comments in the code that direct a programmer or the next generation of analyst to add additional options for selectivity, or different stock-recruitment curves and, alternative likelihood functions for composition data. This is an active area of research in fisheries stock assessment, and the documented code provides an interface in which to explore alternatives.

As an example of flexibility, let's say a reviewer wanted to know how the assessment model differs if you were to treat the egg survey index as a relative index instead of absolute. One option that does not involve making any changes to the code, is to put the egg index in the mile milt day input. In this case, the model will only fit the trends in the egg abundance rather than treating them as absolute. More importantly, no potentially dangerous code changes were necessary to make the comparisons.

Below are some of the major structural differences and a few warnings to the user to watch out for. For example: is the objective function continuous and differentiable, how to avoid getting stuck in local minima, is fishing mortality really increasing or is selectivity just changing?

The previous age-structured model for Alaska herring stocks assumed the catch was known without error. In this parameterization each year the observed catch was subtracted from the mature spawning biomass using a difference equation. One potential pitfall with this approach is that during the non-linear optimization to find the maximum likelihood estimates of the model parameters, it is possible that the population can go negative. In such circumstances, the search routine can easily get stuck in local minima because the gradient of the objective function is not continuous. My recommendation is not to condition the model on catch, but to fit the model to the catch and estimate the fishing mortality rates directly.

When allowing estimated model parameters to vary over time (e.g., time-varying selectivity, or time-varying natural mortality rates), estimated trends in the asymptotic fishing mortality rates may differ slightly with trends in the average fishing mortality. The fishing mortality rates may appear to be stable, but this statement is only true if trends in selectivity are also invariant over the same time period.

Lastly, if you feel confident that the data are informative such that you would like to try and estimate the variance parameter for the recruitment deviations (σ_R), you'll likely discover that the model may tend to converge to either an observation error only model (i.e., $\sigma_R \to 0$), or less likely a process error only model (only if the user specifies very small observation errors in the data file). There are a number of options that might be considered to address this statistical "errors-in-variables" problem. The simplest approach is jointly estimate an additional variance term (a feature commonly implemented in Stock Synthesis), or preferably integrate over the random variables (recruitment deviations) using numerical methods (e.g., MCMC). For example, a common observation is that MLE estimates of σ_R in this model will be less than the median estimates of σ_R obtained from random samples of the joint posterior distribution. If the data are not that informative, or there is a lot of conflicting data or model misspecification that leads to greater uncertainty, informative priors for σ_R will probably be required to obtain convergence. The alternative to MCMC is a mixed-effects, or random-effects, models which are becoming more popular in the last 5 years.

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Schnute, J. and Richards, L. (1995). The influence of error on population estimates from catch-age models. *Canadian Journal of Fisheries and Aquatic Sciences*, 52(10):2063–2077.

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IN THE SUPERIOR COURT FOR THE STATE OF ALASKA

FIRST JUDICIAL DISTRICT AT SITKA

SITKA TRIBE OF ALASKA, Plaintiff, v. STATE OF ALASKA, DEPARTMENT OF FISH AND GAME, and the ALASKA BOARD OF FISHERIES, Defendants, and SOUTHEAST HERRING CONSERVATION ALLIANCE, Defendant-Intervenor.	Case No. 1SI-18-00212CI

AFFIDAVIT OF ANDREW ERICKSON

STATE OF ALASKA)
) ss.
THIRD JUDICIAL DISTRICT)

ANDREW B. ERICKSON, being duly sworn, states that:

1. I am counsel of record for Sitka Tribe of Alaska ("STA") in the matter of *Sitka Tribe of Alaska v. State of Alaska, Department of Fish & Game and the Alaska Board of Fisheries*, Case No. 1SI-18-00212CI.

2. I am competent to make this declaration and the facts stated herein are made with personal knowledge and are true and correct to the best of my knowledge.

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3. I have reviewed the following exhibit attached to STA's October 23, 2020 Opposition to the State's and SHCA's Cross-Motions for Summary Judgment & Reply in Support of STA's Cross-Motion for Summary Judgment Re: Constitutional Claims.

4. Exhibit 1 is a true and accurate copy of a report provided to ADF&G by Dr. Steve Martell of the University of British Columbia that describes the current model used by ADF&G and Dr. Martell's proposed changes.

5. On September 11, 2020, I emailed Assistant Attorney General Aaron Peterson to request the "Martell Report." On September 15, 2020, Mr. Peterson emailed me the document that is now produced as Exhibit 1.

FURTHER AFFIANT SAYETH NAUGHT

10/23/2020
Date

Andrew B. Erickson

<u>Acknowledgment</u>

The foregoing was acknowledged before me this 23rd day of October 2020, by Andrew B. Erickson, at Anchorage, Alaska.

Notary Public in and for Alaska
My Commission expires: 03 · 07 · 2024

CHERI L. WOODS
My Commission Expires Mar 7, 2024
NOTARY PUBLIC
STATE OF ALASKA

<u>Certificate of Service</u>

On October 23, 2020 a true and correct copy of the foregoing document was served electronically on:

Aaron Peterson, aaron.peterson@alaska.gov
Jeff Pickett, jeff.pickett@alaska.gov
Michael A. D. Stanley, madslaw@alaska.net

Cheri Woods