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**Comparison of Estimated Biomass of CSNA**

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In the May 2016 coastal pelagic species (CPS) data-limited workshop sponsored by the Pacific Fishery Management Council at the Southwest Fisheries Science Center (SWFSC), the workshop panel recommended comparison of spawning biomass estimates of the central subpopulation of northern anchovy (CSNA) from the CalCOFI ichthyoplankton-based model (i.e., MacCall et al. 2016) with an estimate of total biomass from recent ATM surveys (Zwolinski et al. 2016, 2017). Here, we provide that comparison for the one year when both estimates are currently available, 2015.

In this document, we clarify definitions and highlight *consistency of results* from these different sources. We demonstrate that there are no conflicting interpretations of biomass estimates for the CSNA.

Estimates have been developed for **spawning biomass** (MacCall et al. 2016) and **total biomass (**Zwolinski et al. (2016, 2017**)**. Spawning biomass represents only the mature portion of the population that is spawning. Total biomass includes the spawning biomass plus any immatures (age-0 and age-1 fish that are not spawning).

Estimates from MacCall et al. (2016), with follow up in Thayer et al. (2017), are of spawning biomass based on geo-spatially weighted abundances from eggs and larvae caught in net trawls on the CalCOFI winter and spring surveys. Estimates in Zwolinski et al. (2016, 2017) are of total biomass, estimated in summer from acoustic signals and fish caught in net trawls using the acoustic-trawl method (ATM). Spatially, the core CalCOFI survey covers primarily the Southern California Bight and accounts for the upper water column, but does not sample extensively nearshore. These spawning biomass estimates utilize a correction factor to scale to the anchovy central subpopulation area (from Bahia del Rosario, Baja California Norte, up to Point Reyes, CA). The inner-most standard CalCOFI stations are also used to scale all the way to shore, since catch at these stations was not significantly different from additional inshore stations sampled since 2005 (i.e., SCCOOS stations; Davison et al. 2017). The ATM survey spans from San Diego to north of Pt. Arena, covering much of the anchovy central subpopulation area within the U.S., but does not account for the upper-most part of the water column, nor the nearshore regions.

Direct comparison of the two methods in 2015 yields the following:

CalCOFI-based spawning biomass in spring 2015 was estimated at 5,300 mt , but with low precision (CV=1.23; Thayer et al. 2017). Consequently, the mean spawning biomass over the previous 4-7 years was also reported, roughly 20,000 mt (2009-2015) or 25,000 mt (2012-2015) (Thayer et al. 2017).

The preliminary ATM-based total biomass estimate in summer 2015 was 31,427 mt (CV=0.25; Zwolinski et al. 2016). To compare this with the spawning stock biomass, one needs to estimate and remove the juvenile (age-0) proportion of the population. We assume that anchovy > 100 mm standard length are adults and part of the spawning population (Parrish et al. 1986). Anchovy > 100 mm were caught in the 2015 ATM survey in spatial clusters 2, 5, 6, 7 and 15 (see Zwolinski et al. 2016, Fig. 3). Converting length distribution data (Zwolinski et al. 2016, Table 2) to mean weights, 26% of the biomass of the population was > 100 mm and thus assumed age 1+, resulting in an estimate of 8,300 mt of spawning biomass from the ATM survey. This estimate has a minimum CV=0.25 given survey results from the total biomass estimate (pers. comm. J. Zwolinski/SWFSC).

This comparison demonstrates coherence between the CalCOFI-based and ATM-based abundance estimates, with both approaches resulting in a very low spawning abundance in 2015. In fact, given the uncertainty of the estimates we are unable to tell them apart. Inherent differences include the fact that the ATM survey includes older fish transitioning from

age-0 to age 1+ between spring when the CalCOFI data were collected and summer when the ATM survey was conducted (so precluding any mortality, biomass is augmented by growth of individuals from spring to summer).

Notably, neither method currently samples the extreme nearshore region, where anchovy may concentrate at low population sizes (although the CalCOFI-based method scales results to include nearshore; see above). Therefore, absolute spawning biomass may be larger, but only slightly due to the small nearshore area not sampled directly. Approximately 1,700 $km^2$ along the coast were surveyed aerially in 2015 by the California Department of Fish and Wildlife, but no anchovy were observed in this nearshore area in 2015 (Lynn et al. 2017).

Preliminary CalCOFI ichthyoplankton data just became available for spring 2016; unfortunately data are not yet available for winter 2016 nor winter or spring 2017. We can work to develop 2016 spawning biomass estimates from CalCOFI data for additional comparisons between the two methods in conjunction with the Southwest Fisheries Science Center.

**Summary:**

| | **CSNA biomass estimate derived from:** | |
|---|---|---|
| **Estimate includes:** | **CalCOFI** | **ATM** |
| Total biomass? | No | Yes, includes juveniles |
| Spawning biomass? | Yes | Yes, can be estimated using age/length data |
| Southern CA? | Yes, directly surveyed | Yes, directly surveyed |
| Central CA? | Yes, scaled up using DEPM | Yes, directly surveyed |
| N. Baja, Mexico? | Yes, scaled up using DEPM | No |
| Upper water column? | Yes, directly surveyed | No, acoustics miss upper ~10m |
| Nearshore? | Yes - tesselated from inner-most stations to shore | No, but estimates being derived from aerial survey |
| **2015 biomass estimate:** | **5,300 mt** | **8,300 mt** |
| *Sample type:* | *Eggs/larvae* | *Adults/juveniles* |
| *Survey timing:* | *Spring* | *Summer* |

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September 5, 2017

Mr. Phil Anderson, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220

**RE: Agenda Item C.1 – Acoustic Trawl Survey Methodology Review Terms of Reference**

Dear Chair Anderson and Council Members:

We write with respect to the proposed Terms of Reference (ToR) for the 2018 Acoustic Trawl (AT) Survey Methodology Review that the Pacific Fishery Management Council (Council) will consider at its September 2017 meeting. Our organizations request that the Council approve the ToR with the suggested additions detailed below. We thank the Council, the Southwest Fisheries Science Center (SWFSC), and state fish and wildlife agencies for their work to ensure the best information possible on the status of coastal pelagic species (CPS) stocks, particularly the central subpopulation of northern anchovy (CSNA).

As the SWFSC and Council prepare to evaluate the AT Survey, we recommend that the following be included in the final ToR as items to be addressed during the AT Methodology Review:

- Identification of correction factors to estimate the proportion of CSNA biomass inshore of the AT Survey area, as well as any biomass missed in surface waters.
- Refinement of the target strength for differentiating between anchovy, sardine, and non-target species.
- Description of methods to ensure that AT Survey results can be used to distinguish between spawning stock biomass and overall biomass for CSNA.

Here, we describe these suggestions in more detail, beginning with a brief summary of our organizations' recent comments to the Council regarding the management of CSNA.

**Concerns Regarding CSNA Management**

As the Council is aware, northern anchovy is a keystone forage species in the California Current Ecosystem (CCE) and is preyed upon by a wide variety of marine wildlife, including

commercially and recreationally valuable fish, mammals, and seabirds.[1] Anchovy is the single most important prey species for CCE seabirds[2] and first or second most important for the broader suite of marine predators, such as humpback whales, chinook salmon, dolphins, and pinnipeds.[3]

For several years, our organizations have expressed concerns to the Council about the status of northern anchovy and the lack of active management of the stock, especially in light of its crucial role in the CCE's food web.[4] One of our key recommendations has been the prioritization of a full stock assessment for the central subpopulation in particular. CSNA was last assessed in 1995, but this highly variable stock is currently being managed using information that's even older,[5] potentially placing both CSNA and dependent predators at risk – particularly during periods of low abundance such as the stock's recent collapse.[6] We appreciate that the Council has voiced similar concerns regarding the lack of a recent assessment, and we thank the Council for its November 2015 and November 2016 requests to the National Oceanic and Atmospheric Administration's Fisheries Service (NOAA Fisheries) to conduct a full assessment for CSNA. Further, we appreciate the efforts of the SWFSC to begin work on developing this stock assessment, and recommend that it be completed as soon as practicable.

## The AT Methodology Review and CSNA Management

In addition to its requests to NOAA Fisheries regarding a stock assessment for CSNA, the Council provided direction to the Scientific and Statistical Committee (SSC) at its April 2017 meeting to "evaluate the utility of ATM indices and the resulting abundance estimates to calculate a biomass estimate and an estimate of FMSY for CSNA."[7] The Council suggested that this evaluation be informed by the upcoming Methodology Review, and discussed further at the April 2018 meeting. As part of the April 2018 CSNA agenda item, the Council may advance motions in regard to "Anchovy Abundance and Reference Point Update,"[8] an important step toward updating status determination criteria (SDCs) and setting annual harvest specifications, both of which are critically needed in order to meet Magnuson-Stevens Fishery Conservation and

[1] Pacific Fishery Management Council, July 2013, Ecosystem Initiatives Appendix to the Pacific Coast Fishery Ecosystem Plan, at A-11.
[2] Szoboszlai, A.I., J.A. Thayer, S.A. Wood, W.J. Sydeman, L.E. Koehn. 2015. Forage species in predator diets: Synthesis of data from the California Current. *Ecological Informatics* 29:45-56.
[3] Ainley, D. et al. 2015. California current system–predators and the preyscape. *Journal of Marine Systems* 146: 1-2.
[4] In addition to our organizations' individual comments from the past three years, our joint comments can be found at: Pacific Fishery Management Council, November 2015, Public Comment under Agenda Item H.3; Pacific Fishery Management Council, June 2015, Supplemental Public Comment under Agenda Item G.3; and Pacific Fishery Management Council, September 2014, Supplemental Public Comment under Agenda Item I.6.
[5] Existing SDCs and reference points for CSNA are based on a long-term average MSY value derived from a 1991 bio-economic model (Conrad 1991) that in turn relies on a time-series of CSNA abundance from 1964 to 1990.
[6] MacCall, A. D., W. J. Sydeman, P. C. Davison, J. A. Thayer. 2016. *Recent Collapse of Northern Anchovy Biomass off California*. Fisheries Research. 175:87-94; Thayer, J.A., A.D. MacCall, P.C. Davison, W.J. Sydeman. 2017. *California Anchovy Population Remains Low, 2012-2016*. CalCOFI Reports, Vol. 58; Zwolinkski, J., D.A. Demer, B.J. Macewicz, G.R. Cutter, Jr., S. Mau, D. Murfin, J.S. Renfree, T.S. Sessions, K. Stierhoff. November 2016. *Distribution and Biomass of the Central-Stock Northern Anchovy During Summer 2015, Estimated from Acoustic-Trawl Sampling*. NOAA Technical Memo; Pacific Fishery Management Council, March 2017, *California Current Integrated Ecosystem Assessment (CCIEA) California Current Ecosystem Status Report*, Agenda Item F.1.a, NMFS Report 1.
[7] Pacific Fishery Management Council, April 2017, Council Meeting Decision Summary Document at 5.
[8] Pacific Fishery Management Council, June 2017, Year-at-a-Glance Calendar.

Management Act (MSA) requirements for managing this actively fished, fluctuating forage species.

We appreciate that the results of the AT Methodology Review will factor into the Council's discussion in April and beyond, as well as in the SWFSC's ongoing work to develop an integrated stock assessment for CSNA. Further, we note that a key objective of the upcoming review is to "evaluate the usefulness of the ATM for [Pacific mackerel, two sub-stocks of northern anchovy, and jack mackerel] even though portions of their populations are outside the range of the ATM survey…"[9] While we understand that there are concerns with the existing AT Survey's precision in estimating abundance of CSNA in particular – specifically that the survey may result in both positively and negatively biased estimates for CSNA – the AT Survey nonetheless provides some of the best available scientific information on the status of CPS stocks, including CSNA. The MSA requires that "[c]onservation and management measures [are] based on the best scientific information available."[10] Further clarification on this requirement holds that the Council and NOAA Fisheries "must utilize the best scientific data *available*, not the best scientific data *possible.*"[11] The existing AT Survey meets the definition of best available science and therefore we suggest its results can and must be used to inform management of CSNA. At the same time, we fully support efforts to improve and strengthen the survey, and hope that the Methodology Review will help to reduce or resolve uncertainties presently associated with it.

To this end, we appreciate that the proposed ToR includes guidance to "provide sufficient information for the review panel to determine whether the results of [the AT] Survey as reviewed are suitable" for developing indices of relative and absolute abundance to be used in either an integrated stock assessment or in application of a harvest control rule for each of the CPS stocks under consideration, including CSNA.[12] In order to bring CSNA management into alignment with the Council's broader goals of precautionary, ecosystem-based management, as well as the CPS Fishery Management Plan's specific goals to prevent overfishing, achieve optimum yield, and provide adequate forage for dependent predators,[13] we believe a key objective of the 2018 Methodology Review should be ensuring that data provided by the AT Survey are used to develop relative and absolute indices of abundance, as well as estimates of absolute abundance, for CSNA that are as accurate and reliable as possible. We offer the suggestions below with that goal in mind.

## Recommendations

***Derive correction factors to estimate the proportion of CSNA biomass inshore of the AT Survey area, as well as biomass which may be missed in surface waters.***

[9] Pacific Fishery Management Council, September 2017, Acoustic Trawl Methodology Review Proposed Terms of Reference, Agenda Item C.1, Attachment 1 at 1.
[10] 16 U.S.C. § 1851(a)(2).
[11] *Blue Water Fishermen's Assn. v. Nat'l Marine Fisheries Serv.,* 226 F.Supp.2d 330, 338 (D. Mass. 2002) (quoting *Building Indus, Ass'n of Superior California v. Norton,* 247 F.3d 1241, 1246-47 (D.C.Cir.2001)) (emphasis in original).
[12] Proposed Terms of Reference at 5.
[13] Pacific Fishery Management Council, Coastal Pelagic Species Fishery Management Plan (as amended through Amendment 15) at 13.

In response to a November 2016 request from the Council, the CPS Subcommittee of the Science and Statistical Committee (SSC) and the CPS Management Team (CPSMT) developed a joint report[14] that describes several methods for developing an updated Overfishing Limit (OFL) for CSNA, along with associated processes and timelines for each option. The Joint Report identifies a primary concern with using AT Survey-based biomass estimates to generate an updated OFL or other status determination criteria for CSNA: because the AT Survey is unable to sample waters inshore of 50 meters and portions of the upper water column, correction factors must be derived in order to estimate the proportion of the biomass inshore of the survey area as well as any biomass missed in surface waters. A 2011 methodology review of the AT Survey reached a similar conclusion with respect to CSNA.[15]

While we support the notion that development and application of correction factors would yield a more complete picture of CSNA abundance and allow for AT Survey estimates to be fully calibrated to account for unsampled areas, at least in U.S. waters, we note that the unsampled nearshore area in particular may be unlikely to substantially impact AT-based abundance estimates. Davison et al. describe[16] (as have others[17]) the tendency of anchovy to contract shoreward during periods of low abundance. As these inshore waters are not accessible to ATM survey vessels, anchovy found there are generally not "seen" or counted by the ATM survey (or by other surveys such as CalCOFI cruises, though CalCOFI estimates are scaled all the way to shore). The question remains whether this missed inshore biomass is large enough to appreciably alter the results of a survey-based abundance estimate. Davison finds that the relatively limited area of these inshore waters is simply too small to translate into a large biomass of CSNA, particularly during periods of low overall abundance: "…it is clear that even though there is a dense population of anchovy nearshore, it doesn't amount to a large biomass due to the restricted spatial distribution."[18]

Despite this potential for a nearshore correction factor to be relatively minor, we appreciate and support the proposed ToR's guidance on the overall question of correction factors for unsurveyed areas,[19] and agree that such factors can improve the accuracy and reliability of AT-based estimates. We request that the final ToR include further detail with respect to deriving correction factors, in addition to the proposed ToR's recommendation regarding descriptions of cooperative sampling with industry and state partners. While cooperative research and sampling may be important to adequately surveying inshore areas and the upper water column, and are already showing encouraging signs of progress, a more complete discussion of how best to derive and apply correction factors would further advance the AT Survey's application to CSNA management. For example, nearshore and aerial sampling efforts could benefit from detailed protocols describing how best to identify species and calculate estimates. It is our understanding

[14] Pacific Fishery Management Council, April 2017, Agenda Item G.2.a, Joint SSC/CPSMT Report on Central Subpopulation of Northern Anchovy Overfishing Limit Process.
[15] Pacific Fishery Management Council, April 2011, Report of the ATM Methodology Review, Agenda Item C.3.a, Attachment 1.
[16] Davison, P.C., W.J. Sydeman, J.A. Thayer. 2017. *Are There Temporal or Spatial Gaps in Recent Estimates of Anchovy off California?* CalCOFI Reports, Vol. 58.
[17] MacCall *et al*., 2016.
[18] Davison *et al.*, 2017, at 11.
[19] Proposed Terms of Reference at 5.

that existing aerial surveys provide a visual estimate of biomass, but cannot be readily reproduced; one way of possibly improving the rigor of these surveys might be to further analyze aerial survey photographs (perhaps using methods common in seabird and other aerial surveys) to estimate the mean area of portions of anchovy schools not visible from above.

***Refine the target strength for differentiating between anchovy, sardine, and non-target species.***

When the AT Survey underwent a methodology review in 2011, the review panel's recommendations for future research and data needs included "Make efforts to obtain target strength measurements for *in situ* CPS in the California Current Ecosystem."[20] The proposed ToR for the 2018 AT Methodology Review notes that the SWFSC has made progress toward this objective: "The ability to measure target strengths of live fish collected from the survey area can now be conducted at the Technology Tank at the SWFSC…"[21] We support the proposed ToR's recommendation that target strengths of CPS from the CCE be provided to the review panel, and suggest that the methodology review consider the best approach to fully incorporating target strength measurements and assignments into the AT Survey results. Doing so can help improve the accuracy of biomass estimates for each CPS stock in the survey, while also helping to distinguish anchovy and sardine in particular from non-target species of similar size with swim bladders.

For example, the AT Methodology Review could investigate opportunities to further develop and integrate information on the differences in body shape and swim bladder characteristics between species – data that could assist with making distinctions between anchovy and sardine at different size classes, and between juvenile rockfish and anchovy at the smaller end of the length/size spectrum. Similarly, non-target species (such as juvenile rockfish, greenling, and senorita) could be included when apportioning out the catch to apply to the acoustic signal. This may particularly improve estimates in areas where higher concentrations of non-target species are likely present and/or during times or conditions when CPS abundance is low.

***Describe methods to ensure that AT Survey results can be used to distinguish between spawning stock biomass and overall biomass for CSNA.***

In addition to a discussion of how best to distinguish between anchovy, sardine, and non-target species, it will also be helpful for the Methodology Review to describe methods for differentiating between CSNA spawning stock biomass (SSB) and overall biomass. This will allow abundance estimates resulting from the AT Survey to better delineate the portion of biomass – SSB – most relevant to developing reference points, status determination criteria, and ultimately catch limits. We appreciate that the proposed ToR includes guidance related to trawl survey design that specifically seeks to address whether "fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters…"[22] While this validation will aid in better understanding any differences in the species composition of daytime acoustic surveys versus nighttime trawls, we suggest that an explicit discussion of procedures for quantifying SSB in particular will be vital to strengthening

[20] April 2011 Report of the ATM Methodology Review at 16.
[21] Proposed Terms of Reference at 3.
[22] Proposed Terms of Reference at 4.

the AT Survey. Such procedures may be as straightforward as applying the mean anchovy weight of each size class to the number of individuals in each class as identified in the AT Survey, calculating the proportion of biomass of each size class relative to the total, and then adding up the biomass of any size classes estimated to be adult (Age 1+).

**Conclusion**

In conclusion, we request that the Council approve final ToR for the 2018 AT Methodology Review that help to ensure data provided by the AT Survey are used to develop relative and absolute indices of abundance, as well as estimates of absolute abundance, for CSNA that are as accurate and reliable as possible, and that these estimates are utilized to inform management, as required by the MSA. Such information will be critical as NOAA Fisheries continues work toward an integrated stock assessment, and as the Council considers new methods for setting reference points and SDCs for CSNA that better reflect and correspond to the status of the stock.

Thank you for your consideration, and for your work to ensure sustainable fishing and healthy ocean ecosystems.

Sincerely,

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