# 10. Assessment of the Northern Rockfish stock in the Gulf of Alaska

## Executive summary

## Executive Summary

***Summmary of Changes in Assessment Inputs***

*Changes in input data*: The input data were updated to include survey biomass estimates for 2019; fishery size compositions for 2018 and 2019; fial catch for 2018 and 2019, preliminary catch for 2020.

*Changes in assessment methodology*:

1. **Fitting to VAST model-based biomass index.** In the 2018 assessment a Vector Autoregressive Spatio-temporal (VAST) model replaced the design-based stratified-random biomass index from the GOA bottom trawl survey. The current assessment was fit to two biomass indices produced by different VAST model structures…

***Summary of Results***

The 2019 projected age 2+ total biomass is 87,409 t.

## Summaries for Plan Team

## SSC and Plan Team Assessment comments

## Introduction

Description of alternative models included in the assessment, if any (e.g., alternative M values or likelihood weights); note that the base model (i.e., the model most recently accepted by the SSC, either after reviewing the previous year’s final assessment or the current year’s preliminary assessment) must be included Per recommendation of the SSC (10/15), please use the following convention for numbering models: When a model constituting a “major change” from the original version of the base model is introduced, it is given a label of the form “Model yy.j,” where yy is the year (designated by the last two digits) that the model was introduced, and j is an integer distinguishing this particular “major change” model from other “major change” models introduced in the same year. When a model constituting only a “minor change” from the original version of the base model is introduced, it is given a label of the form “Model yy.jx,” where x is a letter distinguishing this particular “minor change” model from other “minor change” models derived from the original version of the same base model. Specifically, please use one of the following four options to distinguish “major” from “minor” changes:

### Biology and distribution

The northern rockfish, *Sebastes polyspinis*, is a locally abundant and commercially valuable member of

### Evidence of stock structure

Gulf of Alaska northern rockfish grow significantly faster and reach a larger maximum length than Aleutian Islands northern rockfish (Clausen and Heifetz 2002).

## Fishery

***Description of the directed fishery***

All of these grounds can be characterized as relatively shallow (75–150 m) offshore banks on the outer continental shelf.

Data from the observer program for 1990-98 indicated that 82% of the northern rockfish catch during that period came from directed fishing for northern rockfish and 18% was taken as incidental catch in fisheries for other species (Clausen and Heifetz 2002).

***Description of the catch time series***

Total commercial catch (t) of northern rockfish in the GOA for the years 1961-2018 is summarized by foreign, joint venture, and domestic fisheries (Table 10.2 and Figure 10.1).

***Bycatch and discards***

The only detailed analysis of incidental catch in slope rockfish fisheries of the Gulf of Alaska is that of Ackley and Heifetz (2001) who examined data from the observer program for the years 1993-95.

## Data

The following table summarizes the data used in the stock assessment model for northern rockfish (bold denotes new data for this assessment):

Source Data Years Fisheries Catch 1961-2018 NMFS bottom trawl surveys Biomass index 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017 NMFS bottom trawl surveys Age 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017 U.S. trawl fisheries Age 1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, 2008, 2010, 2012, 2014, 2016 U.S. trawl fisheries Length 1990,1991,1992, 1993, 1994, 1995, 1996, 1997, 2003, 2007, 2009, 2011, 2013, 2015, 2017

### Fishery data

*Catch* Catch of northern rockfish ranges from 185 t to 17,430 t during 1961 to 2020. Detailed description of catch is provided above (within the “Description of the catch time series” section) and in Table 10.2 and Figure 10.1

*Age and size compositions*

Observers aboard fishing vessels and at onshore processing facilities have provided data on length and age compositions of the commercial catch of northern rockfish. Length compositions are presented in Table 10.6 and Figure 10.2 and age compositions are presented in Table 10.7 and Figure 10.3; these tables also include associated annual sample sizes and number of hauls sampled for the age and length compositions. The fishery age compositions indicate that stronger than average year-classes occurred around the year 1976 and 1984. The fishery age compositions from 2004 and 2006 also indicate that the 1996-1998 year-classes were strong. The clustering of several large year-classes in each period is most likely due to aging error. Recent fishery length compositions (2003-present) indicate that a large proportion of the northern rockfish catch are found to be larger than 38 cm, which is the current plus length bin.

### Survey data

*Biomass Estimates from Trawl Surveys*

Bottom trawl surveys were conducted in the Gulf of Alaska triennially from 1984 – 1999 and biennially from 1999 – 2015. The surveys provide an index of biomass, size and age composition data, and growth characteristics. The trawl surveys have used a stratified random design to sample fishing stations that cover all areas of the Gulf of Alaska out to a depth of 1,000 m (in some surveys only to 500 m). Generally, attempts have been made through the years to standardize the survey design and the fishing nets used, but there have been some exceptions to this standardization. In particular, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed in this report, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 introduced an element of uncertainty as to the standardization of these two surveys. Also, a different survey design was used in the eastern Gulf of Alaska in 1984, and the eastern Gulf of Alaska was not covered by the 2001 survey. These data inconsistencies for the eastern Gulf of Alaska have had little effect on the survey results for northern rockfish, as relative abundance of northern rockfish is very low in the eastern Gulf of Alaska. The design-based trawl survey indices of biomass for northern rockfish have been highly variable from survey to survey (Table 10.8). In particular, the 2011 biomass estimate (173,641 t) was 93% larger than the 2009 estimate (89,896 t), while the 2009 biomass estimate was 60% smaller than the 2007 estimate (227,069 t). The 2007 biomass estimate was 36% smaller than the 2005 estimate (358,998 t), which was over 440% larger than the 2003 estimate (66,310 t). The 2013 biomass estimate (370,454 t) was the highest estimated biomass on record and was similar to the 2005 estimate. This increase is largely explained by a three-fold increase in the Chirikof region. The 2017 design-based trawl survey biomass index (150,325 t) represented an increase of 207% from the 2015 index 48,933 t), but is 59% below the high 2013 index (Table 10.8). The 2017 design-based trawl survey index is 12% lower than the long-term average (170,158 t). Such large fluctuations in biomass do not seem reasonable given the long life, slow growth, low natural mortality, late maturity, and relatively modest level of commercial catch of northern rockfish, hence our proposal to inform the 2018 GOA northern rockfish assessment with an alternative Vector Autoregressive Spatio-temporal (VAST) model-based index from these same survey data. The precision of some of the biomass estimates has been low and is reflected in the high CVs associated with some survey biomass estimates of northern rockfish, that are the result of few very large catches during the survey (Table 10.8). In both 1999 and 2001, a single very large survey haul of northern rockfish greatly increased the biomass estimates and resulted in wide confidence bounds. The haul in 2001 was the largest individual catch (14 t) of northern rockfish ever taken during a Gulf of Alaska survey; this tow accounted for 58.7% of total survey catch by mass in that year. In contrast, the 2005 and 2007 survey had several large hauls of northern rockfish in the Central Gulf and confidence bounds were narrower (Table 10.8). The 2009 survey did not have any very large hauls and the biomass estimate was lower and more precise than the 2005 and 2007 estimates. The 2011 survey had several large hauls and the confidence bounds are comparable to 2007. The 2013 survey had several large catches in the Chirikof region but relatively low catches in other areas resulting in a CV of 60% (Figure 10.5). The 2015 biomass estimate was much more precise and had a CV of 34%, similar to other low biomass estimates from past surveys, while the 2017 biomass estimate was over three times as large as 2015 with a CV of 45%. The highly variable biomass estimates for northern rockfish suggest that an alternative to the design-based estimators may be useful to reduce the variability in biomass estimates, which is why in this assessment we recommend a model-based index of bottom trawl survey biomass.

*Age and Size composition*

Ages for northern rockfish were determined from the break-and-burn method (Chilton and Beamish 1982). These age compositions (Table 10.9 and Figure 10.6) indicate that recruitment of northern rockfish is highly variable. Several surveys (1984, 1987, 1990, and 1996) show especially strong year-classes from the period around 1975-77; although they differ as to which specific years were greatest, likely due to age determination errors. The 1993, 1996, and 1999 age compositions also indicate that the 1983-85 year-classes may be stronger than average. Recent age compositions (2005, 2007, 2009, and 2011) indicate that the 1996-98 year-classes may also be stronger than average, which is in agreement with recent age compositions obtained from the commercial fishery described above. Trawl surveys provide size composition data for northern rockfish but are not used directly in the current age structured assessment model (Table 10.10 and Figure 10.7). In years with age readings, trawl survey size composition data are multiplied by an age-length key (computed from length-stratified otolith collections) to obtain survey age compositions. Similar to the fishery length compositions discussed above, a large proportion of northern rockfish lengths are greater than the current plus length bin (38 cm); especially in recent years. Also similar to the fishery age compositions, the proportion of older fish has been increasing since the mid to early 2000s.

### Maturity data

In previous stock assessments for northern rockfish, age at maturity was been based on a logistic curve fit to ovarian samples collected from female northern rockfish in the central Gulf of Alaska (GOA) in the spring of 1996 (n=75, C. Lunsford pers. comm. July 1997, Heifetz et al. 2009). A more recent study reevaluating maturity of northern rockfish (Chilton 2007, n=157) has been published, providing additional information for maturity-at-age. This study collected ovarian samples from female northern rockfish throughout the year in both 2000 and 2001. In a report submitted to the GOA Groundfish Plan Team in September 2010, the two studies were compared and the advantages and disadvantages of the different approaches for studying maturity (histology versus visual inspection) were discussed (Rodgveller et al. 2010). In this year’s assessment, as in the 2011 assessment, we combine the data from both studies to estimate maturity of northern rockfish. Due to the relatively small sample sizes for each study, the close proximity in time for each study (4 years apart compared to the 51 year time series used in this assessment), and the large difference in the age at 50% maturity (12.8 years used in previous assessments compared to 8 years obtained by Chilton 2007), we combine these data and estimate an intermediate maturity-at-age rather than consider time-dependent changes in maturity (Figure 10.8). There could be time-dependent changes in maturity-at-age for northern rockfish, although, additional data would be necessary to evaluate this hypothesis.

## Analytical Approach

### Model structure

### Alternative models

### Parameters estimated outside the assessment model

### Parameters estimated inside the assessment model

### Uncertainty approach

### Data weighting

## Results

### Model evaluation

### Time series

### Harvest recommendations

### Status determination

#### Specified catch estimation

#### Alternate projection

### Apportionment of ABC

## Ecosystem considerations

### Ecosystem effects on the stock

### Rockfish fishery effects on the ecosystem

## Data Gaps and Research Priorities

## Literature Cited

Ackley, D. R., and J. Heifetz. 2001. Fishing practices under maximum retainable bycatch rates in Alaska’s groundfish fisheries. Alaska Fish. Res. Bull. 8:22-44.

Allen, M. J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Tech. Rep. NMFS 66, 151 p.

Alverson, D. L., and M. J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer 36(2): 133-143.

Berkeley, S. A., M. A. Hixon, R. J. Larson, and M. S. Love. 2004. Fisheries Sustainability via Protection of Age Structure and Spatial Distribution of Fish Populations. Fisheries 29:23-32.

Bettoli, P.W., and L.E. Miranda. 2001. Cautionary note about estimating mean length at age with subsampled data. N. Amer. J. Fish. Man. 21:425-428.

Beyer, S. G., S.M. Sogard, C.J. Harvey, and J.C. Field. 2015. Variability in rockfish (Sebastes spp.) fecundity: species contrasts, maternal size effects, and spatial differences. Environmental Biology of Fishes 98(1): 81-100.

Boldt, J. L., and L. J. Haldorson. 2004. Size and condition of wild and hatchery pink salmon juveniles in Prince William Sound, Alaska. Transactions of the American Fisheries Society 133:173. Brodeur, R. D., 2001 Habitat -specific distribution of Pacific ocean perch (Sebastes alutus) in Pribilof Canyon, Bering Sea. Continental Shelf Research 21:207-224.

Byerly, M. M., 2001. The ecology of age 1 Copper Rockfish (Sebastes caurinus) in vegetated habitats of Sitka sound, Alaska. M.S. Thesis University of Alaska, Fairbanks.

Carlson, H.R., and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, Sebastes spp., in rocky, coastal areas of southeastern Alaska. Mar. Fish. Rev. 43(7): 13-19.

Chilton, E., 2007. Maturity of female northern rockfish Sebastes polyspinis in the central Gulf of Alaska. Alaska Fish. Res. Bull. 12:264-269.

Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60.

Clausen, D., and J. Heifetz. 2002. The Northern rockﬁsh, Sebastes polyspinis, in Alaska: commercial fishery, distribution, and biology. Mar. Fish. Rev. 64: 1-28.

Courtney, D.L., J. Heifetz, M. F. Sigler, and D. M. Clausen. 1999. An age structured model of northern rockfish, Sebastes polyspinis, recruitment and biomass in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2000. Pp. 361-404. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Courtney, D.L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (Sebastes spp.). In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O’Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 429–449.

de Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, Sebastes aleutianus and S. alutus. Biol. Reprod. 71: 1036-1042.

Drinkwater, K., 2004. Summary Report: Review on evaluation of fishing activities that may adversely affect Essential Fish Habitat (EFH) in Alaska. Center of Independent Experts Review (CIE) June 2004, Alaska Fisheries Science Center, Seattle, Washington.

Du Preez, C. and V. Tunnicliffe. 2011. Shortspine thornyhead and rockfish (Scorpaenidae) distribution in response to substratum, biogenic structures and trawling. Mar. Ecol. Prog. Ser 425: 217-231.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Freese, J.F., and B.L. Wing. 2003. Juvenile red rockfish, Sebastes spp., associations with sponges in the Gulf of Alaska. Mar. Fish. Rev. 65(3):38-42.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall, London. 526 pp.

Gertseva, V., and J. T. Thorson. 2013. Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2013. National Marine Fisheries Service, Northwest Fisheries Science Center, Fisheries Resource and Monitoring Division, Seattle, WA.

Gharrett, A. J., A.K. Gray, and J. Heifetz. 2001. Identification of rockfish (Sebastes spp.) from restriction site analysis of the mitochondrial NM-3/ND-4 and 12S/16S rRNA gene regions. Fish. Bull. Fish. Bull. 99:49-62.

Gharrett, A. J., A. K. Gray, D. Clausen and J. Heifetz. 2003. Preliminary study of the population structure in Alaskan northern rockfish, Sebastes polyspinis, based on microsatellite and tDNA variation. Fisheries Division, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau AK 99801 Unpublished contract report. 16 p.

Gharrett, A. J., R. J. Riley, and P. D. Spencer. 2012. Genetic analysis reveals restricted dispersal of northern rockfish along the continental margin of the Bering Sea and Aleutian Islands. Trans. Am. Fish. Soc. 141:370-382.

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. Hannah, R. W., and S. J. Parker. 2007. Age-modulated variation in reproductive development of female Pacific Ocean Perch (Sebastes alutus) in waters off Oregon. Pages 1–20 in J. Heifetz, J. DiCosimo, A. J. Gharrett, M. S. Love, V. M. O’Connell, and R. D. Stanley, editors. Biology, assessment, and management of North Pacific rockfishes. University of Fairbanks, Alaska Sea Grant Program, Report AK-SG-07-01, Fairbanks. Hanselman, D., P. Spencer, S.K. Shotwell, and R. Reuter. 2007. Localized depletion of three Alaska rockfish species, p. 493-511. In J. Heifetz, J. DiCosimo, A. J. Gharrett, M. S. Love, V. M. O’Connell, and R. D. Stanley (editors), Biology, Assessment, and Management of North Pacific Rockfishes. University of Alaska Sea Grant Program Report No. AK-SG-07-01, University of Alaska, Fairbanks.

Hanselman, D.H., B. Clark, and M. Sigler. 2013. Report of the groundfish plan team retrospective investigations group, part II: the compilation. Presented at September 2013 Plan Team, 12 pp. <http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Retrospectives_2013_final3.pdf>

Heifetz, J., 2002. Coral in Alaska: distribution, abundance, and species associations. Hydrobiologia. 471:19-28.

Heifetz, J., D. Hanselman, J. Ianelli, S.K. Shotwell, and C. Tribuzio. 2009. Assessment of the Northern Rockfish Stock in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the 2010 Gulf of Alaska groundfish fishery, p. 817-874. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Heifetz, J., and D. M. Clausen. 1991. Slope rockfish. In Stock assessment and fishery evaluation report for the 1992 Gulf of Alaska groundfish fishery, p. 5-1 - 5-30. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Heifetz, J., D. M. Clausen, and J. N. Ianelli. 1994. Slope rockfish. In Stock assessment and fishery evaluation report for the 1995 Gulf of Alaska groundfish fishery, p. 5-1 - 5-24. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hulson, P.-J. F., D. H. Hanselman, S. K. Shotwell, and J. N. Ianelli, 2011. Assessment of the northern rockfish stock in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 893-970. North Pacific Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99501.

Ito, D. H., 1982. A cohort analysis of Pacific ocean perch stocks from the Gulf of Alaska and Bering Sea regions. U.S. Dept. Commer., NWAFC Processed Rept. 82-15.

Jones, G.L., and J.P. Hobert. 2001. Honest exploration of intractable probability distributions via Markov Chain Monte Carlo. Statistical Science 16(4):312-334.

Kamin, L. M., K. J. Palof, J. Heifetz, and A.J. Gharrett, A. J. 2013. Interannual and spatial variation in the population genetic composition of young-of-the-year Pacific ocean perch (Sebastes alutus) in the Gulf of Alaska. Fisheries Oceanography. doi: 10.1111/fog.12038

Krieger, K. J., 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull. 91: 87-96.

Krieger, K.J., and B. L. Wing .2002. Megafauna associations with deepwater corals (Primnoa spp.) in the Gulf of Alaska. Hydrobiologica 471: 83-90.

Laman, E.A., S. Kotwicki, and C.N. Rooper. 2015. Correlating environmental and biogenic factors with abundance and distribution of Pacific ocean perch (Sebastes alutus) in the Aleutian Islands, Alaska. Fishery Bulletin 113(3).

Leaman, B. M., 1991. Reproductive styles and life history variables relative to exploitation and management of Sebastes stocks. Environmental Biology of Fishes 30: 253-271.

Malecha, P.W., D.H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfishes (Scorpaenidae) from Alaska waters. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-172, 61 p.

Maunder, M. N., and A. E. Punt. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70:141-159.

Methot, R. D., and I. G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1744-1760.

Miller, J.A., and A L. Shanks. 2004. Evidence for limited larval dispersal in black rockfish (Sebastes melanops): implications for population structure and marine-reserve design Canadian Journal of Fisheries and Aquatic Sciences, 61(9) pp. 1723-1735.

National Marine Fisheries Service. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. <http://www.fakr.noaa.gov/habitat/seis/efheis.htm>. Quinn, T. J., and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, New York, 542 p. Rodgveller, C., J. Heifetz, and C. Lunsford. 2010. Maturity estimates for Pacific ocean perch (Sebastes alutus), dusky (S. ciliatus), northern (S. polyspinus), rougheye (S. aleutianus), and blackspotted (S. melanostictus) rockfish. Report submitted to the Gulf of Alaska Groundfish Plan Team.

Rodgveller, C.J., C.R. Lunsford, and J.T. Fujioka. 2012. Effects of maternal age and size on embryonic energy reserves, developmental timing, and fecundity in quillback rockfish (Sebastes maliger). Fishery Bulletin 110(1): 36-45.

Shelton, A. O., J. T. Thorson, E. J. Ward, and B. E. Feist. 2014. Spatial semiparametric models improve estimates of species abundance and distribution. Canadian Journal of Fisheries and Aquatic Sciences 71:1655-1666.

Spencer, P.D., and J.N. Ianelli. 2012. Assessment of the Pacific ocean perch stock in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands, p. 1291-1348. North Pacific Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99501.

Stefansson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science 53:577-588.

Thorson, J. T. 2018. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. Fisheries Research. 210: 143-161.

Thorson, J. T., and K. Kristensen. 2016. Implementing a generic method for bias correction in statistical models using random effects, with spatial and population dynamics examples. Fisheries Research 175: 66-74.

Thorson, J. T., A. O. Shelton, E. J. Ward, and H. Skaug. 2015a. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science. Doi: 10.1093/icesjms/fsu243.

Thorson, J. T., H. J. Skaug, K. Kristensen, A. O. Shelton, E. J. Ward, J. H. Harms, and J. A. Benante. 2015b. The importance of spatial models for estimating the strength of density dependence. Ecology 96:1202-1212.

Thorson, J. T., I. J. Stewart, and A. E. Punt. 2011. Accounting for fish shoals in single- and multi-species survey data using mixture distribution models. Canadian Journal of Fisheries and Aquatic Sciences 68:1681-1693.

Thorson, J. T., and E. J. Ward. 2014. Accounting for vessel effects when standardizing catch rates among cooperative surveys. Fisheries Research 155:168-176.

Ver Hoef, J. M., and J. K. Jansen. 2007. Space—time zero-inflated count models of Harbor seals. Environmetrics 18:697-712.

von Szalay, P. G., and N. W. Raring. 2016. Data report: 2015 Gulf of Alaska bottom trawl survey., U.S. Dep. of Commer.

Withler, R.E., T.D. Beacham, A.D. Schulze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, Sebastes alutus, in Queen Charlotte Sound, British Columbia. Mar. Bio. 139: 1-12. Yang, M-S., 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Yang, M-S., 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.

Yang, M-S., and M. W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

Fig cap text

# Tables

Table 1: Summary of key management measures and the time series of catch, ABC, and TAC for northern rockfish in the Gulf of Alaska

| year | catch |
| --- | --- |
| 1,999 | 1 |
| 2,000 | 2 |