22. Assessment of the Octopus Stock Complex in the Gulf of Alaska

M. Elizabeth Conners and Christina L. Conrath
Alaska Fisheries Science Center
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Executive Summary

In 2011, the GOA fisheries management plan was amended to provide separate management for, several groups formerly in the "other species" category, including octopus. In compliance with the reauthorized Magnuson-Stevens act, each group must have its own annual catch limit. Catch limits for octopus for 2011 - 2014 were set under Tier 6 with an alternative method based on using the average of the last 3 surveys as a minimum biomass estimate. This method is continued for 2015- 2016.

For management purposes, all octopus species are grouped into a single assemblage. At least seven species of octopus are found in the Gulf of Alaska (GOA). The species composition both of the natural community and the commercial harvest is not well documented, but research indicates that the Giant Pacific octopus *Enteroctopus dofleini* is the most abundant octopus species in shelf waters and makes up the bulk of octopus catches in commercial fisheries. Octopuses are taken as incidental catch in trawl, longline, and pot fisheries throughout the GOA; a portion of the catch is retained or sold for human consumption or bait. The highest octopus catch rates are from Pacific cod pot fisheries in the central and western GOA (NMFS statistical areas 610 and 630).

In general, the state of knowledge about octopus in the GOA is poor. A number of research studies and special projects have been initiated in recent years to increase knowledge for this assemblage; these include studies of delayed mortality of discarded octopus and development of an octopus-specific fishing gear for possible scientific use. A review by the Center for Independent Experts of the stock assessments for North Pacific non-target species was conducted in May 2013. Suggestions and recommendations from this review are discussed below.

Summary of Changes in Data

There was no survey of the GOA in 2014, so survey results from summer 2013 remain the most recent fishery-independent data. Commercial catch data for the octopus complex have been updated through October 17, 2014. The estimated total catch for 2013 was 423 t and the partial catch for 2014 was 709 t.

Summary of Changes in Asessment Methods

There are no proposed changes in assessment methodology.

Summary of Results

The current data are not sufficient for a model-based assessment. The SSC and Plan Teams have discussed the difficulties in applying groundfish methodologies to octopus and have agreed to treat octopus as a Tier 6 species. There are no historical records of directed fishing for octopus, and the authors and Plan Teams are concerned that historical catch methods may result in an overly conservative catch limit. In 2010 - 2014, the GOA Plan Team chose to use an approach where the average of three most recent survey biomass estimates is used as a minimum biomass estimate, and a mortality factor applied. The OFL for octopus in 2014 and 2015 was set at 2010 tons. Since there are no new survey data, this number remains the recommended OFL for 2015 and 2016. There is insufficient data to determine whether the complex is being subjected to overfishing, is currently overfished, or is approaching a condition of being overfished.

Summary of Harvest Recommendations

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
Tier 6 (3 survey biomass * M)	6(alt)	6(alt)	6(alt)	6(alt)
OFL (t)	2,009	2,009	2,009	2,009
ABC (t)	1,507	1,507	1,507	1,507
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing		n/a	n/a	n/a

Responses to SSC and Plan Team Comments

At their December 2013 meeting, the SSC requested information on octopus stock structure and supported the use of a three-survey average for estimating minimum biomass. The SSC and plan team reviewed a random effects model for survey biomass in 2013, but elected to await further research before adopting this approach for species complexes. The SSC also expressed support for several research priorities from the recent CIE review, including estimating mortality from tagging studies, gathering and updating growth rates for octopus from ongoing studies, and investigating the sue of a size-structured model. These projects are all being conducted; a size-structured model for octopus is under development but was not ready for the 2014 assessment cycle. In regards stock structure, a limited amount of research has been conducted recently on octopus genetics; this information will be added to the description of life history of *Enteroctopus dofleini* in the next full assessment. The work to date identifies a possible sub-species within Prince William Sound, but does not indicate any strong variation between octopus sampled at GOA locations from southeast Alaska to Dutch Harbor (Toissant et al. 2012),

Area apportionment of catch for a possible directed octopus fishery was discussed in the 2013 assessment, and the plan teams and SSC accepted an apportionment method based on survey data. The SSC made several recommendations to the Council of factors to be considered before allowing a directed octopus fishery. These included further development of survey techniques through an experimental fishery, a possible minimum size limit, and 100% observer coverage of any directed fishery. The assessment authors are in full concurrence on these recommendations.

Responses to CIE Review Comments

In May 2013, a panel from the Center for independent Experts (CIE) reviewed the AFSC stock assessments for non-target species. The panel reviewed assessments for sculpins, sharks, skates, grenadiers, squid, and octopus. The panel provided comments both on individual assessments and on the overall Tier 5 and Tier 6 process. All of the reviewers agreed that for Tier 5, “The main problem is the assumption that trawl survey biomass indices are legitimate estimates of absolute biomass”. The reviewers suggested that issues of survey coverage, catchability, selectivity, and habitat coverage (i.e. extending survey data to represent untrawlable areas) all made is difficult to treat survey estimates as absolute biomass. These issues are being addressed by the AFSC survey groups as far as funding and staffing will allow, but probably cannot be fully resolved. For octopus, the difficulties with survey biomass estimates include lack of survey coverage of shallow areas and rocky habitats; an unknown but probably large catchability effect, size selectivity issues, and large variance of estimates due to the fairly rare occurrence of octopus in trawl catch. These issues have already been recognized for octopus and are discussed under “Model Parameters”. The reviewers agreed with the existing assessments that “The bottom trawl is likely inadequate for sampling other nontarget species such as squid, sharks and octopus.”

The reviewers also recommended that the determination of ABC be based on a species-specific assessment of uncertainty rather than a fixed percentage of OFL. Changing this procedure is feasible but would require changes to the regulatory structure of FMPs and is best addressed at the plan teams, SSC, and Council. All three reviewers also noted various problems with the use of historical incidental catch data for stock assessment, and recommended that where there was no other alternative, the time period of historical be selected on a species-specific basis.

Specific to the octopus assessment, the reviewers primarily noted difficulties and limitations with all of the methods that have been used or proposed to date. One reviewer stated “*If budget allows, I recommend that a dedicated survey with habitat pot gear as developed by Conners et al. (2012), with some refinement, be used to track year-to-year variation in octopus biomass overtime in different areas*.” Research to develop and refine the pot gear is currently being conducted. Another reviewer concluded that the consumption estimate approach was probably the best of a set of poor alternatives, and suggested several ways to check and refine consumption model estimation. While the consumption model estimates have not been updated for this assessment, the suggested modifications will be examined during the next update of consumption estimates.

The third reviewer strongly advocated that ”*The use of M as a proxy for F_{MSY} is unnecessary and may be inappropriate for many species (as F_{MSY} depends strongly on the stock-recruitment relationship and the fishery selectivity). It is preferable to construct a simple species/stock-specific simulation model and use it to explore the plausible parameter space to determine an appropriate proxy for F_{MSY}.*” and provided an example of such a model for octopus. This model suggested that $F_{40\%B0}$ would be a better alternative to catch regulation that F_{MSY}. In the absence of any reliable estimate of B, however, it would be difficult to calculate this quantity.

Based on CIE comments, the author has started to examine a size-based assessment model for octopus, both to use as a simulation model for indentifying monitoring and management metrics and for possible fitting to habitat pot data. This model is not yet ready to present to the plan teams, but will be brought forward in 2015.

Data

Incidental Catch Data

Incidental catch of GOA octopus is shown in Table 1. Catches in 2007-2010 were between 250 and 350 t. Incidental catch in 2011 was the highest ever observed, with a total annual catch over 900 tons. The majority of this very large catch came during the fall Pacific cod pot fishery in statistical areas 610 and 630. Commercial catch data for the octopus complex have been updated through October 17, 2014. The estimated total catch for 2013 was 423t and the partial catch for 2014 was 709t. As in previous years, the majority of the 2013-2014 catch came from Pacific cod fisheries, primarily pot fisheries in statistical reporting areas 610 and 630. Approximately 50% of this catch was retained in each year.

Analytic Approach, Model Evaluation, and Results

The available data do not support population modeling for either individual species of octopus in the GOA or for the multi-species complex. As better catch and life-history data become available, it may become feasible to manage the key species *E. dofleini* through a size-based model. For the last few years, the GOA plan team has elected to use a special approach under Tier 6, which uses a minimum biomass estimate and a mortality rate based on life history parameters, assuming the logistic model used for Tier 5.

Parameters Estimated Independently – Biomass B

Estimates of octopus biomass based on the semi-annual GOA trawl surveys (Table 2, Figure 1) represent total weight for all species of octopus, and are formed using the sample procedures used for estimating groundfish biomass (National Research Council 1998, Wakabayashi et al. 1985). The positive aspect of these estimates is that they are founded on fishery-independent data collected by proper design-based sampling. The standardized methods and procedures used for the surveys make these estimates the most reliable biomass data available. The survey methodology has been carefully reviewed and approved in the estimation of biomass for other federally-managed species. There are, however, some serious drawbacks to use of the trawl survey biomass estimates for octopus.

Older trawl survey data, as with industry or observer data, are commonly reported as *octopus sp.*, without full species identification. In surveys prior to 2003, most octopus collected were not identified to species. In more recent years, a greater fraction of collected octopus is identified to species, but some misidentification may still occur. Efforts to improve species identification and collect biological data from octopus are being made, but the survey is only beginning to provide species-specific information that could be used in a stock assessment model.

As noted in previous assessments, the survey trawl may not be suitable gear for sampling octopus. The bottom trawl net used for the GOA survey has roller gear on the footrope to reduce snagging on rocks and obstacles and may allow benthic organisms, including octopus, to escape under the net. Given the tendency of octopus to spend daylight hours near dens in rocks and crevices, it is entirely likely that the actual capture efficiency for benthic octopus is poor (D. Somerton, personal communication, 7/22/05). Trawl sampling is not conducted in areas with extremely rough bottom and/or large vertical relief, exactly the type of habitat where den spaces for octopus would be most abundant (Hartwick and Barringa 1989). The survey also does not sample in inshore areas and waters shallower than 30m, which may contain sizable octopus populations (Scheel 2002). The estimates of biomass in Table 2 are based on a gear selectivity coefficient of one, which is probably not realistic for octopus. For this reason, these are probably conservative underestimates of octopus biomass in the regions covered by the survey. The large numbers of survey tows with no octopus also tend to increase the sampling variability of the survey estimates; in many years, octopus were present in less than 10% of the survey tows.

There is a considerable difference in size selectivity between survey trawl gear and industry pot gear that catches most of the octopus harvested. The average weight for individual octopus in survey catches is 2.0 kg; over 50% of survey-collected individuals weigh less than 0.5 kg. Larger individuals are strong swimmers and may be more adept at escaping trawl capture. In contrast, the average weight of individuals from commercial pot gear was over 20 kg. Pot gear is probably selective for larger, more aggressive individuals that respond to bait, and smaller octopus can easily escape commercial pots while they are being retrieved. Unlike the BSAI, the depth range of octopus catches in the GOA is similar between industry and survey data, although pot fisheries tend to be concentrated in shallower shelf waters**.** There is also a seasonal difference between summer trawl surveys and the fall and winter cod seasons, when most octopus are harvested. In general, it may be possible to use trawl survey data as an index of interannual variation in abundance, but the relationship between the summer biomass of individuals vulnerable to trawls and the fall or winter biomass available to pot fisheries will be difficult to establish. The biomass of octopus estimated by the trawl survey is expected to be a minimum estimate of octopus biomass, as the larger octopus are not well represented.

Species-specific methods of biomass estimation are needed for octopus and are being explored. Octopus are readily caught with commercial or research pots. An index survey of regional biomass in selected areas of the Kodiak and Shumagin regions would be appropriate and is highly feasible. It may also be feasible to estimate regional octopus biomass using mark-recapture studies or depletion methods (Caddy 1983, Perry et al. 1999). For the 2015 assessment, a size-based stage-structure model is being explored.

Parameters Estimated Independently – Mortality Rate M

It is important to note than not all species of octopus in the GOA have similar fecundity and life history characteristics. This analysis is based on *E. dofleini*, which probably make up the majority of the harvest. Since *E. dofleini* are terminal spawners, care must be taken to estimate mortality for the intermediate stage of the population that is available to the fishery but not yet spawning (Caddy 1979, 1983). If detailed, regular catch data within a given season were available, the natural mortality could be estimated from catch data (Caddy 1983). When this method was used by Hatanaka (1979) for the West African *O. vulgaris* fishery, the estimated mortality rates were in the range of 0.50-0.75. Mortality may also be estimated from tagging studies; Osako and Murata (1983) used this method to estimate a total mortality of 0.43 for the squid *Todarodes pacificus*. Empirical methods based on the natural life span (Hoenig 1983, Rikhter and Efanov 1976) or von Bertalanffy growth coefficient (Charnov and Berrigan 1991) have also been used. While these equations have been widely used for finfish, their use for cephalopods is less well established. Perry et al. (1999) and Caddy (1983) discuss their use for invertebrate fisheries.

If we apply Hoenig's (1983) equation to *E. dofleini*, which have a maximum age of five years, we get an estimated M = 0.86. **Rikhter and Efanov's (1976) equation gives a mortality value of 0.53 based on an age of maturity of 3 years for *E. dofleini*.** The utility of maturity/mortality relationships for cephalopods needs further investigation, but these estimates represent the best available data at this time. The Rikhter and Evanov estimate of M=0.53 represents the most conservative estimate of octopus mortality, based on information currently available. If future management of octopus is to be based on Tier 5 methods, a direct estimate of octopus mortality in the GOA, based on either experimental fishing or tagging studies, is desirable. Tagging studies of octopus in the Bering Sea are expected to produce an estimated mortality rate for large octopus by the 2014 stock assessment.

Projections and Harvest Alternatives

None of the existing groundfish Tier strategies are well suited to the available information for octopus. We recommend that octopus be managed very conservatively due to the poor state of knowledge of the species, life history, distribution, and abundance of octopus in the GOA. Further research is needed in several areas before octopus could be managed by the methods used for commercial groundfish species. Regulatory limits under two different strategies are presented below.

Trawl survey estimates of biomass for the species complex represent the best available data at this time. There are serious concerns, however, about both the suitability of trawl gear for accurately sampling octopus biomass and the extent to which the survey catch represents the population subject to commercial harvest. If future management of the octopus complex under Tier 5 is envisioned, then dedicated field experiments are needed to obtain both a more realistic estimate of octopus biomass available to the fishery and a more accurate estimate of natural mortality rates.

For the last few years, the GOA plan team has elected to use a special approach under Tier 6, which uses a minimum biomass estimate and a mortality rate based on life history parameters, assuming the logistic model used for Tier 5. **If the average biomass from the three most recent surveys (2009, 2011, and 2013) of 3,791 tons and the conservative M estimate of 0.53 are used, the OFL and ABC for GOA octopus would be 2,009 and 1,507 tons, respectively. These limits were presented in the 2013 full stock assessment for GOA octopus, and are recommended for continued use as catch limits for 2015-16.**

Because of the overall lack of biological data and the large uncertainty in abundance estimates, we do not recommend a directed fishery for octopus in federal waters at this time. We anticipate that octopus harvest in federal waters of the GOA will continue to be largely an issue of incidental catch in existing groundfish fisheries.

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Table 1. Estimated state and federal catch (t) of all octopus species combined, by target fishery. Catch for 1997-2002 estimated from blend data. Catch for 2003-2014 data from AK region catch accounting. *Data for 2014 are as of October 17, 2014; catch figures for flatfish targets have been revised to include the IFQ Halibut fishery.

	Target Fishery						
Year	**Pacific cod**	**Pollock**	**Flatfish***	**Rockfish**	**Sablefish**	**Other**	**Total**
1997	193.8	0.7	1.3	2.3	22.4		232
1998	99.7	3.5	4.3	0.8	0.3		112
1999	163.2	0.0	2.4	0.5	0.2		166
2000	153.5	-	0.7	0.2	0.5		156
2001	72.1	0.2	0.8	0.0	2.0		88
2002	265.4	0.0	17.2	0.7	1.0		298
2003	188.9	-	16.6	0.6	2.9	0.1	210
2004	249.8	0.0	2.8	0.4	0.1	16.5	270
2005	138.6	0.1	2.4	0.2	0.2	1.7	149
2006	151.0	3.4	1.9	0.5	0.3	0.2	166
2007	242.0	1.5	9.7	0.1	1.8	-	257
2008	326.0	0.0	5.2	2.9	0.2	0.1	339
2009	296.8	0.1	10.1	1.2	0.3	0.9	310
2010	263.7	0.8	15.4	3.7	0.5	41.9	326
2011	859.4	2.3	49.9	0.9	0.8	1.1	918
2012	408.1	0.4	4.6	0.9	0.8	-	421
2013	320.4	0.3	112.4	1.5	16.5	0.0	423
2014*	586.9	6.7	79.4	4.4	6.6	2.1	709

Table 2. Biomass estimates for octopus (all species combined) from GOA bottom trawl surveys.

Survey	Survey	Hauls with Octopus		Estimated
Year	Hauls	Num	%	Biomass (t)
1984	929	89	9.6%	1,498
1987	783	35	4.5%	2,221
1990	708	34	4.8%	1,029
1993	775	43	5.5%	1,335
1996	807	34	4.2%	1,960
1999	764	47	6.2%	994
2001	489	29	5.9%	994
2003	809	70	8.7%	3,767
2005	839	56	6.7%	1,125
2007	820	71	8.7%	2,296
2009	824	172	20.9%	3,791
2011	704	75	10.6%	4,897
2013	**548**	**62**	**11.3%**	**2,685**

Figure1. GOA octopus survey biomass estimates and confidence intervals.