Discussion paper regarding assessment of squid in the BSAI & GOA
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Overview

Assessment of squid in the BSAI and GOA areas was reviewed in May 2013 by the Council of Independent Experts (CIE). The reviewers had a number of comments regarding Tier 6 management in general and squid assessment in particular. Many of the concerns they raised are issues that have been discussed repeatedly at the Plan Team and SSC level, but they also noted that the approach used for making harvest recommendations should be consistent between the BSAI and GOA areas. This document was prepared as a response to the CIE review and includes suggestions for alternatives to the current assessments that would be consistent between the BSAI and GOA.

Brief history of squid catches and management

Recent assessments (Ormseth 2011, 2012) provide extensive detail regarding squid catch and management history and the differences between the BSAI and GOA. In the BSAI, squid catch data begin in 1977 with some large catches during the foreign and joint-venture that may indicate targeting (Table 1 and Figure 1). In the GOA, catch records begin in 1990 with little indication of directed fishing (Table 1 and Figure 1). Recent patterns of incidental catches are similar in both areas, with years of relatively low catch interspersed with much higher than average catches. The 2014 catch of squid to date appears to be well above the average of recent catches with 1,461 t taken in the BSAI as of 9/8/2014. This exceeds the TAC of 310 t but remains well below the ABC of 1,907 t and the OFL of 2,624 t. The 2014 GOA catch (57 t as of 9/8/2014) is well below the TAC of 1,148 t.

Management of squid also differs between the two areas. In the BSAI, squid have been managed as a target or "in the fishery" stock since the NPFMC Tier system was adopted. Harvest recommendations are made using the Tier 6 approach, with OFL equal to the average catch 1978-1995. In contrast, squid in the GOA were managed as part of the Other Species complex until 2011 when the complex was split into 4 species groups. At that time, the SSC selected a Tier 6 approach for squid that specified an OFL equal to the maximum catch during 1997-2007 because catch data from the earlier period were unavailable.

The abundance of squid in the BSAI and GOA is highly uncertain. Survey biomass estimates (Table 2) have acceptable CVs but undoubtedly underestimate squid populations. Estimates from mass-balance ecosystem models indicate that squid biomass may be two orders of magnitude higher (880,000 t in the BSAI and 369,000 t in the GOA; Aydin et al. 2007) but these estimates are also highly uncertain. Survey biomass estimates are higher in the GOA than in the BSAI (recent averages of 7,759 t and 4,932 t, respectively), but this may be due in part to differences in survey design between the two areas. Relative to the EBS shelf and slope surveys, the GOA trawl survey has a higher density of stations in deeper waters and slope habitats where squid are more likely to be encountered.

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Summary of CIE reviewer's comments (detailed comments can be found in the appendix)

1) The reviewers asserted that the management approach for squid should be consistent between the BSAI and GOA areas.
2) There was general skepticism regarding the use of catch data for setting harvest specifications for non-target stocks.
3) The reviewers gave conflicting advice regarding the appropriate catch periods for OFL estimation, but were unanimous that the BSAI period was inappropriate because it straddles the foreign and domestic fishing eras.

Response to CIE review and suggested alternatives for squid management

The CIE reviewers raised valid concerns, and many of the issues they identified have been discussed by the Plan Teams and SSC in previous years (e.g. when sharks were established as a separate stock complex in 2011). In many ways addressing the CIE's comments on squid also means addressing the general problem of data-limited stocks and Tier 6 management. There are 3 possible alternatives for proceeding with the assessment and management of squid:

1) *Maintain the current split approach*: Because catch and management histories are different between the BSAI and the GOA, it may be appropriate to maintain the status quo (i.e. refute the CIE reviewer's comments).
2) *Use identical Tier 6 approaches for both BSAI and GOA*: If consistency between the two areas is of value, a common methodology needs to be adopted for making harvest recommendations. This document considers a number of such possibilities.
3) *Develop a new approach*: Since the current Tier 6 alternatives are problematic for squid management, an alternative would be to develop an approach that recognizes that current incidental catches are unlikely to be a conservation concern for squid stocks. This approach would directly address the issues of allowing current fishing practices to continue and prohibiting the development of a directed fishery unless sufficient data are collected to properly evaluate and monitor squid stocks.

Catch-based alternatives

Catch-based approaches to setting harvest specifications have been debated with the understanding that the Tier 6 approach was designed to prevent the development of directed fisheries unless sufficient data became available to a bring the stock to a higher tier. The CIE reviewers did not offer any new suggestions for using catch data. For exploring alternatives in this document (results are in Table 3), the following approaches were used: OFL = average catch, OFL = maximum catch, OFL = the upper bound of a 95% or 99% confidence interval of average catch. Several time periods were investigated, with the following rationale:

- 1997-2007: This is the period currently used in the GOA squid SAFE and represents a recent era of catches
- 1990-2007: This period represents the modern era of fish management in the BSAI and GOA, with a finite endpoint.
- 1978-1985: This is the period during which it is believed there was some targeting of squid. Unfortunately there are no catch data from the GOA during this period.

Results of the various approaches are shown in Table 3. Because there may have been some targeting of squid during the foreign fishery era, setting OFL equal to the average catch during 1978-1985 seems most consistent with the concept of Tier 6 management, i.e. that a sustained level of catch in a target fishery can be used as a proxy for MSY. However, those catches occurred following a significant change in the environment (generally warmer conditions) and may represent anomalies rather than sustainable catch levels. Squid populations are generally highly responsive to environmental changes (e.g. PFMC 2011) and tracking this level of interannual variability is problematic. A second problem is that catch data from this period are unavailable for the GOA. Both areas appear to support large squid populations. Survey biomass estimates in the GOA are 1.6 times as large as those in the BSAI; in contrast, ecosystem model estimates in the BSAI are 2.4 times as large as the GOA estimates. Since it is unclear which area has the larger population, the BSAI specifications could be applied to the GOA as well.

F x *B* approaches

An extensive review of stock assessment information from areas of the U.S. with directed squid fisheries (e.g. SWFSC 2001, NEFSC 2006, NEFSC 2010, PFMC 2011) demonstrates the difficulty of developing valid biological reference points for squid populations. This is due to their high natural mortality rate, multiple annual spawning cohorts, terminal spawning, and other factors. There is also difficulty in obtaining sufficient data to inform reference points. As noted above, biomass estimates are likely to be minimum estimates. Therefore the AFSC Tier 5 approach, where $F_{OFL} = M$ and OFL = F_{OFL} x biomass may be inappropriate for squid populations. Because options for squid management are limited, several alternative versions of the *F* x *B* approach were explored for this discussion:

Estimates of F: Natural mortality rates for squid are usually estimated at weekly or monthly timescales, so an *M* appropriate for annual specifications would be very high (equal to 1.0 or greater) and not realistic for use in an *F* x *B* approach. Two alternatives for $F_{OFL} = M$ were used:

- *F* = 0.3: This approach is supported by a yield-per-recruit analysis conducted for *Loligo pealei*, a squid species inhabiting the northwest Atlantic Ocean with roughly similar life history characteristics to *B. magister* (longevity approx. 2 years, max. length approx. 25 cm; Lange and Sissenswine 1983). For this species, F_{max} was determined to be approximately 0.3, depending on assumptions regarding *M* (Lange and Sissenswine 1983).
- Depletion function: This option was developed for an earlier squid assessment (Tenbrink et al. 2006). For this option the methodology is adapted to account for the effect of harvesting and natural mortality on squid biomass throughout the year by including a decay function based on total mortality (G. Thompson, AFSC, pers. comm. 2006,). Using this approach, and assuming an M of 1.0, OFL is estimated as average survey biomass * F_{OFL} * (1-exp(-*Z*))/(*Z*), where $Z = M+ F_{OFL}$, $M = 1.0$ and $F_{OFL} = M = 1.0$. ABC is calculated using the same approach, but substituting $F_{ABC} = 0.75 * M$ for F_{OFL}.

Estimates of biomass: As noted above, the survey biomass estimates could be considered as minimums. Populations of squid in the GOA appear to be variable suggesting only recent estimates should be used. For the GOA, survey estimates from 2009, 2011, and 2013 were averaged. For the BSAI, the biomass average included only data from the most recent years (2010 and 2012) when all 3 BSAI surveys were

conducted. An alternative biomass estimate, also suggested by one CIE reviewer, is the biomass estimate from the AFSC's mass-balance ecosystem models.

Evaluation of F x B results: Results are in Table 3. The depletion option produces higher estimates of OFL and ABC. Using the ecosystem model estimates of biomass results in large OFLs and ABCs.

New approaches

The validity of a new squid management approach is based on the recognition that current levels of incidental catches in the BSAI and GOA appear to be well below those that would pose a conservation concern. Current catch is likely much less than MSY. This is supported by the following observations:

- Due to their rapid growth and maturation and short lives, squid have inherently high stock productivity, and evidence from other areas (e.g. NEFMC 2010) suggests it is unlikely that a highly productive stock could be overfished in the absence of an intensive directed fishery. This is part of the rationale for the ACL exception in the Magnuson-Stevens Act for animals with a lifespan of 1 year or less.
- Although the biomass estimates from the ecosystem model are highly uncertain, and *F* x *B* approaches may be problematic for squid, it is apparent that the bottom trawl surveys substantially underestimate squid biomass. Thus even a very precautionary *F* x *B* approach would specify a higher OFL than is currently used.
- The best catch-based estimate, using 1978-1985 data, suggests that the OFL could be substantially higher than the current specification.

Because squid are unlikely to pose a conservation concern, it might be possible to depart from approaches based on estimation of OFL and instead focus on the twin objectives of 1) ensuring that specifications do not unnecessarily constrain current fisheries and 2) prohibiting the development of a directed fishery without sufficient information to properly manage stocks. Two potential means of achieving these goals are described briefly to provide a basis for discussion at the Joint Plan Team meeting in September 2014:

1) *Move squid to the Ecosystem Component (EC) category*: Squid meet the requirements for inclusion as EC species in the National Standard Guidelines. This option would not provide a limit to squid catches, but it would be possible to mandate catch monitoring and periodic review and return squid to the specification process if conservation concerns developed or there was interest in a directed fishery.
2) *Make harvest specifications based on total allowable catch (TAC) rather than OFL*: Under this option, ABC and TAC would be set at a level slightly larger than the maximum value of recent catches. OFL would then be specified at a level above the ABC to account for management uncertainty (i.e. uncertainty in limiting catches to the TAC). This approach would satisfy the objectives for management while prohibiting directed fishing (unless better information becomes available) and is very unlikely to exceed a fishing mortality rate that would achieve MSY for such a highly productive, short-lived species.

Neither of these approaches addresses the potential problem of spatially-concentrated high catches of squid that can occur in the BSAI and GOA. For example, in the BSAI during 2006 and 2007, large squid catches were highly localized along the shelf break and in the vicinity of canyons (Figure 2). As with any

fishing operation, there is the potential that removing a portion of the prey base (i.e., squid) in specific areas may adversely affect foraging opportunities for other species. On several occasions during the past decade the current catch limits have caused fisheries to move away such areas of high concentrations to avoid exceeding the squid TAC, and these actions may also be beneficial in that they limit the depletion of squid in localized areas. These observations are speculative because no information exists regarding the relationship between fishery removals of squid and changes in foraging opportunities for predators. Additional management measures to limit catch in particular areas (e.g. temporary spatial closures) could be used to complement any new management approach.

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Table 1. Squid catches in the BSAI and GOA, 1977-2014. The 2014 data are incomplete; last updated September 8, 2014.

year	BSAI total	GOA total
1977	6,734	0
1978	8,971	0
1979	6,538	0
1980	6,372	0
1981	5,945	0
1982	5,039	0
1983	3,980	0
1984	3,167	0
1985	1,620	0
1986	868	0
1987	131	0
1988	417	0
1989	306	0
1990	626	60
1991	632	117
1992	880	88
1993	683	104
1994	604	39
1995	459	25
1996	1,167	42
1997	1,474	97
1998	915	59
1999	441	41
2000	384	19
2001	1,766	91
2002	1,344	43
2003	1,282	97
2004	1,014	162
2005	1,186	636
2006	1,418	1,530
2007	1,188	416
2008	1,542	98
2009	360	345
2010	410	139
2011	336	238
2012	688	22
2013	299	319
2014	*1,461*	*57*

Table 2. Trawl survey biomass estimates (t) for the GOA and BSAI. Estimates for the BSAI include data from the EBS shelf and slope surveys, and the Aleutian Islands survey. BSAI data are only shown for those years where all 3 surveys conducted. CV= coefficient of variation; for the BSAI the 3 survey CVs were averaged.

	GOA squid	CV	BSAI squid	ave CV
1984	3,308	0.14		
1985				
1986				
1987	5,083	0.3		
1988				
1989				
1990	4,309	0.16		
1991				
1992				
1993	9,476	0.14		
1994				
1995				
1996	4,911	0.14		
1997				
1998				
1999	2,127	0.13		
2000				
2001	6,612	0.27		
2002			3,391	0.21
2003	6,322	0.18		
2004			4,898	0.44
2005	4,899	0.18		
2006				
2007	11,991	0.2		
2008				
2009	8,603	0.16		
2010			4,423	0.31
2011	4,431	0.14		
2012			5,440	0.27
2013	10,243	0.16		
2009-2013 average	7,759		4,932	

Table 3. Alternative approaches for determining squid harvest recommendations in the BSAI and GOA.

	BSAI		GOA	
current approach	OFL = 1978-1995 average		OFL = 1997-2007 maximum	
current specifications	OFL	ABC	OFL	ABC
	2,620	1,970	1,530	1,148
catch-based approaches	OFL	ABC	OFL	ABC
78-85 average	5,204	3,903	5,204	3,903
78-85 max	8,971	6,728	8,971	6,728
90-07 average	970	728	204	153
90-07 max	1,766	1,325	1,530	1,148
90-07 CI 95%UB	1,158	868	373	279
90-07 CI 99%UB	1,217	913	426	319
97-07 average	1,128	846	290	218
97-07 max	1,766	1,325	1,530	1,148
97-07 CI 95%UB	1,377	1,033	558	418
97-07 CI 99%UB	1,455	1,091	642	482
F x *B* approaches				
recent biomass average	4,932		7,759	
ecosystem model estimate	880,006		369,309	
	OFL	ABC	OFL	ABC
F=0.3 (survey)	1,479	1,110	2,328	1,746
decay function (survey)	2,132	1,936	3,354	3,046
F=0.3 (ecosystem model)	264,002	198,001	110,793	83,095
decay function (ecosystem model)	380,455	345,471	159,664	144,983

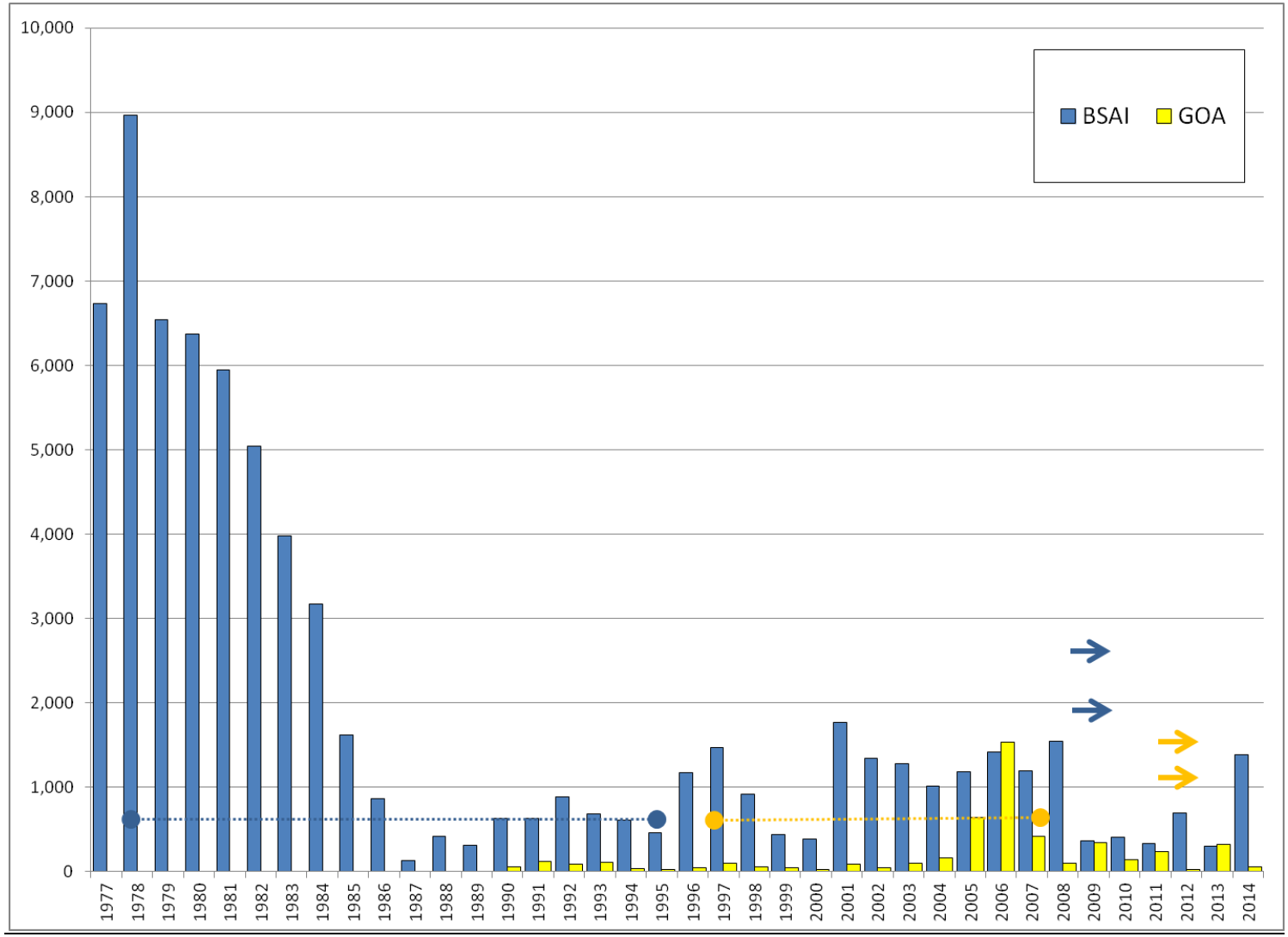
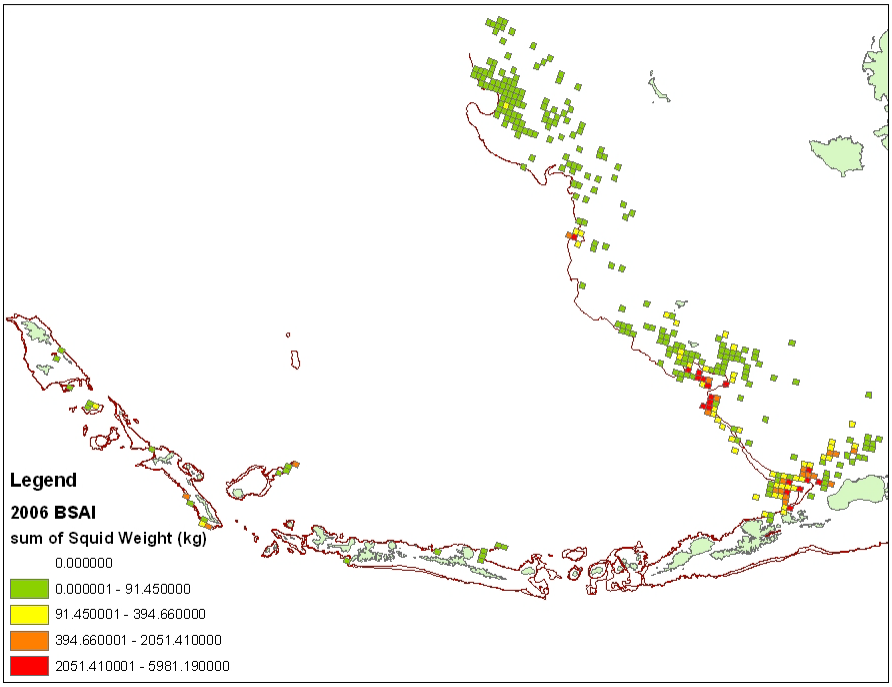


Figure 1, Catch of squid in the BSAI and GOA, 1977-2014. Blue arrows indicate current OFL & ABC for BSAI squid; yellow arrows indicate current OFL & ABC for GOA squid. Horizontal dashed blue line indicates time period used for BSAI specifications; horizontal dashed yellow line indicates period used for GOA specifications.

2006 BSAI



2007 BSAI

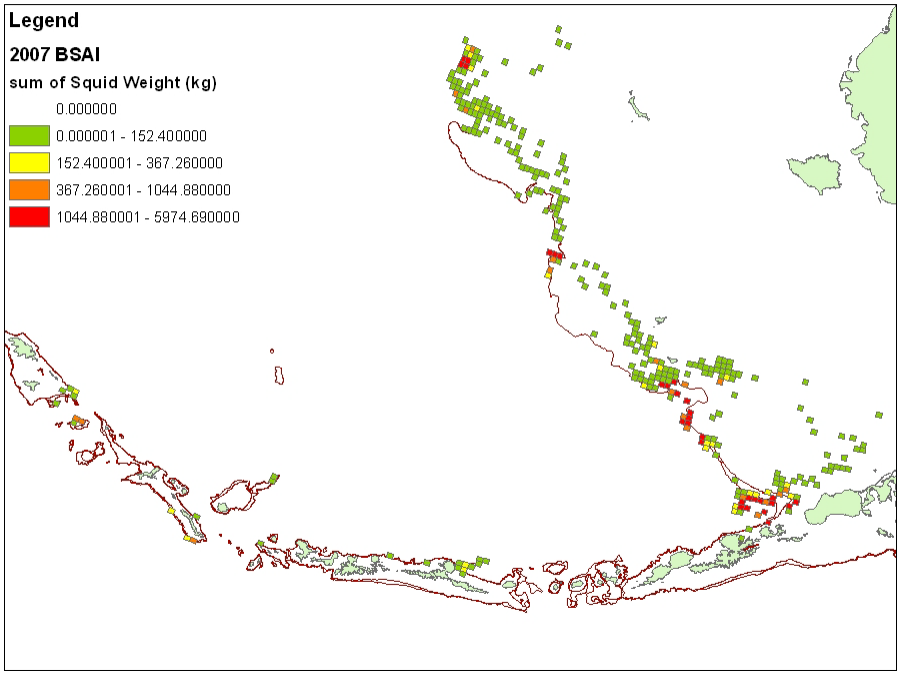


Figure 2. Distribution of annual squid catches from 2006-2007. Each 100 km^2 grid cell depicts the total observed catch in kg. For confidentiality, only grid cells containing data from three unique vessels are shown. Data are from the AFSC Fisheries Monitoring and Analysis program. Catch values delineating color legend are not consistent among years.

Appendix: Specific CIE reviewer comments on Tier 6 and/or squid management

Reviewer Cieri

It is difficult to understand why two adjacent stocks, with very similar catch histories, would use different periods and different metrics to set an OFL. Further, a productive fishery for both these stocks occurred in the 1977---1987 time frame. As such, it is recommended that (Recommendation 12) the average catch 1977---1987 be used as a basis of seeing the OFL for both squid complexes separately.

Reviewer Cordue

Tier 6 assessments require a reliable catch history from 1978-1995 and OFL is calculated as a maximum or average catch over this period. It is inappropriate to predefine a period without reference to a particular stock. An average catch can only be a reasonable proxy for MSY if there has been some stability in catch and effort over the period. Therefore, the period should be chosen on a stock-specific basis. Also, for non-target species the average historical catch could be a gross underestimate of MSY. Therefore, it is preferable to base the OFL estimate on almost anything else, for example, noisy fishery-independent survey biomass indices, or even a food-web or ecosystem biomass estimate if such is available.

For a target fishery where the catch and effort have been fairly stable over a large number of years it makes some sense to use average catch as a proxy for MSY. For a non-target fishery it makes much less sense. If the fish are not targeted, the bycatch level is likely to be less than MSY and, potentially, hugely less than MSY. Certainly it is not appropriate to determine average catch over a pre-defined range of years, for a number of bycatch species, and take the averages as proxies for MSY. The pre-defined year range of 1978-1995 was used for BSAI squid which is inappropriate as it was a target fishery in the first part of that period and then changed to a bycatch fishery – there was no stability in catch or effort. A period when there is some stability in catch and effort should be used – so for squid, this would be a later period when it was a non-target species. If fishery-independent survey indices are available, they should be used in preference to historical catch even if they are quite noisy. Also, I suggest that if food-web or eco-system based estimates are available, they would also be preferable to historical-catch based estimates for non-target species. If historical catch has to be used then the average over a period is not appropriate – it is just asking for trouble in that more than half of the time (because of the 25% buffer between OFL and ABC and assuming the distribution of catches is symmetric) the ABC will be exceeded. Use of the maximum provides more of a buffer for variation in catches, but it would be better to use the upper bound of a one-sided 95% or 99% confidence interval as this directly incorporates information on catch variability. Either a lognormal or normal distribution could be assumed for the annual catches (depending on what the distribution of annual catches looks like over the period chosen). Obviously, catches would have to be monitored to make sure that they were varying within the provided buffer rather than increasing from the previous average level (which might mean that the species was being targeted).

Reviewer Volstad

It is appropriate to base the assessment of squid on Tier 6 since the AFSC bottom trawl surveys are directed at groundfish species, and therefore do not provide reliable biomass estimates for the generally pelagic squid. However, mean catch from 1977 to 1995 is likely to be significantly higher than current

catch levels, and it is uncertain if catches at this level would be sustainable. Main concern with squid by-catch is that squid is prey to other species (sperm whales, salmon, etc. which target different sizes). An option may be to use ecosystem models to assess what maximum catch should be. I recommend not using historic catch data to set ABC. Catch records for squid between 1977 and 1995 can be broken into "foreign" (1977-1987; when foreign vessels dominated the Alaska fleet), "joint venture" (1981-1989; shared fishing activities between domestic and 11 foreign partners), and "domestic" (from 1987-present). Since 1990, only domestic vessels have operated in Alaskan waters. The foreign catches were much larger than present-day catches and likely present a mix of directed and incidental catches, and it is not documented that these catch levels were sustainable. Current catches are well under the total allowable catch limits but could increase because markets for squid exist and fisheries might develop rapidly. Following the new design of the observer program implemented in 2013, reliable estimates of squid catch, with quantifiable precision, may be obtained. An alternative to the Tier 6 assessment in the future is to monitor catch trends for species in the squid complex based on observer data. If cpue in pelagic commercial fisheries do not significant decline over time this may be adequate indication of sustainable stock levels.