AFSC groundfish and crab surveys and their role in fisheries management

Executive Summary

AFSC groundfish and crab surveys are essential for proper assessment and management of target stocks and protection of associated non-target species. The AFSC conducts a series of annual and biennial bottom trawl, echo-integration/trawl, plankton, and longline surveys that are conducted from both NOAA ships and chartered fishing vessels. It also conducts surveys and integrated ecosystem assessments. This analysis examines the short-term consequences of survey reductions primarily by retrospective analysis (i.e., examining "what-ifs" by dropping past surveys from existing assessments). This provides an idea of the conservation and economic impacts that might be expected under reductions in survey effort. The results presented here do not fully depict the long term implications of reductions in survey frequency

Impacts on target species include:

- Decreased precision in biomass estimates resulting in increased uncertainty in ABCs
- Foregone economic opportunities (e.g., for eastern Bering Sea pollock, Bering Sea yellowfin sole, and snow crab combined, total of $147.8 million in lost revenues if the 2010 survey had not been conducted). Potential annual economic losses for all stocks combined could be quite large
- Increased interannual variation in ABC recommendations that could lead to loss of market share or increased costs to industry
- Higher risk of overfishing, particularly for stocks with declining population trends
- Fishery revenues could be reduced for several years following overharvest if stocks require rebuilding
- Potential loss of MSC certification
- Loss of important biological information on age, growth, spatial distribution, and maturity needed for stock assessment that may affect ABCs in a variety of ways

Impacts on ecosystem-based management include:

- Inability to spatially apportion catches in SSL foraging areas (e.g. GOA pollock and BSAI Atka mackerel)
- Loss of ability to assess non-target species, many of which directly depend on survey biomass estimates for ABC/OFL specifications
- Loss of important information needed to advance understanding of climate links to fish production, distribution and predator-prey interactions
- Loss of information needed to produce Fishery Ecosystem Plans and Integrated Ecosystem Assessments – key components of providing ecosystem based advice to fishery managers. Information used to write IEAs and the Ecosystem Considerations chapter for the Council are dependent upon data collected on both survey and other non survey cruises (e.g. Climate and Ecosystem cruises).

Overview

The Alaska groundfish multi-species management system is based on extensive data available from the AFSC observer program and dedicated research cruises. Catch of target and prohibited species (e.g., salmon, crab, herring, and Pacific halibut) are estimated at sea or in processing plants to provide real time information to ensure that fisheries do not exceed total allowable catches (TACs) or violate other fishery restrictions (such as time-area closures). Data collected from dedicated research surveys together with high quality observer data make it possible to build detailed population dynamics models. These are used to provide biologically based quota recommendations that feed directly to this multispecies management system. This ensures that fishing remains at or below precautionary levels. Timely data from the AFSC scientific groundfish bottom trawl and echo-integration/trawl (EIT) surveys play an instrumental role in this process.

AFSC surveys also have a broader function as platforms for essential biological, ecological and oceanographic research. Samples collected on surveys are used to determine critical life history information (early survival, age, growth, etc.) for commercially valuable fish species. Diet information collected during surveys forms the keystone of the ecosystem modeling performed by the AFSC, which is becoming increasingly important as we move towards ecosystem-based fisheries management. AFSC surveys are especially valuable because understanding the scope and pattern of natural changes in marine ecosystems requires many years of data. For example, the Eastern Bering Sea shelf bottom trawl survey provides almost thirty years of annual data collections. Plankton surveys for groundfish eggs, larvae, and zooplankton prey have occurred annually for over 30 years and provide data on both initial spawning success as well as climate conditions, lower trophic level production (prey availability), initial groundfish survival, and bottom-up processes. A disruption of these unbroken time series would limit our ability to understand natural variability and measure our impact on the ecosystem. Surveys also enhance the interaction between NMFS and the wider scientific community: during the last 3 decades federal, state, and university scientists have produced hundreds of studies using AFSC survey data.

Table 1 illustrates the relative effort by main survey regions for the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) bottom trawl surveys in a previous analysis. The number of bottom trawl surveys in both the AI and GOA currently occur on a biennial schedule and the EBS bottom trawl survey occurs every year. Sampling densities differ by region because of habitat and community composition differences. Annual winter EIT surveys of spawning pollock are conducted in both the Bering Sea and Gulf of Alaska. The summer EIT survey of Bering Sea shelf pollock is conducted on a biennial schedule and a summer EIT survey of GOA pollock is also planned to be conducted on a biennial schedule. An annual longline survey to assess sablefish, rockfish, grenadier, and sharks is also conducted from a chartered fishing vessel but the frequency of this survey is not likely to decrease since the primary cost of the survey is supported by the sale of the research catch by the chartered vessel.

As part of NOAA's attempt to utilize resources in the most efficient manner, AFSC conducted a review of their current funding allocations to fishery independent surveys and the impact of reductions in funding on the quality of stock assessment advice. In this document we report on the impact of scenarios involving reductions in the frequency of surveys.

Table 1. Regional statistics (of management areas to 1000 m depth) on trawl survey coverage based on 2000-2006 data.

	Annual Bering Sea	Biennial Bering Sea Slope	Biennial GOA	Biennial Aleutian Islands
Area of survey region (km^2)	495,599	32,724	286,860	64,415
Mean number of days/survey	121	65	197	135
Mean number of hauls/survey	396	198	712	404
Mean hauls/10,000 km^2/survey	8	60.5	24.8	62.6

Analyses were developed to compare recent actual management practices with the current set of surveys with the most likely scenario of quota recommendations had the recent surveys been cancelled. The North Pacific Fishery Management Council adopts annual harvest specifications and biological reference points for species or species complexes based on the availability of information. For data rich species, age structured models have been developed that integrate information from fishery dependent and fishery independent sources. For data limited species, harvest specifications are directly tied to survey results. We provide examples of the impact of reductions in the frequency of surveys on stock assessments under data rich (age structured assessments) and data limited (non-age structured assessment) cases.

Implications of dropping the 2011 EBS shelf trawl survey (charter vessels)

The approach to addressing this question was simply by examining retrospective consequences by doing "what if" analyses of assessment results had either the 2010 or 2009 EBS shelf trawl surveys been unavailable for assessment purposes. Three examples are given: pollock, yellowfin sole, and snow crab.

EBS pollock

Pollock play a central role in the EBS ecosystem and represent the largest component of fishery landings within the US by volume. The current management system relies on the assessment analysis for quota recommendations. In recent years, the abundance has been at historic low levels and quotas have been heavily constrained by the control-rule which is designed to have spawning biomass return to above B_{msy} levels. The impact of omitting recent bottom trawl surveys is very high for these reasons.

This stock has recently dropped to low levels due to low recruitment during environmentally unfavorable conditions, but is projected to increase to be above the target spawning biomass in 2011. For this evaluation, contrast was compared by dropping the 2009 data back in 2009 and doing the same thing in 2010. This resulted in a shift in recommended ABC from 813,000 t (for the 2010 fishery) to 732,000 t (Ianelli et al. 2009). This is a difference of 81,100 t of pollock or approximately $94 million in reduced first wholesale revenue, representing lost income and employment in the harvest and processing sectors.

In 2010, the effect of dropping the bottom trawl survey would have reduced the maximum permissible ABC by 8%. The impact on the TAC (assuming ABC=TAC and the full TAC is taken as retained catch) would have been about 101,000 t or $117 million in lost revenue.

The control rules used for estimating ABC for pollock are directly tied to uncertainty: as uncertainty increases, the ABC level decreases following formal risk-averse practices. The importance of the surveys shows that in the near term, the recommended ABC, OFL, and effective TAC levels are sensitive to surveys planned for 2011.

Plans to drop the spring Bering Sea larval survey would preclude an assessment of the abundance, size, and distribution of walleye pollock eggs and larvae, which provides a first indication of the incoming walleye pollock year class. Moreover, these data are important annual indicators of spawning distribution and spawning biomass of walleye pollock adults in the Bering Sea.

BSAI Yellowfin sole

Dropping the 2010 bottom-trawl survey estimate from the assessment resulted in a relatively small reduction in the recommended ABC (6,000 t, representing a 2.7% decrease). Based on this assessment, maximum potential lost revenue due to ignoring the 2010 survey estimate and assuming the full ABC is taken as retained catch, would have been about $16 million. However, only about 50% of the ABC is generally taken as retained catch, and potential lost revenue would be more on the order of about $8 million.

Snow crab

Crab management is delegated to the State of Alaska and by agreement, NMFS provides support to this effort by way of annual bottom trawl surveys of the Bering Sea shelf region, as well as performing the annual stock assessment for several crab stocks, including Eastern Bering Sea snow and tanner crab. The annual bottom trawl surveys have a long history of being directly applied for quota recommendations. For the purpose of this exercise, the impact of not having the 2010 survey data was considered by comparing the 2010/2011 ABC recommendations based on stock assessment model results with and without the 2010 survey data. Scenarios where the 2010 snow crab assessment ABC recommendations included the 2010 survey data resulted in a retained catch estimate of 33,300 t, compared to an estimate of 29,200 t without 2010 survey data (12.3% reduction). The 4,100 t reduction in the retained catch component of ABC represents approximately $22.8 million in lost revenue.

	% Change in ABC without 2010 survey	Potential lost revenue (millions of dollars)
EBS pollock	-8.0%	$117.0
BSAI yellowfin sole	-2.7%	$8.0
Snow crab	-12.3%	$22.8
Total		$147.8

Implications of dropping the Aleutian Islands Survey-- Aleutian Islands Atka mackerel

In 2008 the entire Aleutian Islands survey (last conducted in 2006) was cancelled and this proved to have important consequences for stock assessment and data for developing the Steller Sea Lion Biological Opinion.

The Bering Sea/Aleutian Islands (BSAI) assessment for Atka mackerel is heavily reliant on survey biomass, age, length, and weight data to assess the status of the stock. The bottom trawl survey is the only fishery independent input for the assessment. Atka mackerel are a patchily distributed species with schooling behavior which can result in survey estimates with large variances. Decreased survey coverage (fewer stations) can have a large impact on survey biomass variability which greatly contributes to uncertainty in stock status. In the past, ABC recommendations for Atka mackerel have been set below the maximum permissible because of uncertainty in stock status due to high survey biomass variability.

Decreased survey frequency has the greatest potential for impact to the stock assessment. A previous analysis estimated total loss in revenue between 2001 and 2006 from omitting the most recent two surveys was about $42.7 million. Atka mackerel are a relatively fast-growing and highly productive groundfish stock. Dropping surveys, as was done with the 2008 Aleutian Islands survey can miss important recruitment events, leaves too large a gap in the survey time series for determining stock trends, and lags or even prohibits our ability to determine current stock status and make appropriate stock projections. The bottom trawl survey has historically been a consistent and reliable indicator of incoming recruitment and year class strengths due to its ability to catch 2 year old fish which are unavailable to the fishery. The biomass, age, and weight data collected from the survey are critical to the age-structured stock assessment model to estimate numbers at age and population biomass.

The ability to monitor trends in Atka mackerel abundance has also played a role in managing time area closures to mitigate potential indirect affects with the endangered stock of Steller sea lion. Atka mackerel are an important prey item for Steller sea lions.

Implications of a partial Gulf of Alaska bottom-trawl survey

Reductions in survey coverage or sampling density of the Gulf of Alaska biennial survey have been proposed. Given that possibility, it has been suggested that, as a starting point, the survey would drop stations deeper than 500 meters because these stations are more difficult to sample and take longer per tow. These stations only comprised about 4% of all sampling conducted in 2005, 2007, and 2009. Extending these cuts to stations 300 meters and deeper would reduce stations by 10%. Even though these stations take longer to sample, it would be hard to envision that these cuts would be equivalent to a 50% cut in days at sea, so some thinning of the remaining stations would also be required. The major deepwater species that would be affected by removing the deep water stations are shown in Table 2.

The species with the most biomass in the deeper waters is the giant grenadier. This species is a large and important ecological component of the slope biomass, but at this time it is not in the Fishery Management Plan. This is proposed to change in the near future, and would represent approximately a 35,000 t ABC that is based entirely on the trawl survey. Sablefish, while an important slope component, is not assessed by the trawl survey beyond 500 meters because of a dedicated longline survey, but the assessment does use the portion of the survey between 300-500 meters. If these strata were removed, the trawl survey would not be used in the sablefish assessment for 2012 and would result in decreased precision of management

quantities such as ABC. Short-spined thornyhead are sampled well by the survey, but have a significant proportion of biomass in the deeper continental slope waters. This assessment depends solely on the trawl survey biomass estimates, and these estimates would become much less precise if forced to rely on previous estimates for those deep strata. Dover sole, shortraker rockfish, and rougheye/blackspotted rockfish have a limited amount of biomass deeper than 500 meters, but significant biomass deeper than 300 meters. Dover sole and rougheye/blackspotted rockfish are assessed using age-structured models and would probably not be immediately affected much by cutting stations deeper than 500 meters, but both assessments depend on the trawl survey for information deeper than 300 meters. Shortraker rockfish has 71% of its biomass deeper than 300 meters and relies solely on the trawl survey to set ABC, and cutting stations deeper than 300 meters would greatly increase the uncertainty of the ABC. Pacific ocean perch, the dominant rockfish in the Gulf of Alaska, has very little biomass deeper than 300 meters, but if the limited sampling effort in the 200-300 meter strata were reduced, this could greatly decrease the precision of its biomass estimate.

If significant cuts to the GOA survey are required, it will likely require cutting deep stations and additional thinning of the remaining stations. Overall, this will decrease the precision of abundance estimates of both Tier 5 stocks (based only on trawl survey biomass estimates) and Tier 3 stocks (age-structured models). If this situation happens once, it will likely have a minimal immediate effect on management quantities. However, if this becomes a continuing problem, such cuts would require eventually dropping some deep water species to Tier 6 (catch-only) because the biomass estimates would become unreliable. Thinning the stations will also result in less overall certainty in all species assessed using trawl survey biomass estimates. While the current management system does not make an explicit additional buffer as uncertainty increases (except Tier 1, of which there are none in the GOA), a probability-based uncertainty buffer is a likely future outcome of changes from the Annual Catch Limit guidance of the Magnuson-Stevens re-authorization. This would mean that as the uncertainty of our estimates of biomass or ABC increase, the buffer would increase so that we have the same probability of exceeding overfishing limits. For example, calculating the "P*=0.12" buffer for Gulf of Alaska POP using the uncertainty of spawning biomass as a proxy for the uncertainty of ABC ,would result in a decrease of about 4% in ABC for each survey missed. Clearly, for some species, these increased buffers could result in millions of dollars of lost revenue. On the other hand, if these approaches are not adopted, as uncertainty increases, our probability of unintentionally overfishing a stock increases as the trawl survey biomass estimate CV increases.

Table 2. Average percent biomass of major deepwater species (the species that are in the top 20 in total Gulf of Alaska biomass) estimated to be deeper than 500 meters and 300 meters in the 2005, 2007, and 2009 NMFS Gulf of Alaska bottom trawl survey.

Species	**Percent deeper than 500m**	**Percent deeper than 300m**
Giant grenadier	75%	99%
Sablefish	42%	61%
Short-spined thornyhead	35%	65%
Dover sole	10%	27%
Shortraker rockfish	3%	71%
Rougheye/blackspotted rockfish	<1%	60%
Pacific ocean perch	<1%	4%

Implications of dropping winter acoustic surveys in the Gulf of Alaska

Winter acoustic surveys in the Gulf of Alaska are used in three primary ways: stock assessment of walleye pollock, apportioning the total allowable catch between management areas, and conducting research on recruitment processes of walleye pollock. Cancelling the scheduled surveys for 2011 would have detrimental impacts on all of these activities.

The Shelikof Strait acoustic survey is used as an annual index of abundance in the Gulf of Alaska pollock assessment, which is used directly to provide scientific recommendations on acceptable biological catch. This survey has been conducted continuously since 1981 (except 1982, 1987, and 1999). Two other surveys are used in the assessment, a biennial bottom trawl survey conducted by NMFS, and an annual survey conducted by ADFG. However each survey targets a different component of the stock, and they are considered complementary, rather than redundant. Integrated assessments that use all reliable data sources are generally considered to provide the most robust assessment of stock status. Cancelling the Shelikof Strait acoustic survey would result in a less precise assessment or potentially a biased assessment, leading to greater scientific uncertainty in ABC recommendations.

Acoustic surveys in other parts of the Gulf of Alaska (i.e., Shumagin Islands, Sanak Gully, Chirikof Island) are used to apportion total allowable pollock catch between management areas, as required by protection measures for endangered Steller Sea Lions promulgated under Endangered Species Act. An average of the four most recent surveys is used to apportion the TAC between areas. Missing a year would mean that this apportionment would not as accurately reflect the current distribution of biomass, which can be highly variable. If harvest rates are disproportionate to biomass, there may be impacts on Steller Sea Lion recovery. Furthermore, apportionment has large economic impacts on coastal fishing communities in the Gulf of Alaska, particularly Kodiak, Sand Point, and King Cove. Stakeholders in these communities are very aware of the results of these surveys, and their impact on amount of fish that can be harvested by the local fleet.

The Shelikof Strait acoustic survey provides a measure of spawning stock biomass, and an index of age-1 abundance, which is needed to study mortality during the first winter experienced by the young pollock.

Implications of dropping the FOCI Late Larval and Age-0 pollock Surveys.

Finally, Gulf of Alaska pollock has long been a focus of research on recruitment process in marine fish populations. This research relies on long time series to identify environmental factors that are important in determining year class strength. The AFSC FOCI late spring larval pollock survey has been conducted annually for over 30 years and provides information on larval size, condition, and hatch date distribution for the incoming year class, and well as data on initial conditions that affect prey distribution, composition, feeding, growth and survival of walleye pollock young. The survey generates a prediction for larvae that will survive to 15 mm as well as a recruitment prediction. It has yielded new insights into how climate affects pollock and other fish larvae and these data are being used in a comparative approach to marine ecosystem organization. The data collected on pollock, Pacific cod, arrowtooth, sablefish and Pacific Ocean perch are important for GOA IERP (see below).

The fall biennial FOCI age-0 pollock survey has been conducted since 2000 and provides an early index of pollock recruitment by reporting the abundance, distribution, and size of young-of-the-year prior to the first winter. These data along with the acoustic age 1 surveys, provide

data necessary to determine entering year class strength and where and when year class strength (i.e. recruitment) is determined.

Implications of survey reductions on non-target species assessment and the GOA IERP

Because many non-target stocks are in Tier 5 (OFL = M * survey biomass), regular survey biomass estimates are critical for harvest level specification. While it is difficult to quantify the effects of reduced surveys on catch levels and the buffer between OFL and ABC (because uncertainty in the survey biomass estimates is not explicitly linked to those quantities), any reduction in surveys reduces our ability to respond to conservation concerns. This is especially true for stocks such as the skate complex, which contains a number of species with sensitive life histories and remains the target of commercial interest in much of Alaska.

Skates in the EBS and loss of slope survey

One of the possible survey reduction scenarios is the loss of the EBS slope survey in 2012. In the EBS, most of the skate biomass is on the shelf (and consists mostly of one species, *Bathyraja parmifera*), but most of the skate diversity exists on the slope. The loss of the slope survey is unlikely to significantly impact the assessment of *B. parmifera*, which constitutes ~95% of the BSAI skate biomass and for which an age-structured model exists. However, losing the slope survey would impair our ability to monitor the abundance of the less common skate species in the BSAI, and would disrupt an emerging EBS slope time series that has finally been achieved after years of infrequent research activity.

Implications of dropping surveys and NOAA ship time on the GOA IERP

The success of the GOA IERP is perhaps not immediately critical for managing fish stocks in the GOA, but the project will provide a great deal of diverse, valuable information. This is particularly true for forage fish stocks. Losses in surveys and NOAA ship time impacts the GOA IERP in several ways. The timing of the GOA IERP fieldwork (2011 and 2013) was in large part chosen so that it would coincide with the GOA bottom trawl survey and the GOA-wide acoustic surveys. Several of the GOA IERP principal investigators are relying on food habits data from the GOA trawl survey. In a larger sense, the occurrence of the multifaceted IERP effort with two major survey efforts in the same year will provide an unprecedented level of coverage of the GOA for many different trophic levels. The result is a broad-based view of the GOA ecosystem which will be extremely valuable. The loss of days at sea on NOAA vessels also impacts the GOA IERP. An important winter FOCI cruise that was intended to provide data on larval arrowtooth flounder and sablefish, two of the focal species of the GOA IERP has already been dropped. An additional late-spring FOCI survey which would provide information of larval walleye pollock, Pacific cod, and Pacific ocean perch is in danger of being cancelled (see above). These cruises are critical to comprehensive GOA IERP work to determine connectivity of spawning and nursery habitat for key economic and ecological species. Central to the success of the GOA IERP synthesis component is accurate life history information to seed and groundtruth the hydrographic and trophic models, which depends, in large part, on joint AFSC-PMEL FOCI surveys planned for winter, spring, and summer. Long-term, there are a number of other FOCI and PMEL cruises on the *Oscar Dyson* that are either essential to the success of some components of the GOA IERP or have the same synergistic effect described earlier for the GOA surveys, including the application of an ecosystem approach to fisheries management and IEAs. The GOA IERP is an unparalleled opportunity for the AFSC to leverage its existing resources with millions of dollars from NPRB. Personnel from the AFSC, as well as many of the divisions, have already invested a great deal of time and money on the GOA IERP and that

investment will grow in the next 4 years. The results of those efforts are diminished by reducing GOA surveys and NOAA ship time.

Ecosystem level considerations

Beyond collection of baseline catch data necessary to maintain a fishery-independent time series of population abundance, critical biological, ecological, and oceanographic information that is routinely gathered would also be lost, or hampered with severe reductions in survey frequency as well as reduction in the number of climate and ecosystem cruises. Bottom trawl surveys also provide important information needed to advance an ecosystem approach to management including:

- Ocean temperature, plankton and water column stratification data to link fish distribution, abundance, recruitment and growth to habitat and predict effects of climate.
- Non-target fish and invertebrate abundance and size composition needed to assess impacts of fishery by-catch.
- Food habits information needed to build and verify multi-species and ecosystem models that predict ecosystem effects of fishing.
- Biological data on target species such as size, age, growth, maturity, condition, food habits, genetics, parasites and other pathologies, distribution.
- Spatial distribution of fish and shellfish to assess their response to natural or anthropogenic forcing needed to conduct assessments of essential fish habitat and to predict shifts in species interactions.

Early life history and climate and ecosystem cruises provide important information needed to advance an ecosystem approach to management including:

- Maintenance of sentinel mooring or station time series that characterize the ecosystem.
- How ocean conditions respond to climate variability and impact the recruitment of target species.
- Which target and non target species are most resilient to climate change.

These observations are integrated into individual stock assessments that assess ecosystem effects on the managed stock and impacts of the fishery on other ecosystem components. They are also integrated into a synthetic report of annual ecosystem conditions (Ecosystems Considerations Chapter) important to the Science and Statistical Committee of the Council for interpreting the annual stock assessments. This information is also crucial for:

- EA and EIS documents prepared to assess ecosystem impacts of various fisheries management actions.
- Biological Opinions related to endangered species.
- Fishery Ecosystem Plans.
- The Integrated Ecosystem Assessment report provided to the North Pacific Fishery Management Council.

Conclusion

The utility of AFSC groundfish surveys extends beyond simple applications used directly for fisheries management (e.g., within stock assessments for the purposes of recommending

annual catch quota levels). Recent reductions in bottom trawl survey effort have affected the ability to monitor a number of key species. In particular, deep water stations in the Gulf of Alaska were eliminated in the 2003 survey and in 2001 the entire eastern portion (about one quarter of the region) of the survey was omitted due to budget constraints. Additionally, the normally scheduled survey of the slope region of the Eastern Bering Sea was cancelled in 2006 and the number of stations sampled in 2006 for the Aleutian Islands region was reduced by 20%. In 2008 the entire Aleutian Islands survey (last conducted in 2006) was cancelled. **Analyses conducted at the AFSC show that further reductions in survey effort will hamper the ability to adequately manage groundfish stocks.** These analyses indicated that for targeted fish stocks that have been increasing, the lack of surveys in the future will result in much lower quotas for the fishery and hence lost opportunity for employment and economic benefit. For stocks that are decreasing, the lack of survey information will result in over-harvests and hence losses to the protection of those stocks and the ecosystem in general. Fishery revenues could be reduced for several years following overharvest if stocks require rebuilding. Loss of this information may translate into more precautionary actions being taken with respect to avoiding endangered species and ecosystem impacts.