Revised application for an exempted fishing permit allowing up to five Alaska Seafood Cooperative vessels to access the Red King Crab Savings Area and Area 516 closures to evaluate potential for reducing the total red king crab bycatch of the Bering Sea winter/spring flatfish fishery

Date of Application: August 2016

Requested dates for permit to be in effect:

January 20 through April 30, 2017 and January 20 to April 30, 2018

Applicant Information:

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Introduction: This application for an exempted fishing permit (EFP) is being proposed by the Alaska Seafood Cooperative (AKSC), one of the two Amendment 80 fishing cooperatives. AKSC's vessels have fished for flatfish, Pacific Ocean Perch, and Atka mackerel in the Bering Sea and Aleutian Islands for more than 20 years. Our cooperative was formed in 2008 upon implementation of Amendment 80. AKSC currently has 16 active vessels with approximately 10 specializing in BS/AI flatfish and the others fishing flatfish when they are not fishing Atka mackerel/ POP or fishing in the Gulf of Alaska. All of our vessels are required to carry two full-time NMFS-trained observers when fishing and observers sample all hauls for catch composition. Catch for each haul is accounted for by certified flow scales as required by NMFS regulations. AKSC and its member companies have a proven track record for conducting fisheries in a manner that minimizes bycatch of prohibited species such as crab and halibut and AKSC has also been a leader in applied cooperative research to explore and develop ways to reduce bycatch and bycatch mortality in groundfish fisheries of the BS/AI.

Exemptions requested and participating vessel information: If approved, AKSC's proposed EFP would include up to ten Alaska Seafood Cooperative member vessels over the two winter/spring seasons in 2017 and 2018. Half of these (up to five vessels) would have access to two Bering Sea closed areas that overlap within NMFS' Statistical Zone 1 (east of 165 degrees West longitude) for each year of the EFP. Additionally, all ten participating vessels would be exempted from specific catch handing regulations associated with prohibited species from January 20 to April 31 over the two years. An exemption from catch handling regulations is needed to allow vessels to collect and hold all catches of red king crab (RKC) and other prohibited crab species (e.g. *C. bairdi*, *C. opilio*) until data collections by sea samplers are completed after all the fish from each haul has passed over the vessel's flow scale.

Our request for an exemption to the closures is designed to allow participating vessels to do the test fishing that is the subject of this EFP in a manner that incorporates their normal fishing groups in order to allow them to fully exercise their proven crab bycatch avoidance methods.

These include making test tows and sharing catch and bycatch information. The incorporation of normal AKSC vessel fishing group arrangements is a key element of the EFP objectives. The five vessels selected to have access to the closures in 2017 would not have access to it in 2018 and vice versa for the other five vessels such that each team of EFP vessels would have access to the closures in one of the two years of the EFP. Both groups of EFP vessels (with and without access to the closures) would share catch information and fully employ the crab bycatch avoidance measures they normally use during each year of the EFP. This is designed to allow the EFP to evaluate what access to the closures does in terms of improvement in crab bycatch avoidance according to our expectation of being able to better follow dense schools of flatfish into the closed areas and thereby reduce RKC bycatch.

Figure 1 below shows where the Red King Crab Savings Area (RKCSA) and Area 516 closures are located in relation to other management areas within crab management Zone 1 of the Bering Sea (Zone 1 includes all of the Bering Sea shelf east of 165 degrees West longitude and south of 58 degrees North latitude). The NMFS regulations for these closures can be found at: https://alaskafisheries.noaa.gov/sites/default/files/679b22.pdf.

Prior to the final issuance of this permit, AKSC will provide a list of the 10 vessels (or fewer) we select for the EFP and indicate which ones need to be exempted from the closures in each year of the EFP.

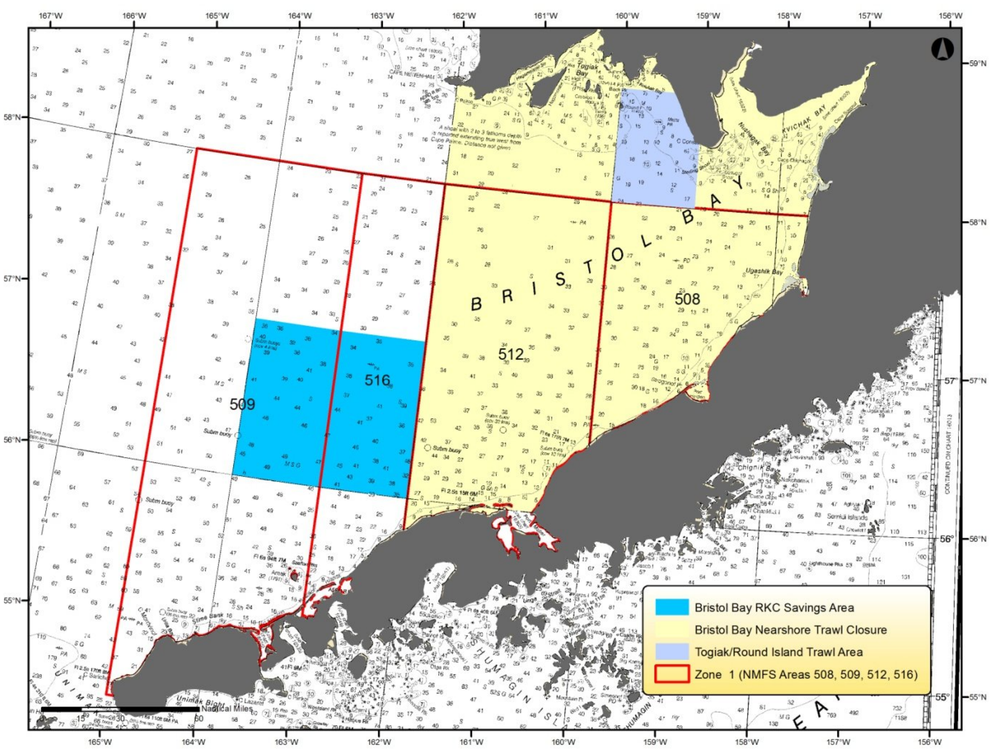

Figure 1 showing Zone 1 (east of 165 degrees West longitude inside the red rectangles) and trawl fishing closures within Zone 1.

Purpose:

The objective of the EFP is to investigate whether the RKC bycatch performance of the Bering Sea winter/spring flatfish fishery across Zone 1 is improved by allowing fishing under an EFP inside the Red King Crab Savings Area and Area 516 closures. Briefly, operators in the fishery hypothesize that access to closed fishing areas would allow flatfish boats working together to reduce crab bycatch rates by maintaining high target catch rates throughout the winter/spring flatfish fishing season (additional background provided below). To address this hypothesis, the EFP is designed to allow for comparison of RKC bycatch performance for vessels with access to the closures. This will be done by looking at crab bycatch rates for vessels with and without access and by comparing hauls that occur within the current closures against those from outside the closures. Bycatch rates will be compared by number of RKC per metric ton of groundfish, per hour of towing, and per distance towed. The hourly and distance comparisons will require participants to log when the gear is actually at fishing depth not simply the set and retrieval locations and times.

Importantly, the exemptions provided in this EFP allow fishermen to fish in their normal operational configurations and without being constrained to pre-defined numbers of fishing hauls inside versus outside the closures. This is to ensure that the normal best fishing and bycatch avoidance practices employed by the fleet (maximize target catch while minimizing RKC bycatch)[1] are maintained. Fishing inside the closures would only occur when captains deem it appropriate. In this manner, data on RKC bycatch from hauls that occur inside the closures would be comparable to those that occur outside the closures, namely that gear deployment practices and information sharing on catch rates of target and non-target species designed to maximize target catch rates and minimize RKC bycatch are consistent across all hauls in or out of the closures.

To achieve the overall goal of this EFP, specific objectives are:

1) For vessels collaborating to reduce crab bycatch, examine the relative catch rates for RKC and other managed crab species for the EFP vessels with access to the closed areas compared to the EFP vessels that do not have access and for hauls inside the closed areas relative to hauls outside the closures.
2) Collect information on haul-level attributes such as target catch amount, seafloor water temperature, depth, towing speed, haul duration (time), inter alia, in order to begin to explore possible correlation between environmental and fishing behaviors to bycatch performance data for flatfish vessels in the winter/spring fishery.

[1] Bycatch avoidance best practices employed by the AKSC vessels include daily communications between vessels to relay information about bycatch and the sharing of spatially-specific catch and bycatch data on a fast turn-around basis. This information is used by AKSC fishermen to rapidly identify bycatch hot spots so that vessels can avoid them and bycatch is reduced. Additionally, AKSC does weekly bycatch management conference calls that include vessel captains/mates, company vessel managers, and AKSC cooperative managers, in order to further disseminate bycatch information throughout the fleet.

3) Collect information on sex, size, and reproductive condition of crab taken as bycatch during exempted fishing within closures and in the outside area under the EFP to improve the collective understanding of characteristics and status of crab within closed areas and outside areas (see below).
4) Collect information to improve the understanding of the relationship between subsampling-based haul-level RKC bycatch estimates and census-based RKC accounting. This will be done by quantifying the variance in bycatch estimation incurred by catch subsampling.
5) Use data obtained during the EFP in real time to avoid bycatch hotspots and areas where RKC are molting during the EFP. Avoidance of hotspots and areas with molting crab is a high priority for the AKSC and leadership at Alaska Bering Sea Crabbers. The data from this EFP will allow flatfish fisheries to track better track in-season bycatch hotspots and enable, for the first time, avoidance of areas with molting RKC (should molting crab be encountered).
6) Work with the leadership of Alaska Bering Sea Crabbers to use information gained from this EFP to improve the future bycatch avoidance efforts of the Amendment 80 sector.

Motivation:

The bycatch of RKC in Zone 1 of the Bering Sea (see portion of above figure east of 165 degrees West longitude) is managed under an annual bycatch cap against which numbers of crab taken incidentally are counted (https://alaskafisheries.noaa.gov/sites/default/files/679b21.pdf, pgs 9-10. The annual bycatch cap for Zone 1 red king crab is further subdivided into sectors (e.g. Amendment 80, Trawl Limited Access), and then into cooperative-specific caps for the Amendment 80 sector or seasonal allowances in the case of the Trawl Limited Access. Estimates of RKC bycatch and other prohibited species catches (PSC) in the groundfish fisheries are made by the NMFS Regional Office catch accounting system from sampling done by NMFS-trained observers. Each AKSC member vessel is required under Amendment 80 regulations to have two observers whenever fishing in the Bering Sea/Aleutian Islands.

The AKSC allocates the Zone 1 red king crab and other PSC species bycatch to its member companies. These companies further subdivide these allowances to vessels they operate. In every year since the implementation of Amendment 80, avoiding attainment of red king crab bycatch allowances has been a priority for AKSC vessels. AKSC captains have on several occasions met with the captains in the Bering Sea crab fisheries and through these communications have an improved understanding of the importance of avoidance of RKC bycatch for the crab fishery. Through this communication, AKSC captains have redoubled their efforts to reduce RKC bycatch. Also, in the early phase when Amendment 80 was still under development by the North Pacific Fishery Management Council, AKSC did not oppose the reduction of the RKC bycatch cap that was built into the Amendment 80 program in accordance with what had been discussed with the crab industry.

The relative degree to which RKC allowances constrain flatfish fishing is likely influenced by the spatial overlap of RKC with fishing grounds for rocksole and yellowfin sole which varies from year to year. Additionally, the number of RKC allowed to be taken as bycatch varies annually under the stock abundance-based bycatch cap.

The bycatch allowances per vessel for RKC and other crab PSC species under this EFP will not be different from those normally allocated. To be clear, no additional bycatch is being requested or reallocated among vessels. Participating vessels will primarily be targeting northern rock sole and yellowfin sole, two economically important fishery species for the Amendment 80 sector. Depending on fishing conditions and localized abundance, a limited number of tows during the EFP may result in proportionally large catches of pacific cod resulting in the tows being classified as “cod target” by the NMFS catch accounting system. This is normal for these fisheries in the winter and spring.

Origins of the RKC bycatch hypotheses motivating this EFP application:

The underlying hypothesis that RKC bycatch could be reduced with access to the closed areas originated from discussions at AKSC’s annual captains meetings over the last three years where captains were asked to generate ideas to further develop bycatch reduction tools. In that regard, virtually every captain/mate in attendance indicated that the most productive approach at this point would be allowing them to track dense schools of flatfish without interruptions. Their reasoning, beyond the obvious catch efficiency gains, is that high target catch per unit effort results in less fishing effort (reduced potential for interaction with RKC), and that in their experience, when target species catch rates were high, they generally have lower RKC bycatch. This would, they also suggested, lead to improvements not just for prohibited species bycatch but for reduced wear and tear on gear, lower fishing costs, and potential reduction in seafloor impacts associated with trawling.

According to captains, rocksole and yellowfin sole, the main target flatfish species on the Bering Sea shelf, tend to move across the shelf in the winter and spring at different times. From their experience, some having fished flatfish for up to 30 years, captains hypothesize that flatfish schools migrate across the Bering Sea shelf from north to south or northeast to southwest and these movements tend to occur in waves that can be five to seven days apart. Captains report evidence of flatfish aggregations transiting the closure areas while tracking dense fish schools going into or out of the closure areas and by observing them via echo sounder while steaming across the closure areas. These observations suggest that the target catch per unit effort would be maximized by “following the fish” uninterrupted through the closures that are the focus of this EFP. With the closed areas in place today, when fishing breaks off from tracking a school due to a closure boundary, subsequent fishing may be less productive until another school is located. Fishermen indicate that when target catch rates drop off, tows become considerably longer and crab bycatch rates or totals often increase.

Fishermen have advanced several mechanisms explaining why harvest on dense schools of target flatfish reduces crab bycatch and other PSC. Some indicate bycatch is reduced by the ability to make tows of shorter duration; others suspect that dense schools of flatfish displace bycatch species. Regardless, all captains agree that increasing their ability to follow schools of flatfish will have positive results for reducing RKC and possibly other types of prohibited species bycatch.

Further support embedded in the hypothesis that access to the closed areas would reduce RKC bycatch is that anecdotal observations from fishermen suggest the RKCSA may not necessarily be an area where red king crabs tend to aggregate in winter and spring. In some years, the NMFS bottom trawl survey does show aggregations of RKC in a portion of the RKCSA and to the east in Bristol Bay but that survey occurs during summer, and not during the spring/winter fishing season discussed herein; RKC distributions may be different during the spring/winter fishing season than in summer. To see this, go to the Alaska Fisheries Science Center's website: http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm; select "stone crabs (Lithodidae)" for group, and "Red King Crab (Paralithodes camtschaticus)" as species. Then scroll through survey catch rates for the different survey years.

At present, it is not known whether RKC are more abundant in the closed areas relative to open areas at the time when rocksole and spring yellowfin sole fishing occurs. To assess the true distribution of crab within and outside the closed areas, a dedicated crab survey specifically designed to sample crab throughout Zone 1 would be needed. In contrast, this EFP has an explicit objective of assessing whether fishing under standard best practices but with access to target flatfish in closed areas can lower crab bycatch rates as described above. As such, the data collection proposed provides information on RKC bycatch rates associated with flatfish fishing, and not a scientific index on the abundance and spatial distribution of RKC throughout the closures. As a result, we emphasize that activity under this EFP is not designed as an RKC survey comparing crab distribution inside versus outside the closures.

Data collected in this EFP will be informative and useful in several additional areas such as providing more information about the sex and size of crab taken as bycatch in these fisheries through the EFP's greatly expanded crab sampling (see Objective 3 and discussion below). This is because collections will include all crab caught during the EFP instead of being limited to crab that come up in observer sampling. Additionally, data on shell condition and egg maturity is not part of the normal groundfish observer data collections but having this information is important to crab managers and the crab industry and this project will provide the necessary training for collection of these data which will then be provided to Dr. Robert Foy at the Alaska Fisheries Science Center.

Our expectation that the EFP data will make a valuable contribution to the collective understanding of RKC bycatch in flatfish fishing stems from what we learned in the preparation of information for this application. First, as is discussed in the statistical power analysis section of this application, the data we evaluated showed that approximately 90-95% of hauls targeting flatfish during the winter/spring had zero RKC in the sample. For hauls where observer sampling found some RKC, these were then expanded via the NMFS catch accounting system to the haul level, often resulting in a large estimated number of RKC in the haul (often hundreds).

In our discussions with flatfish captains during EFP development, we heard that captains go on deck to watch as hauls are being dumped into the vessel's stern tank and from this they feel that RKC occur in hauls at a higher frequency than the 5-10% suggested in the data. At the same time, captains report that they virtually never see hauls with hundreds of RKC (as is suggested by the expanded haul-level data). In fact, captains told us they rely on what they see from watching the codend being dumped instead of relying on observer data to make decisions about whether to stay in an area or not.

This comment by captains was not a criticism of observer sampling but intended to help us understand how they make decisions about whether to leave or stay in areas they are fishing. At the same time, this shows that the data collected in the EFP will be useful for evaluating sampling variance and possibly improvements in sampling methods. It may even lead to ideas for ways the industry could collect information on haul-by-haul bycatch rates to improve their voluntary bycatch avoidance efforts.

To see what we could learn about the size/sex of RKC that might be encountered in the hauls inside the RKCSA, we turned to the data on crab measured by groundfish fishery observers. AKSC does not get crab length data normally so we requested NMFS' Alaska Science Center provide it to us. What we asked for was compiled observer data reporting numbers of RKC that were sampled by observers in Zone 1 over the last three completed fishing years (2013-2015). The seasonal period specified for our data request was January through the end of April, the time period corresponding to this EFP. For these data we requested an additional break-out by sub-adult and adult RKC carapace length groupings by sex for non-pelagic trawl hauls targeting flatfish in Zone 1. For these groupings, we further requested that the data be grouped spatially for crab sampled from the "10 minute strip" portion of the RKCSA and from hauls occurring in the remainder of Zone 1.

With these data we set out to look at what fraction of RKC were of adult size (by sex) inside the "10 minute strip" portion of the RKCSA using it as a proxy for what might be found in the RKCSA in comparison to the remainder of Zone 1. In responding to our data request, NMFS also included the same RKC bycatch data from fixed gear vessels (targeting Pacific cod) that fished inside the RKCSA, 10 minute strip, and in the remainder of Zone 1. This was helpful because observer data from fixed gear is currently the only source of information on sex and size of crab taken as bycatch inside the RKCSA during the seasonal period of interest for this EFP. Differences in size selectivity for fixed gear and differences in sampling methods for fixed gear versus trawl need to be kept in mind with these data. For this reason we have intentionally avoided making bycatch rate or size of crab comparisons between gears.

As background for the data in the tables below, the number of sampled crab for non-pelagic trawl (NPT) in flatfish fisheries ("n=" in the tables below) is the total number of males plus females for non-pelagic fishing that were sampled by observers each year. These numbers sum to 199, 322, and 281 for 2013-2015 respectively. During these years, the estimated total number of RKC taken as bycatch by the two Amendment 80 cooperatives were 22,427; 26,331; and

12,615 (see: https://alaskafisheries.noaa.gov/fisheries-data-reports). The mechanics of how the NMFS catch accounting system converts the number of RKC in the sample to the total number in haul for hauls with non-zero sample amounts of RKC is, to the best of our understanding, the ratio of the haul weight (allocated species weight from the flow scale) to the sample weight multiplied by the number of RKC in the sample.

Percent mature Male RKC for RKCSA, 10 min strip, and remainder of Stat Area 509/516

	2013	% mature RKCSA*	%mature 10 min	%mature 509/516
	LONGLINER	95%	97%	96%
n=	225	64	38	123
	NON PELAGIC	100%	94%	97%
n=	88	3	18	67
	POT OR TRAP	n/a	n/a	50%
n=	8	0	0	8
	2014	% mature RKCSA	%mature 10 min	%mature 509/516
	LONGLINER	84%	82%	90%
n=	762	73	129	560
	NON PELAGIC	95%	92%	98%
n=	192	37	38	117
	POT OR TRAP	n/a	50%	70%
n=	14	0	4	10
	2015	% mature RKCSA	%mature 10 min	%mature 509/516
	LONGLINER	100%	100%	98%
n=	217	10	7	200
	NON PELAGIC	100%	100%	89%
n=	102	10	11	81
	POT OR TRAP	n/a	n/a	60%
n=	10	0	0	10

* non-pelagic tows "inside" RKCSA presumably due to GIS position rounding

Percent mature Female RKC for RKCSA, 10 min strip, and remainder of Stat Area 509/516					
	2013	% mature RKCSA	%mature 10 min	%mature 509/516	
	LONGLINER	65%	71%	84%	
n=	1,016	404	268	344	
	NON PELAGIC	44%	44%	65%	
n=	111	9	27	75	
	POT OR TRAP	n/a	n/a	36%	
n=	94	0	0	94	
	2014	% mature RKCSA	%mature 10 min	%mature 509/516	
	LONGLINER	76%	82%	77%	
n=	808	126	144	538	
	NON PELAGIC	55%	20%	50%	
n=	130	31	35	64	
	POT OR TRAP	0%	n/a	n/a	
n=	2	2	0	0	
	2015	% mature RKCSA	%mature 10 min	%mature 509/516	
	LONGLINER	69%	61%	85%	
n=	342	35	31	276	
	NON PELAGIC	61%	73%	34%	
n=	64	18	11	35	
	POT OR TRAP	n/a	n/a	36%	
n=	14	0	0	14	
	* non-pelagic tows "inside" RKCSA presumably due to GIS position rounding				

Noting the number of RKC sampled by observers for non-pelagic trawl is relatively small compared to total estimated catch numbers, this increased our interest in conducting a whole haul count of RKC for each EFP haul and looking at sampling variance. From this we would have data to compare sampled crab to total estimated catches from sampling (EFP Objective 4) to examine sampling variance per haul and at higher levels of data aggregation. The census of crab would also provide more systematic data for bycatch avoidance efforts of captains during the EFP (both inside and outside the closed areas) which is desirable because captains want to know how accurate their estimated numbers are from watching a codend being dumped.

Despite the relatively low numbers of sampled crab for NPT over 2013-2014 period, we looked to see what it says about the RKC that we might encounter inside the closed areas using the 10 minute strip portion of the RKCSA as a proxy for the entire RKCSA. The question of interest for us (and likely for the crab fishery) was whether we would be more likely to encounter mature animals in the closures relative to areas outside the RKCSA. Looking at the data for the non-pelagic" (bottom trawl) in the above data tables, we did not see a consistent pattern suggesting that RKC from the 10 minute strip portion of the RKCSA comprised a higher fraction of mature crab for either males or females. If anything, it appears that a greater proportion of RKC from <u>outside</u> the 10 minute strip tended to be mature. But given the small number of sampled crab and the small differences in proportions of mature crab, it may be that the differences are not meaningful.

Data from pot and longline gear appear to show the same pattern; RKC inside the closures did not have a higher ratio of adult RKC relative to the outside area. If anything, the data seem to suggest the opposite but year to year variability is also considerable. Of note is that the number of RKC measured by observers for longline gear is considerably greater than for trawl. Without a full understanding of how sampling works for those fisheries we do not know why this occurs. Finally, RKC selectivity for fixed gears likely differs substantially from trawls and so these data should be interpreted carefully.

With the limitations in available observer data for characterizing crab in the RKCSA or 10 minute strip compared to the remainder of Zone 1 from January through April, what can be said is that we do not see evidence that the RKC we might encounter in the closed areas would be comprised more of mature males or females. The small number of sampled crab does highlight the importance of Objective 3 of the EFP to get better data to characterize the sex and size of RKC in the closed areas relative to areas currently open to the flatfish fisheries.

Finally, in our discussions with stakeholders during the development of the EFP, we heard concern from Bering Sea crab industry, crab managers, and scientists about fishing around Bristol Bay red king crab during molting. Molting is currently thought to occur mostly in May-July when fishing for rock sole and yellowfin in the eastern part of Zone 1 is generally completed. It has been suggested, however, that molting may occur earlier in some years, perhaps due to climate change or at least differences in temperature regimes between years. Given the concern for avoiding areas with molting crab, we have agreed to work with our member vessels to move away from areas where molting RKC are encountered, should they be encountered, during EFP fishing. This will apply to fishing inside and outside the closed areas during the EFP. From what we have been told by the crab industry based on research done by their cooperative research foundation, the spatial aspects of molting are such that EFP boats could make relatively small movements to effectively move away from molting crab if they are encountered because their research has shown that molting RKC apparently tend to be in small/discrete patches. If this is the case, moving away from these areas along the lines of what flatfish vessels normally do to avoid bycatch is potentially effective for avoiding molting RKC.

Methods:

This document incorporates several revisions to AKSC's 2015 EFP application reflecting substantial input from NOAA's Alaska Fishery Science Center, NPFMC's Science and Statistical Committee (SSC), and the Bering Sea crab industry. Most of this was provided during last year's application review process along with some additional ideas from an informal evening discussion with interested SSC members (February 2016). Finally, we asked researchers at the Fisheries, Aquatic Science & Technology Laboratory (FAST Lab) at Alaska Pacific University to assist us with a Statistical Power Analysis. Notably, revisions in this EFP application include:

- Clarification on anticipated fishing effort (hauls) conducted inside versus outside the closed areas under exempted fishing and information that helps scale that to the overall fishery
- Power analysis to assess the feasibility of statistical inference to compare RKC bycatch rates for hauls that occur inside closures to rates experienced outside the closures (where all hauls are conducted under standard best fishing practices and the same data collection methods) under anticipated fishing levels
- Modifications to our methods to include census-based RKC accounting for the set of five AKSC vessels named under the EFP with access to closures as well as for the set of five AKSC vessels named under the permit without access to the closures
- Additional detail on anticipated analytical methods to collect target species and bycatch data from within and outside the closures including methods to assess the accuracy of subsampling-based RKC bycatch estimates against census counts
- Additional detail on data collection of haul-level information for subsequent exploration of haul-level RKC bycatch dynamics (e.g. bottom water temperature, depth, towing speed, haul duration) which may be useful for examining bycatch dynamics across fishing in the EFP

Data collection

The approach to data collection for the EFP was formulated using what we learned working with the observer data discussed above. Because we are interested in conducting analyses that compare catch rates for tows inside the closures to outside and no information on sampling variance is available, we selected "whole-haul" (census) accounting of RKC and other managed crab species for this EFP. For this revised permit application, we have described in detail how we will conduct our census and collect our data in response to questions raised by the SSC last December.

A census of crabs per haul will be conducted in the following manner: Crew members in the factory on EFP vessels will collect all the crab on the conveyor belt in the factory where the crew normally sorts catch downstream of the observer's sampling station. Each participating vessel will designate factory personnel (e.g. factory manager and assistant factory manager) on each factory shift to oversee collections of crab to ensure crew are following this procedure. The crew will place the crab in a tote that will be labeled with the vessel's log book haul number for that tow. Prior to the start of the EFP on each vessel, AKSC's project manager will work with the participating vessels and the sea samplers to come up with a set of vessel-specific procedures that ensure full collection of crab and good tracking of the crab by haul number.

After all crab are sorted out and placed in the designated tote, a sea sampler hired for purposes of the EFP will conduct all EFP data collections. Sea samplers will be on all EFP vessels throughout their participation in the EFP. The sea samplers will be hired through the vessel's observer provider company and have the same qualifications as NMFS groundfish observers in Alaska. Additionally, sea samplers participating in this project will be provided additional training to supplement the portion of their groundfish observer training pertaining to crab.

The duties of sea samplers and those of the EFP vessel's two observers will be separate and sea samplers' work will not interfere or constrain the work of the observers. Crew collection of crab will be done on the conveyor belt that moves fish out of the tanks and the collection point will be "downstream" of the observer station. The work done by sea samplers will not utilize the tables or other equipment used by observer.

Samplers will collect data on: number of crab per haul by managed crab species (e.g. RKC, *C. bairdi*, *C. opilio*), carapace length of each animal, sex of each animal, presence of eggs for females and egg maturity, and shell condition. Because sea samplers will have the same training as groundfish observers, this means they are already trained in all of these duties except shell condition and egg maturity. For this reason, the supplemental training provided for sea samplers will serve as a refresher for most of these duties and the only new area will be assessment of egg maturity and shell condition.

The training will be done by Mr. Joe Chaszar. Mr. Chaszar currently provides training for federal fishery observers deployed in the federal/state managed scallop fishery in Alaska. An example of the data collection worksheets that will be used by sea samplers in the EFP is included as Appendix 1 below.

To assess the effects of environmental conditions on bycatch rates, all EFP vessels will deploy temperature logging devices provided by NMFS that record temperatures at depth over the course of each fishing season during the EFP. This and other sources of data on environmental conditions such as the data on NOAA's website on sea ice extent (see: http://pafc.arh.noaa.gov/icemap.php) will be used to consider bycatch and target species catch performance in the context of environmental conditions expected to affect seasonal movements of crab and flatfish.

Expanded set of EFP vessels

In its December 2015 review of our EFP application, the SSC raised several issues that related to the "quasi survey" aspects of the application prior to this revised version. These elements came from a desire in the earlier application to make some inferences via the EFP about abundance of

RKC inside the closures versus outside. The intent at that time was not to use the EFP to argue that the closures should be revised but to evaluate whether we were interested helping to fund or provide vessels for a true survey of Zone 1. An actual systematic survey is the only way to estimate the RKC distribution in Zone 1 for winter/spring months was merited. The SSC's review helped us understand that attempting to make any inferences between the open and closed areas via an EFP would be problematic if vessels were making decisions to avoid bycatch and maximize target species catches. Further, some of the steps we included in the EFP application last time would have required the participants to fish either inside or outside the closures when they would not otherwise fish there in order to collect data on catch rates and be able to see if they differed during the same time. This was problematic for fishermen because they were concerned that having to fish in an area they did not select could result in unrealistic/uneconomic fishing and potentially high RKC bycatch rates that could force them to prematurely terminate their EFP participation.

To address this flawed approach from 2015, we have removed all "quasi-survey" elements from the EFP and are now fully focused on how teams of fishing vessels employing normal bycatch avoidance and data sharing measures can perform if they have access to the closures. The addition of a five vessel control team employing the same bycatch avoidance measures/data sharing to the EFP is to help us understand what would have occurred under the ambient environmental/fishing conditions for a given year of the EFP if the vessels would not have had access to the closed areas. Data collection methods are the same for the two teams of vessels to make the data as comparable as possible. The rotation of access to the closures by year is to help account for the possibility that one team is inherently better at bycatch avoidance than the other.

We recognize that an EFP spanning only two years makes comparisons difficult if environmental/fishing conditions are outside of the norm. More years and repetitions would help to address all the possible permutations of conditions and difference in bycatch avoidance performance to make these comparisons stronger. At the same time, we have expressed up front that this EFP is not intended to collect survey data or any data that would be used to change the current regulations for the closures. We do, however, think it will collect important data and experience on: how to measure catch and RKC bycatch rates; environmental and fishing conditions affecting bycatch rates; size/sex/shell condition of crab inside and outside the closures, and; information about subsampling relative to haul by haul catch or expanded catch estimation. Finally, we fully expect that the experience from this EFP will be useful for AKSC to determine whether it is interested in working with the Alaska Bering Sea Crabbers and the crab industry's research foundation to fund and possibly make vessels available for a systematic survey in collaboration with NMFS scientists.

Use of Existing Data to Characterize the Expected Amount of Fishing Inside the Closures in the Context of a Statistical Power Analysis

As was mentioned above, data are not currently available for non-pelagic trawls from inside the closures to make inferences about characteristics of bycatch inside versus outside to support an analysis of catch rates for target or RKC or other crab species or the statistical power of the EFP (see section below for more discussion of the power analysis). Therefore, data collected by observers on AKSC vessels fishing in areas adjacent to the closures over the previous three seasons (Jan - April, 2013 - 2015) were provided to the FAST Lab at Alaska Pacific University so they could attempt to characterize expected RKC bycatch data from inside the closures. The data consists of all of AKSC's flatfish target tows in the area open to non-pelagic trawling in Zone 1 (NMFS statistical areas 509 and 516) over the last three completed years.

Based on AKSC's data, its member vessels made 1,465, 2,048, and 2,459 hauls targeting flatfish in Zone 1 from January 20 to the end of April for 2013, 2014, and 2015 respectively. Using data supplied by the Alaska Region of NMFS for the total number of non-pelagic trawl hauls targeting flatfish in Zone 1 for that time period, AKSC hauls comprise 84%, 82%, and 83% of the total number of NPT hauls targeting flatfish over the same seasonal time window for 2013-2015. The mean RKC bycatch rates for AKSC flatfish fishing effort over this period ranged from 0.13 to 0.35 crabs/ton target species based on estimated RKC catches of 6,500 - 17,000 animals over the period. To put this into context, based on the annual reports submitted to the NPFMC by each Amendment 80 cooperative, the estimated total number of RKC taken during the period by the two Amendment 80 cooperatives was 22,427, 26,331, and 12,615. Thus AKSC's portion of the total RKC bycatch numbers is approximately 46%, 62%, and 52% of the total per year.

At the haul level, there was large variability in AKSC bycatch rates compared to the mean (sd = 0.9 – 1.3 crabs/ton) over the three years primarily due to most hauls (90 to 95%) having zero RKC bycatch, and the non-zero hauls having very high estimates of RKC bycatch rate (mean = 3.3 crabs/ton) relative to the overall mean values listed above. See Appendix 2 (Statistical Power Analysis) for further details.

According to the design of the EFP, the number of hauls that would be made inside versus outside the closures is not predetermined and will depend on the distribution of flatfish during the fishing seasons encompassed under the EFP. We emphasize that this is due to a desire to standardize fishing behavior for hauls inside versus outside the closures, as well as to secure support from the captains -- fishermen last year were concerned about the having a prescribed numbers of hauls inside the closure as part of that EFP application due to the increased chance of hitting their PSC caps if they were required to fish in areas of potentially high RKC bycatch. Below, we estimate the number of hauls that would be conducted by a set of five AKSC vessels with exempted access using information from past fishing seasons' effort total. In summary, based on data from the last three fishing years we anticipate that sufficient numbers of hauls would be conducted inside the closures by EFP vessels under normal fishing practices to suffice for statistically robust comparisons of differences in RKC bycatch rates from fishing inside versus outside closures, should they exist. Furthermore, if there is inter-annual variability that affects RKC distribution and bycatch, the multi-year request for exempted access under this EFP provides an additional hedge against the risk of too-few hauls experienced in closures for statistically robust comparisons of RKC bycatch dynamics.

In its comments on the 2015 version of this EFP application, the SSC suggested that the applicant identify the expected level of fishing effort that would occur inside closed areas, and to perform a power analysis to determine the extent to which differences in RKC bycatch dynamics from fishing inside closures versus outside closures, ceteris paribus, could be assessed (see Appendix 2 below for the full analysis). For this analysis, bycatch rates outside the closures were treated as a reference value, and thus a one-sample power analysis was implemented (results from two-sample power analyses are also provided in Supplemental Section to the Statistical Power Analysis, Appendix 2). Summarizing those findings here, based on fishing effort from the previous three seasons (2013-2015), five vessels (the maximum number granted access to the closures in a year) are expected to conduct a total of 850 hauls over the time-frame of this EFP in the course of normal fishing. Using historic levels of variability in haul-level bycatch rates from outside the closure as a proxy for likely variability inside the closure, it was estimated that 425 hauls, using an assumption that 50% of the expected hauls for the five boat closure-access group, would be needed to occur inside the closure to detect a haul-level average bycatch rate difference of 0.16 crabs/ton or more between inside and outside (90% power, 5% Type-I error (alpha) level).

While it is impossible to guess at what the true difference in bycatch rates inside and outside the closures might be or the actual number of hauls in the closed area from this EFP, this difference would be similar to the difference in crab bycatch rates between 2013 to 2014 from fishing in open areas (2013/2014 difference = 0.13 crabs/ton) providing sufficient power to detect differences in RKC bycatch rates from fishing inside versus outside closures that might be above and beyond that from “natural” variability in bycatch dynamics, at least as characterized by comparing season-to-season variability in RKC bycatch outcomes. The results of the power analysis assume that mean bycatch rates will be compared inside and outside the closures. However, due to the high zero inflation of the RKC bycatch, the percentage of zero RKC hauls is what largely determines mean bycatch rates. Also, the high zero inflation violates the assumption of normality inherent in the power analysis. An alternative approach is to compare RKC bycatch incidence inside and outside the closures. In other words, compare the proportion of zero hauls inside versus outside. For example, in order to make a statistically significant determination between the proportion of zero hauls in 2013 (90% of all hauls) to 2015 (95% of all hauls), a sample size of 200 hauls would be necessary.

Given the uncertain nature of the level of effort to be devoted within the closures, in addition to looking at bycatch differences between potentially different environmental/temperature conditions, the proposed two year window of the EFP provides a hedge against a single season of poor conditions for fishing inside the closures. Under ideal conditions, with two years of substantial fishing within the closures, the power to detect differences would be increased. If after two years, only a small portion of the EFP fishing occurs in the closed areas, then statistically significant differences may not be detectable at a practical level (i.e. potentially only large differences in RKC bycatch dynamics could be detected across fishing inside closures versus outside closures). While this may present a risk of achieving low statistical power to detect potentially small differences in RKC bycatch dynamics from fishing inside versus outside the closures, we note that this situation would also indicate that fishing inside the RKC closures is not likely to achieve the hypothesized gains in bycatch rate reduction thereby addressing the primary question of this EFP.

Proposed Methods for Analysis of EFP Data

To make meaningful comparisons in RKC catch rates between the participating vessels with access to the closures and those without access, bycatch performance will be evaluated both in terms of numbers of RKC per metric ton of groundfish catch, per hour of towing the net, and per distance towed. While the trawl industry tends to focus on numbers of crab per ton of groundfish in its evaluation of bycatch rates, catch rate per hour and distance towed are also useful for gauging the effectiveness of bycatch avoidance measures. Changes in catch rates for other prohibited crab species of crab will also be examined in terms of numbers of crab/metric ton of groundfish catch and numbers of crabs/hour and distance towed.

Data collected under the proposed EFP will provide opportunity to assess RKC bycatch dynamics in the Savings Area following a suite of three analysis efforts:

(Primary objective) Assess differences in RKC bycatch rates for haul occurring inside the closures under the EFP relative to bycatch rates outside the closures.

We will conduct pairwise comparisons of average bycatch rates from hauls conducted inside closures against hauls outside closures using t-tests and stratifying data as appropriate (e.g. by month, location, and target species, inter alia). Analyses will be conducted using sub-sampling based data and using census-based RKC catch accounting data separately. Similarly, we will compare differences in incidence of non-zero RKC catch hauls as above, but using binomial proportion tests[2].

Explore vessel-level (inherent boat-specific differences in bycatch dynamics), haul-level (e.g. catch amount, target species, tow speed), and environmental (e.g. area, season, depth) factors which may affect RKC bycatch rates and examine whether these attributes affect bycatch rates differently inside versus outside the closures, as well as the relative importance of these attributes in driving bycatch rates.

We will utilize multiple linear regression techniques to explore the association between haul-level covariates and RKC bycatch outcomes. Multi-model selection[3] will be used to explore the strength of support for different covariates as being influential in determining RKC bycatch rates. Data summarized as haul-level average bycatch rates will be modeled as normally-

[2] Zar JH. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River.
[3] Burnham K, Anderson D. 2002. Model selection and multimodel inference. Springer, New York.

distributed data, and zero-inflated regression models will be explored to handle the preponderance of zero-RKC catch hauls expected from fishing over the EFP period[4].

Explore the accuracy of subsampling-based RKC bycatch estimation as compared to crab censuses under the EFP.

We will assess the accuracy of subsampling-based RKC estimates by a direct comparison of subsample estimates with appropriate sample-based uncertainty estimates against haul-level census counts. Summaries considered will include percent and absolute bias, as well as the frequency with which sub-sample based confidence limits correctly include the true (i.e. census-based) RKC bycatch count. Haul-level summaries will be stratified across boats and across fishing inside/outside in order to compare for statistically significant differences in bias and rates at which confidence intervals contain true values.

Clarifying the purpose of EFP data collections compared to Amendment 80 data collections:

Data collected for the EFP is for the objectives of the EFP and those analyses alone. EFP data will not be used to account for participant's Amendment 80 allowances. Catch estimation and accounting during the EFP for purposes of Amendment 80 catch accounting (as well as all AKSC member vessel catch allowance accounting) will be done through the normal data collection and accounting procedures based on the vessels' two observers and catch handling and accounting procedures under Amendment 80 regulations. The EFP applicant and participating vessel personnel recognize from the outset that estimates of crab catches for Amendment 80 catch accounting and those in EFP may very well be different and this shall have no effect on estimation for Amendment 80 catch accounting purposes.

Further, the two observers on each participating Amendment 80 vessel will be engaged only in their normal duties and will not be required or otherwise engaged in any of the data collection activities of the EFP. Similarly, the sea sampler working on the EFP data collections will not participate in any of the data collection activities of the vessel's observers. The only area of potential overlap between the different and separate data collection processes done for the EFP and for Amendment 80 catch accounting will be limited to crab that are part of observer samples. Because the EFP needs to account for all catches of managed crab species, even those in observer samples, a system will be arranged between observers and sea samplers prior to the start of EFP fishing activities to make any crab collected by observer sampling available to the sea sampler once observers are done with their data collections.

In the SSC's review of the 2015 EFP application, there was some concern that a crew census might be problematic from the perspective of an inherent incentive to avoid triggering crab bycatch caps. As is explained above, the EFP data will be used for purposes of the objectives of

[4] Zuur AF et al. 2009. Mixed effects models and extensions in ecology with R. Springer, New York.

the EFP and not to determine the vessel's catch for purposes of Amendment 80 annual catch allowances. Further, this EFP is to learn about bycatch avoidance tools in combination with areas that participants can access, but the results of the EFP are not designed for, or intended to, lead to changes to existing closed areas or other outcomes that could directly benefit participants. The crew census for this EFP is actually no different than AKSC's 2016-2017 deck sorting EFP and previous EFPs where crew are conducting census of the halibut that end up in the factory to learn about haul-specific performance as part of objectives of the EFP. For this reason, and based on the performance AKSC and its member vessels have had with EFP duties for the deck sorting project, we are confident that poor accounting or potential for intentional bias of catch data for this project will not occur in this EFP.

Project management, interim and final reports:

Alaska Seafood Cooperative will be responsible for all aspects of this EFP. This includes monitoring the EFP operations and data collections on each EFP vessel to ensure the objectives of the EFP are being accomplished for each year the EFP is in effect. AKSC will also work with captains, vessel owners, and sea samplers to find solutions to any unanticipated problems that may emerge during EFP operations. AKSC will also work with the observer provider companies to ensure that sea samplers are available for the two EFP field seasons and contract with Mr. Chaszar to provide training to sea samplers for the data collection duties of the EFP.

AKSC will undertake the analysis of EFP data with technical assistance from APU's FAST Lab and Dr. Foy from the AFSC's lab in Kodiak. AKSC will draft interim and final reports on the EFP to inform the NMFS, NPFMC, and interested stakeholders about the findings and any other information critical to a complete understanding of how the fieldwork and data collection activities went and how any unanticipated occurrences affected the outcomes.

An interim report on the EFP detailing the EFP progress and preliminary findings from the first field season will be prepared and submitted to NMFS and the NPFMC not more than 90 days after completion of the 2017 fieldwork. A final report covering findings from the 2017 and 2018 field seasons and a full quantitative analysis of EFP data and findings will be provided to NMFS and the NPFMC not more than 120 days after completion of the second field season.

Milestones:

August 2016: Submission of EFP application for Alaska Region of NMFS for internal review

August/September 2016: Revisions to EFP application as necessary

September 2016: Presentation of EFP application to Crab Plan Team

September-November 2016: Letter from NMFS stating that EFP application is ready for NPFMC review

December 2016: Presentation of revised EFP application to NPFMC and its advisory panels/committees

October-December 2016: Work with Alaska Region on drafting of permit

December 2016: Discussions with observer provider companies to arrange for sea samplers

December 2016: Arrange training of sea samplers

January 2017: Training session(s) for sea samplers and AKSC captains meeting review of EFP responsibilities with captains of permitted vessels

January 2017: Receive final permit from NMFS Alaska Region

January 20, 2107: Commence EFP fieldwork

January-April 2017: Project monitoring and management of EFP by AKSC

May 2017: Receive completed EFP data from participating vessels/sea samplers and begin AKSC error checking, uploading data from deck sheets to electronic database, commence data analysis

Summer 2017: Drafting of preliminary report on first year of EFP for submission to NMFS and presentation to NPFMC in October 2017

October 2017: Presentation of first year EFP preliminary results to NPFMC and incorporation of any suggested changes to EFP (may require amendments to permit)

December 2017: Arrange for sea samplers and training of new sea samplers

January 2018: Training of new sea samplers as needed and commence second year of EFP field testing

January through April 2018: AKSC management of second year of EFP

May 2018: Receive completed 2018 EFP data from participating vessels/sea samplers and begin AKSC error checking, uploading data from deck sheets to electronic database, commence data analysis

Summer 2018: Drafting of final report covering two years of EFP for submission to NMFS; and presentation to NPFMC in October or December 2018

October 2017: Presentation of first year EFP preliminary results to NPFMC and incorporation of any suggested changes to EFP (may require amendments to permit)

Geographical Area of operations for this EFP:

The areas of interest for this EFP are the typical fishing grounds for rocksole and yellowfin sole inside crab management Zone 1 of the Bering Sea shelf. Zone 1 fishing grounds are generally in the 40 to 120 meter range. This area falls within NMFS Statistical Areas 509 and 516. Statistical Areas 508 and 512 (the Bristol Bay area) are generally of the same depth strata but these waters are closed to trawling year round and this EFP does not request any exemptions to those closures even if to some extent the questions being addressed in the EFP might be relevant to those waters as well.

EFP catch handling and data collection procedures:

For purposes of in-season accounting and management of the participating AKSC vessels, tracking and accounting for target and PSC species during the EFP will be done using the same Amendment 80 procedures and data as currently occurs. Species composition sampling by the normal Amendment 80 observers will be used to track the target catch and PSC of participating vessels against their Amendment 80 allowances.

To avoid affecting observer sampling duties, expanded crab data collection will occur after the catch passes over the vessel's flow scale and the observer has had the opportunity to sample unsorted catch for all Bering Sea EFP hauls.

EFP crab data collections will occur as follows:

1. Sea samplers will have the same training and qualifications as NMFS certified groundfish or State of Alaska crab observers plus supplemental training on shell condition.
2. Sea samplers will be employed through the observer provider companies authorized to provide observers for the regular Amendment 80 fisheries or companies providing crab fishery observers.
3. In a suitable location on the conveyor belts after the vessel's flow scale, crew members will remove all crab (including any parts of crab) of all species from each haul.
4. All crab will be placed in a tote or other suitable designated container provided by the EFP vessel for the sole purpose of collecting all crab from each haul.
5. The haul number will be indicated on the tote/container using a system developed at the start of the EFP by the sea samplers, observers, the factory foreman, and other responsible crewmembers.
6. Any crab (or crab parts collected) by observers during their normal sampling duties will need to be accounted for in the census of crab for purposes of this EFP. This will be done through a procedure worked out between the sea sampler and the vessels' groundfish observers to set aside any crab that come up in the observer's sample so that it can be included in the census once the observers have finished with the work on that haul.
7. A short briefing to explain the EFP procedures and data collection protocols will be held on EFP vessels at the outset of the EFP and when new observers or sea samplers begin on EFP vessels. The sea sampler in charge of EFP data collections on the vessel will conduct this briefing.
8. Participating vessels will provide an additional work area for the sea sampler(s) that is sufficient to conduct their duties without negatively affecting the work area for observers.
9. After all crab are collected from a haul, the sea sampler will separate the crab by species and record the number of crab by species. Sea samplers will also record length, sex, and shell condition for each crab. For mature females, egg clutch condition and fullness will also be recorded (see Appendix 1 below).
10. Following their data collections, sea samplers will discard the crab from each haul using the normal conveyor belt or chute used on the vessel to return PSC to the water.
11. Sea samplers will record their data on data sheets developed by the EFP holder (example in Appendix 1 below). In addition, sea samplers will enter their data onto spreadsheets also developed by the EFP holder. Samplers will perform data quality checks of all data following procedures developed by the EFP holder. Data will be periodically transmitted to the EFP holder by the sea samplers.
12. Data collected by sea samplers are not for in-season catch accounting and will be used only for the purpose of the data analysis for the EFP.

13. All equipment needed for the sea samplers to perform their duties will be provided by the EFP holder and the participating EFP vessel.

Responsibilities of EFP vessel captains/mates and crews:

Captains and mates of participating vessels will:

1. Record all tows as EFP tows in the logbook whether inside or outside the closed areas for any Bering Sea flatfish hauls during the time when the EFP is in place.
2. Indicate EFP hauls in the electronic logbook with “EXP”.
3. For all hauls during EFP, record on a spreadsheet provided by EFP PI: haulback location, groundfish catch weight, bottom water temperature (from vessels headrope sounder), bottom depth, towing speed, haul duration (start and end time for net in fishing mode, i.e. when deployed on bottom and before haulback). Additionally, vessels will provide their plotter data to the PI for all fishing activities during the EFP.
4. Provide sufficient room and facilities for the sea sampler(s) to collect the EFP data.
5. Abide by the EFP data collection plan developed in consultation with the EFP holder for each EFP vessel.
6. Provide each sea sampler with a suitable cold water immersion suit and personal locator beacon.
7. Include sea sampler in all safety drills and training exercises in the same manner as is done for observers.
8. Deploy the temperature recording device provided for this project.

Project management responsibilities for the permit holder:

As permit holder, AKSC, through its principal investigator John Gauvin and other authorized personnel, are responsible for:

1. Ensuring that EFP procedures are followed correctly and data integrity meets the needs of the EFP. This will be accomplished mainly through communications with sea samplers and continuous review of the data provided by the samplers.
2. In consultation with each EFP vessel and the sea sampler on each vessel, develop an EFP data collection plan for each EFP vessel. This plan will list the specific handling procedures by crew members for the collection of crab on each EFP haul, where crab will be stored for each haul, work schedules for sea sampler, and other items specific to the collection of data during the EFP.
3. AKSC will remain in regular communication with vessel captains and mates to review any problems with the gear or fishing procedures or the data collection practices/protocols. AKSC and participating vessels and sea samplers will work out solutions to any problems that occur.
4. AKSC will monitor data from the EFP as part of its normal bycatch avoidance activities. Given that the EFP data greatly expands in-season data for bycatch avoidance, we expect this to assist crab bycatch avoidance efforts during the EFP, including the addition of data on shell condition which allows for avoidance of areas with concentrations of molting crab, should these be encountered during the EFP.
5. AKSC will have a field project manager work with vessels prior to the EFP and the managers will be available to meet with an EFP vessel at the dock or out on a trip if

necessary to address problems that are encountered and develop procedures to ensure that data quality is achieved.

6. In the event that an EFP vessel is unable or unwilling to follow the procedures of the EFP, AKSC can remove the vessel from the list of authorized EFP vessels. At its discretion AKSC can elect to start another approved EFP vessel in the place of the one that was removed for the EFP or opt not to do so.

Appendix 1: Crab data collection sheet (example)

Page ________of ________ for Haul

Crab Bycatch Sample Form

Alaska Seafood Cooperative Exempted Fishing Permit

Vessel Name _________________

Sample Date__________________

Haul Number_________________

Sample Time__________________

For all Red King, Blue King, *C. Bairdi, C. Opilio* , and hybrid tanner crabs collect the data listed below. Record the data for each haul on a separate deck sheet. Check with the factory manager or other responsible person to make sure all the crab from that haul is now in the designated tote (tote has vessel haul number) and check with the observer to make sure any crab that came up in the sample is now in the tote for that haul.

				FEMALES			
Species Name	Carapace Size	Shell Condition	Sex	Maturity	Clutch Fullness	Egg Develop	Clutch Condition

SHELL CONDITION	SEX	FEMALE MATURITY
1= soft	0 = Unknown	0 = Unknown
9 = new pliable	1 = Male	1 = immature
2 = new	2 = female	2 = mature
3 = Old	3 = hermaphrodite	
4 = Very Old		

EGGS		
CLUTCH FULLNESS	EGG DEVELOPMENT	CLUTCH CONDITION
0 = no eggs	1 = uneyed eggs	1 = no dead eggs
1 = trace	2 = eyed eggs	2 = dead eggs < 20%
2 = 1/4 full	3 = hatching eggs	3 = dead eggs > 20%
3 = 1/2 full		4 = barren / clean setae
4 = 3/4 full		5 = barren / matted setae
5 = 100% full		6 = barren / no setae

Alaska Seafood Cooperative, 7/1/2016

Appendix 2: Statistical Power Analysis

RED KING CRAB SAVINGS AREA EXEMPTED FISHING PERMIT POWER ANALYSIS

Fisheries, Aquatic Science, and Technology (FAST) Lab at Alaska Pacific University

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1.0 Introduction

In evaluation of the Alaska Seafood Cooperative's (AKSC) 2015 Exempted Fishing Permit application to explore target and crab bycatch rates in the RKC Savings Area of the Bering Sea, the North Pacific Fishery Management Council's Science and Statistical Committee recommended examining the power of anticipated data collected under the proposed permit to assess differences in crab bycatch rates between exempted fishing vessels permitted to fish within the RKC Savings Area and rates experienced in the course of normal fishing practices in open areas (See December 2015 SSC minutes available at: http://www.npfmc.org/meeting-minutes/).

Bycatch rates for red king crab (RKC) in the Bering Sea flatfish fisheries are characterized by high variability. Specifically, in the Amendment 80 Bering Sea groundfish trawl fishery for rocksole and yellowfin sole in the first half of the year, RKC bycatch rates at the level of individual tows are dominated by mostly zero-RKC catch hauls, with variable and low rates of bycatch for non-zero RKC hauls (Table 1).

To begin an evaluation of statistical power associated with the EFP, haul-by-haul observer catch record data were requested from the EFP applicant. AKSC and its member vessels account for over 80% of flatfish hauls in the winter and spring around the Red King Crab Savings/ Statistical Area 516. The data they provided to APU for this power analysis included observer data for all of AKSC member-vessel hauls targeting flatfish in NMFS Statistical Areas 509 and 516 that occurred from January through April, 2013-2015. Data fields included haul date, haul location (lat/long to the nearest tenth of a minute), fishery target (rocksole or yellowfin sole), total weight of allocated groundfish species in the haul, and catch rate of RKC (number per metric ton of target catch),

With these data we have fashioned a power analyses to evaluate differences in RKC bycatch dynamics between hauls occurring *in* and *out* the RKC Savings/Statistical Area 516 closures (henceforth referred to as Savings Area). The objective of the analysis was to attempt to determine the degree to which the expected level of effort proposed in the Experiment Fishing Permit is sufficient to assess statistically significant differences in crab bycatch dynamics in the Savings Area versus outside of the Savings Area – the chief concern for the proposed EFP on the part of the NPFMC's SSC.

Power analyses to assess differences in RKC bycatch rates *in* versus *out* of the Savings Area include several challenges:

1) Data from past fishing seasons in areas near the Savings Area are dominated by zero-RKC (recorded, see below) bycatch hauls, violating basic assumptions of traditional power analyses.
2) Previous fishing data in areas open to fishing indicate spatiotemporal variability in the rates for non-zero RKC bycatch.
3) The variability of potential bycatch rates within the Savings Area is unknown because the area has been closed to all flatfish fishing operations since it was implemented in the late 1990s and proxy data have inherent limitations (see discussion below). The degree to which proxy data for fishing outside the RKCSA represents expected bycatch rates inside the closure is unknown.

4) The number of hauls that will occur inside of the RKC Savings Area, and thus sampling effort, under the permit may vary depending on target and bycatch (including Prohibited Species Catch in general) outcomes during experimental fishing.

To address these significant challenges in a power analysis and in recognition of the data limitations, we took a two-pronged approach to assessing RKC bycatch rates and made some simplifying assumptions about the expected incidence and variability of crab bycatch in the Savings Area.

First, we explored two different RKC bycatch rate dynamics within the flatfish trawl fishery: 1) an overall haul-level bycatch rate which includes a very large fraction of zero-RKC bycatch hauls, and 2) the proportion of hauls that experienced any RKC bycatch. The latter point provides information on the probability a haul will experience any RKC bycatch, which we term RKC bycatch "incidence" --and provides additional insight in RKC bycatch dynamics that might be missed by looking solely at mean bycatch rates across all hauls (Challenge #1 above).

In considering the highly variable "incidence" of RKC in hauls, it should be noted that it is due in part to inherent variability in catch rates (fishermen report that RKC encounters are very infrequent and RKC distribution appears to be very patchy) and to some extent to observer sampling methods (measurement error). Specifically, fishery observers sample catches on Amendment 80 vessels by drawing a relatively small sample (typically 250 kg for hauls that amount to 10 to 40 MT gross weight) using a stratified random sampling design. Unfortunately, at this time there is no way to systematically tease out variability from observer sampling methods and variability from the inherent patchiness of RKC.

Second, we present power analyses across ranges of input parameters such as sampling variances, proposed differences in bycatch rate or bycatch incidence *in* versus *out* of the Savings Area, and proposed sample sizes *in* versus *out* of the Savings Area. In this manner, we can examine power analysis outcomes from sampling scenarios that are most relevant for fishing expected under the Exempted Fishing Permit and provide data summaries from past fishing activity outside the Savings Area to assist in forecasting such scenarios (Challenges #2-#4 above).

2.0 Methods

The goal of a power analysis is to aid in study design to ensure that adequate sampling effort is conducted to make reliable (i.e. sufficiently precise) statistical inference about the key study parameters of interest, here comparisons of RKC bycatch rates and RKC bycatch incidence *in* versus *out* of the Savings Area. Power analyses can be framed in terms of four input parameters:

1) a proposed/desired statistical significance level ("alpha" or Type I error rate, i.e. the probability of erroneously rejecting a null hypothesis—such as no difference in bycatch rates in versus out of the Savings Area-- when in fact it is true),
2) a proposed/desired power level (1 - beta or 1 – the Type II error rate, where the Type II error rate is the probability of failing to reject a null hypothesis when in fact it is truly false),
3) a proposed/desired effect size (i.e. the difference in key parameter of interest for which the "statistical significance" is assessed, for example a 0.1 crab/ton of catch difference in crab bycatch rates *in* versus *out* of the Savings Area), and
4) proposed/necessary sample sizes across the compared groups (*in* versus *out*).

Finally, information on the sampling variability expected for the quantity under investigation is also required, for example as informed by previous fishing outcomes in areas near the Savings Area. The use of data from the NMFS catch accounting statistical areas most proximate to the Savings Area assumes that those areas are representative of RKC abundance in the Savings Area. Conceptually, one might expect the Savings Area to have higher abundance given that it was the area selected for the closure to protect crab. To evaluate whether adjacent areas are reasonably representative one would need to look to at other fishery or independent data given the area is closed to bottom trawl fishing. One source could be the directed fishery for RKC, which does use the area and adjacent areas. However, the RKC directed fishery targets legal-sized males, and the closure is designed to protect all sizes of crab, males and females. The RKC directed fishery also typically occurs in October/November and seasonal movement of crab is known to occur. Another possible source would be the NOAA trawl survey. Trawl surveys are, however, designed and deployed in a manner that attempts to catch all types of fish and motile benthic invertebrates in the path of the net. In contrast, modern flatfish nets use long, elevated sweep extensions and elevated footropes with spacing between bobbins and discs that would not necessarily catch crab at a comparable rate to survey trawls. Also, the NOAA trawl survey occurs in the summer months.

In consideration of all the above factors and limitations, the use of bycatch rates in the flatfish fisheries adjacent to the closure was deemed to be the best available data for this analysis. This was due mainly to the fact that the fishery occurs at the same time of year as the proposed EFP. Also, the selectivity of the flatfish trawl gear for crab is the same as the gear used for the EFP, so this removes selectivity issues that might overcome differences in abundance due to patchiness of RKC.

Specifying the first three input parameters allows us to solve for the required level of the fourth parameter. For example, with information on expected sampling variability associated with crab bycatch rates, and specifying a proposed alpha level of 5%, power (1-beta) of 90%, and examining an 0.1 crab/ton of catch bycatch rate difference *in* versus *out* of the Savings Area, we can calculate the minimum sample size of hauls necessary to satisfy the problem.

Table 1 provides summary information on catch rate data used for the analysis including breakouts by year and groundfish target species. Subsets of the data used for power analyses for this exercise are shaded in grey in Table 1.

To simplify interpretation of power analyses, we chose to implement one-sample power analyses, whereby we evaluate power to detect differences between bycatch quantities of interest from inside the Savings Area against a proposed reference level which we assume is known with certainty (i.e. no sampling variability) wherein fishing outside the Savings Area in the different time periods and fishing targets of interest are used as proxies. In this manner, analysts can propose any arbitrary reference bycatch quantity to reflect a bycatch scenario of interest as might be informed by outcomes from previous years' fishing outside the Savings Area, and then subsequently examine what level of sampling effort inside the Savings Area would be needed to ensure statistically significant detectable differences.

For reference, power analysis calculations for "two-sample" versions of the below tests, whereby in addition to treating bycatch information from within the Savings Area as a sample quantity, the "reference" level to which bycatch quantities inside the Savings Area are compared is itself treated as a sample quantity, were also conducted. Figures summarizing these analyses are presented in the Appendix to this document.

We examined the statistical power to detect a given difference in the per-haul RKC bycatch rate (number of red king crab/ton of groundfish catch) when compared against a reference bycatch rate level using a one-sample t-test minimum detectable size power analysis. This approach uses a proposed sampling standard deviation, σ (e.g Table 1), a proposed sample size, n, a desired significance level (Type I error rate, α), and a desired power level ($1-\beta$, 1- Type II error rate), to solve for a minimum detectable difference, $\delta = |\bar{x} - \mu|$ given the power analysis parameters, where $\bar{x}$ is the sample mean and μ is the true population mean (formulae in section 7.6 of Zar 1999).

In the context of power analysis for the EFP, we can use prior years' fishing outcomes in areas outside the RKC Savings Area to propose a bycatch rate (crabs/ton of catch) reference level and sampling standard deviation (e.g. Table 1), combined with expectations about the number of hauls that will be executed within the Savings Area to determine a minimum detectable difference in bycatch rates. Following typical statistical convention, we conducted analyses assuming a 5% significance level and 90% power (i.e. $\alpha = 0.05$ and $1-\beta = 0.90$), assessing two-sided hypotheses. For example, supposing a crab bycatch rate (crab/ton of catch) sampling standard deviation of 0.75, 500 hauls are made in the Savings Area, and a reference level bycatch rate of 1.0 crabs/ton of catch, then the minimum detectable difference $\delta = 0.108$, indicating we would have 90% power to detect bycatch rates that were >1.108 or <0.892 as being statistically significantly different than a reference level of 1.0 crabs/ton of catch with 95% confidence.

We examined the statistical power to detect a given difference in the proportion of hauls with zero-RKC bycatch as compared to a proposed reference proportion following Cohen's (1970, 1988) arcsin transform approach (Appendix 1). A high proportion of hauls from the Amendment 80 groundfish bottom trawl fishing in areas near the RCK Savings Area have zero recorded RKC bycatch (see summaries in Table 1), resulting in a highly variable and low overall (average across all hauls) RKC bycatch rate. In this respect, it may be instructive to examine differences in RKC bycatch outcomes *in* versus *out* of the Savings Area by viewing RKC bycatch as a binary yes/no event at the haul level and examining for differences in the incidence of having any RCK bycatch from fishing inside the Savings Area. For example, power analysis indicates that given a 95% significance level and 90% desired power (i.e. ? ËÅ and È − ? Å), and considering a proposed reference zero-crab haul proportion of 90%, we would need to observe approximately 285 hauls inside the Savings Area to be able to detect an observed proportion of 95% from fishing inside the Savings Area as statistically significant, and approximately 455 hauls inside the Savings Area to detect an observed 85% haul proportion as statistically significant. Note, owing to the fact that proportions range from 0% to 100%, sample sizes needed to detect effects are different for positive versus negative differences from a reference proportion level.

For the power analysis results to inform the proposed EFP study, we need information on likely sampling and bycatch scenarios expected under the proposed sampling design. As written, the proposed effort in the EFP is to allow 5 vessels to fish within the Red King Crabs Savings/Statistical Area 516 January 20 through April 30. To forecast what number of hauls can be expected under this level of EFP fishing, we used the data provided by the AKSC described above. In each of the three previous years, thirteen to fourteen uniquely identified vessels were included in the data for each year, with the number of hauls per vessel ranging from 5-269 per year. The mean number of hauls per vessel increased each year from 105 hauls in 2013, to 170 hauls in 2015 (2014 median = 146 hauls). Expanding these means to five vessels would result in an EFP effort of 523-850 total hauls. However, this estimate is diminished by vessels with relatively low number of hauls that will likely not participate in the EFP. If we combine all hauls from the top five vessels each year (in terms of number of hauls), we can estimate a maximum amount of effort by five vessels. These maximums increase from 871 hauls in 2013, to 1193 hauls in 2015 (900 hauls in 2014). Thus, based on previous years, EFP vessels may conduct in the range of 523-1193 hauls over the course of the EFP. For a reference point in discussions below, we chose the approximate midpoint of this range, 850 hauls, as a reasonable estimate of the number of total hauls by 5 vessels per season.

Similarly, expectations about bycatch outcomes (i.e. rate, proportion of zero-bycatch hauls, and standard deviation of bycatch rates) are necessary to define relevant sampling scenarios to interpret power analyses results. As discussed above, historical Observer data for the Alaska Seafood Cooperative from January-April fishing from 2013–2015 were used to characterize bycatch outcomes near the Savings Area as a proxy for proposing relevant bycatch scenarios of interest from within the Savings Area.

3.0 Results

Across all the January-April 2013-2015 data, mean crab bycatch was 0.22 crabs/ton of catch, but was highly zero-inflated (92% of all hauls had zero recorded RKC bycatch; Table 1). Crab bycatch rates varied considerably among years (0.13 crabs/ton of catch-0.35 crabs/ton of catch) and tended to decrease within years from January (0.42 crabs/ton of catch) to April (0.07 crabs/ton of catch). This may reflect seasonal abundance/migration of RKC or actions taken by vessel operators to reduce bycatch rates, such as avoiding bycatch hotspots or changing target species within a year (Amendment 80 vessels transition from targeting rock sole to targeting yellowfin). Crab bycatch rates also display high spatial variability, tending to be higher immediately south of the RKC Savings Area and lower to the northwest of the Savings Area (Figure 1).

Given the uncertainty of red king crab bycatch rates expected within the RKC Savings Area, power analyses are presented over a range of proposed bycatch outcomes, sampling effort (EFP fishing effort inside the Savings Area), and sampling variability levels (one-sample: Figures 2-4; two-sample: Figures A.1-A.2).

In order to provide concrete interpretation to the range of possible bycatch and sampling scenarios, detailed power analysis results are examined for two scenarios based upon rock sole targeted fishing in areas adjacent to and outside the RKC Savings Area. These scenarios are believed to be representative of plausible fishing outcomes that might be experienced from fishing inside the Savings Area under the Exempted Fishing Permit.

In Scenario A, we used a proposed red king crab bycatch rates for inside of Savings Area which mirror the crab bycatch rate of 2013 hauls targeting rock sole (0.23 RKC/ton groundfish catch), and bycatch outcomes for outside of the Savings Area which mirror outcomes from fishing targeting rock sole in 2014 (0.39 RKC/ton groundfish catch); see Tables 1 and 2). In Scenario B, we used a proposed red king crab bycatch rates for inside of Savings Area to match the crab bycatch rate of 2015 hauls targeting rock sole (0.16 RKC/ton groundfish catch) and used the rate of that mirrored the 2013 hauls targeting rock sole (0.23 RKC/ton groundfish catch) for outside the Savings Area. Examinations of specific bycatch scenarios A and B focus on rock sole targeted fishing, as such behavior is thought by the flatfish fishing industry to represent differences in bycatch rates that are realistic for the lower bycatch rates available from having access to the Saving Areas under the proposed EFP. Note, the example scenarios examined represent hypothetical fishing outcomes which utilize different years' data to represent bycatch outcomes inside versus outside of the Savings Area, whereas fishing under the proposed EFP will generate data on hauls within the same year (Figure 1). Power analyses scenarios A and B were chosen to reflect observed temporal variability in bycatch outcomes from realized fishing as a proxy for possible spatial variability expected from fishing inside the Savings Area when comparing bycatch outcomes against fishing at the same time in areas adjacent to, but out of the Savings Area.

Contrasts across bycatch scenarios A and B are characterized by a moderate level of difference in the bycatch rate and differences in bycatch variability (SD; Table 1). When considering scenarios about the overall red king crab bycatch rate (crabs/ton of catch) including all hauls (zero and non-zero crab catches), the one-sample t-test power analysis indicates that under Scenario A, which includes a moderate size difference in bycatch rate outcomes proposed for *in* versus *out* of the Savings Area, an anticipated 500 hauls within the Savings Area would provide reasonable power to detect differences on the order of 0.1-0.15 crabs/ton of catch with 95% significance and 90% power. Based upon previous years' fishing in the area, 500 hauls within the Savings Area represents a plausible level of sampling effort expected under the EFP (Table 3; Figure 2-3). Under more substantial fishing effort in the Savings Area, for example attaining 750 hauls within the Savings Area, minimum detectable bycatch rates would tighten to differences of 0.9-0.125, depending on bycatch variability outcomes (Figures 2-3). In contrast, under Scenario B, where the average bycatch rates proposed for fishing *in* versus out of the Savings Area are much closer, a large number of hauls within the Savings Area would be necessary to detect a small average bycatch rate difference. While high sampling effort would be required inside the Savings Area under Scenario B, the difference between average bycatch rates (crabs/ton of catch) inside the Savings Area versus outside the savings is not large (0.22 versus 0.28 crabs/ton of catch, in years 2015 and 2013 January-April for rock sole targeted hauls, respectively; Tables 1-2, Figures 2-3) relative to total bycatch numbers.

In contrast to power analyses for the overall red king crab bycatch rates, examination of power analyses for the proportion of zero-crab hauls indicates that Scenario B would require less sampling inside the Savings Area to produce a statistically significant detectable difference in bycatch outcomes inside versus outside of the reserve (Table 2; Figure 4). This is because the proportion of zero-crab bycatch hauls in Scenario A are identical to 2 significant digits, requiring very high sampling effort inside the Savings Area to detect the difference. On the other hand, power analyses indicate that a relatively small number of hauls within the Savings Area facilitate statistically significant detection of small differences in the proportion of zero-crab bycatch hauls. For example, 200-250 hauls inside the Savings Area would allow for statistically significant detection of differences of 5 to 7.5% in the proportion of zero-crab hauls from sampling inside the Savings Area against a reference level of 90% zero crab bycatch hauls (Figure 4).

4.0 Discussion

Examinations of bycatch scenarios A and B demonstrate that the expected statistical power in assessing differences in bycatch outcomes from fishing inside the RKC Savings Area under the proposed EFP vary greatly with proposed bycatch variability, expected experimental fishing effort inside the

Savings Area, and the magnitude of potential bycatch outcomes across fishing *in* versus out of the Savings Area. Some generalities, however, become apparent. Owing to the high zero-inflation in expected crab bycatch outcomes from groundfish trawling in the area, analysis of overall red king crab bycatch rates (crabs/ton of catch) is made challenging by low and variable bycatch rates. While observer sampling methods likely contribute to some extent the high frequency of zeros, the actual proportion due to observer sampling versus other sources such as the inherent patchiness of the RKC and avoidance of hotspot methods used by fishermen is not known. Target sampling effort on the order of 500 hauls within the Savings Area is expected to result in sufficient statistical power to detect differences in bycatch rates relative to a reference rate, e.g. 0.1-0.15 crabs/ton of catch (Figure 3, lower right).

Detection of differences in the proportion of zero-crab bycatch rates is achievable with relatively low sampling effort within the Savings Area. Sampling effort expected in the Savings Area under the EFP may produce relatively precise detection of differences in bycatch incidence *in* versus *out* of the Savings Area (Figure 4). In many respects, this is a convenient sampling outcome—while overall bycatch rates are of interest, with low average levels of crab bycatch (crabs / ton of catch), bycatch incidence may be a meaningful bycatch outcome metric. Crab encounters during groundfish demersal trawling is a product of two processes: 1) whether or not a haul occurs in crab-occupied habitat (and observer sampling encounters crab), and 2) the density and catchability of crabs in crab-occupied habitat. If crab distribution is patchy, and crabs are available to demersal trawl gear in low density or have low catchability, these processes give rise to the high zero inflation observed in the crab bycatch rates. The analyses here demonstrate reasonable power to detect differences in crab bycatch incidence that might be encountered *in* versus *out* of the Savings Area as informed by previous years' fishing in adjacent areas under effort proposed in the EFP. In order to increase power to detect overall red king crab bycatch rates (crabs/ton of catch), as well as further improve power to assess differences in crab bycatch incidence rates, it may be beneficial to increase the number of boats allowed under the EFP in order to result in additional hauls within the reserve.

Finally, examination of previous fishing years' outcomes suggests that hierarchical models that separate out zero-bycatch processes from non-zero crab bycatch distribution, such as hurdle or zero-inflated models (e.g. Zuur et al. 2009), may be a good statistical approach to modeling fishing data under the EFP.

5.0 References

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Table 1. Descriptive statistics over various subsets of the data[a]

Data subset	No. Hauls	Total Catch (tons)	Total Crab (No. crabs)	Duration (hours)	% Zero Crab hauls	Total Crab/ton catch	Mean (Crab/ton catch)	SD (Crab/ ton catch)
All hauls	5,972	150,835	33,858	16,974	0.92	0.22	0.26	1.09
2013	1,465	51,395	10,281	2,756	0.90	0.20	0.24	0.91
2014	2,048	48,548	17,006	6,442	0.90	0.35	0.37	1.26
2015	2,459	50,892	6,571	7,776	0.95	0.13	0.18	1.03
Jan	592	15,921	6,514	1,609	0.85	0.41	0.55	1.74
Feb	1,622	39,793	10,450	4,737	0.91	0.26	0.28	1.04
Mar	1,361	34,536	6,020	3,983	0.94	0.17	0.19	0.89
Apr	845	20,344	1,373	2,364	0.98	0.07	0.06	0.39
RockSole	4,892	121,678	32,458	14,099	0.91	0.27	0.31	1.19
Yellowfin	1,080	29,157	1,400	2,875	0.98	0.05	0.05	0.39
Rocksole/2013	1,251	42,988	10,158	2,391	0.88	0.23	0.28	0.98
Rocksole/2014	1,774	42,150	16,515	5,638	0.88	0.39	0.41	1.33
Rocksole/2015	1,867	36,540	5,784	6070	0.95	0.16	0.22	1.16
Yellowfin/2013	214	8407	123	365	0.99	0.01	0.02	0.15
Yellowfin/2014	274	6398	491	805	0.97	0.08	0.06	0.39
Yellowfin/2015	592	14352	786	1705	0.98	0.05	0.06	0.44

[a] Total Catch = tons of combined species catch of allocated groundfish species
% Zero Crab hauls = percent of all hauls with zero recorded red king crab bycatch
Total Crab/ton catch: Total red king crab bycatch rate calculated as Total No. Crab divided by Total Catch.
Mean (Crab/ton catch): Mean of red king crab bycatch rates per haul, not accounting for duration of the haul
SD (Crab/ton catch): Standard deviation of red king crab bycatch rates per haul, not accounting for duration of the haul
Greyed rows indicated subsets used for power analysis scenarios

Table 2. Power analysis results for two example scenarios.

			Minimum sample size needed	
Scenario	Date used as proxy for Inside RKCSA	Data for Outside RKCSA	One sample t-test	Proportions
A	2013 rock sole hauls	2014 rock sole hauls	599	>10,000
B	2015 rock sole hauls	2013 rock sole hauls	3,929	200

Table 3. Statistically detectable differences (95% confidence level, 90% power) in proposed bycatch rates (|inside rate – known proposed reference level|, i.e. one-sample calculations) under an assumed red king crab bycatch rate sampling variability of SD = 1.0 crabs/ton of catch and haul sample sizes expected inside the Savings Area from different effort scenarios associated with 5-vessels operating January 20-April 31 (850 total hauls per year) fishing as proposed in the Exempted Fishing Permit.

Sample size (# hauls inside RKCSA)	Scenario to reach sample size	Detectable difference (crabs/ton)
200	~25% inside from 5 vessel EFP	0.23
425	50% inside from 5 vessel EFP	0.16
850	100% inside from 5 vessel EFP	0.11

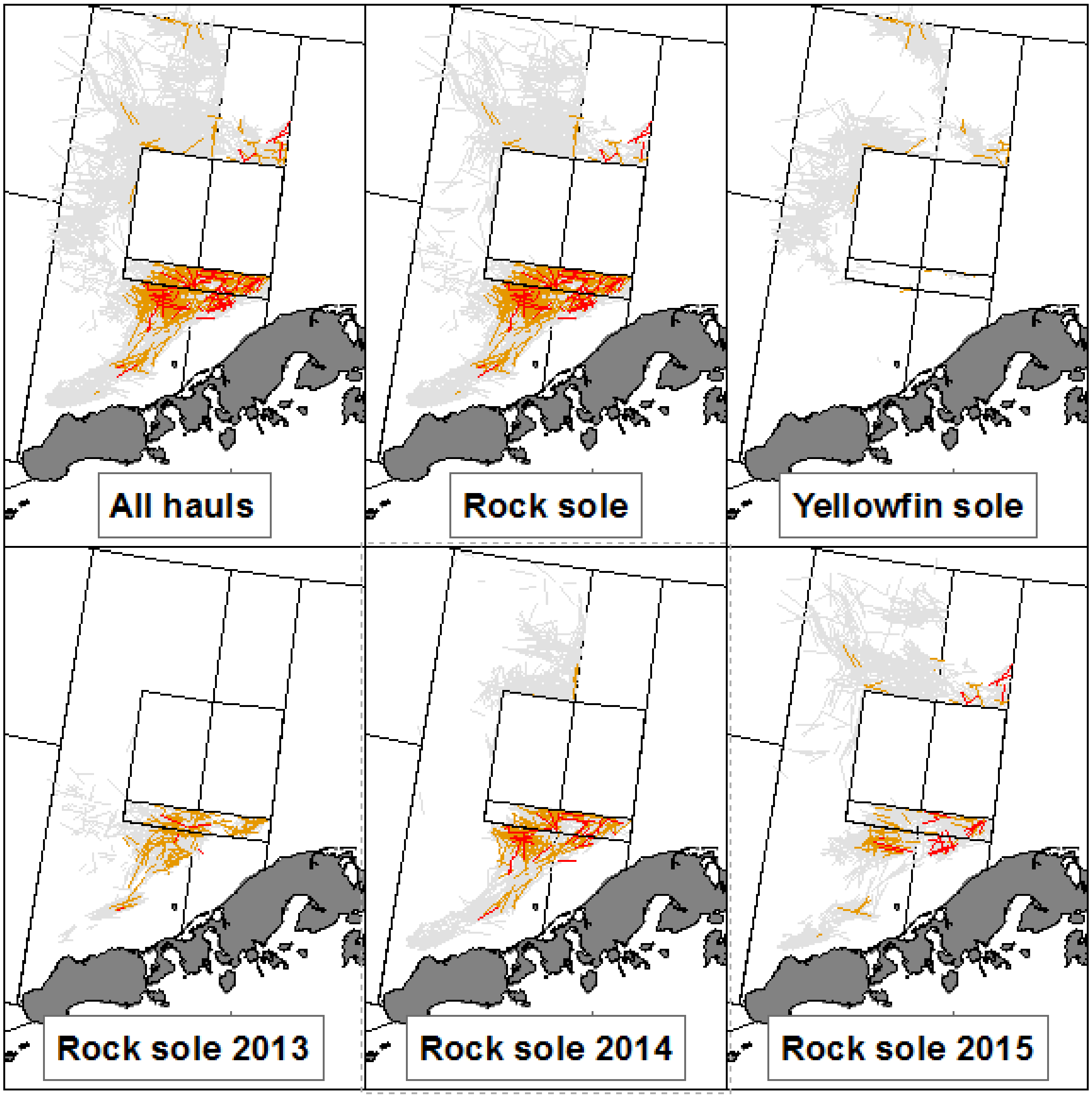

Figure 1. Spatial distribution of Red King Crab bycatch rates (crabs/ton of flatfish catch). Top row plots aggregate all data across 2013-2015 for the months January to April. Bottom row plots aggregate data across January to April within a given year. Lines represent straight line between haul start and end locations. Grey lines represent hauls with zero crabs sampled. Orange lines represent 0-5 crabs/ton. Red lines represent >5 crabs/ton (max is 19 crabs/ton).

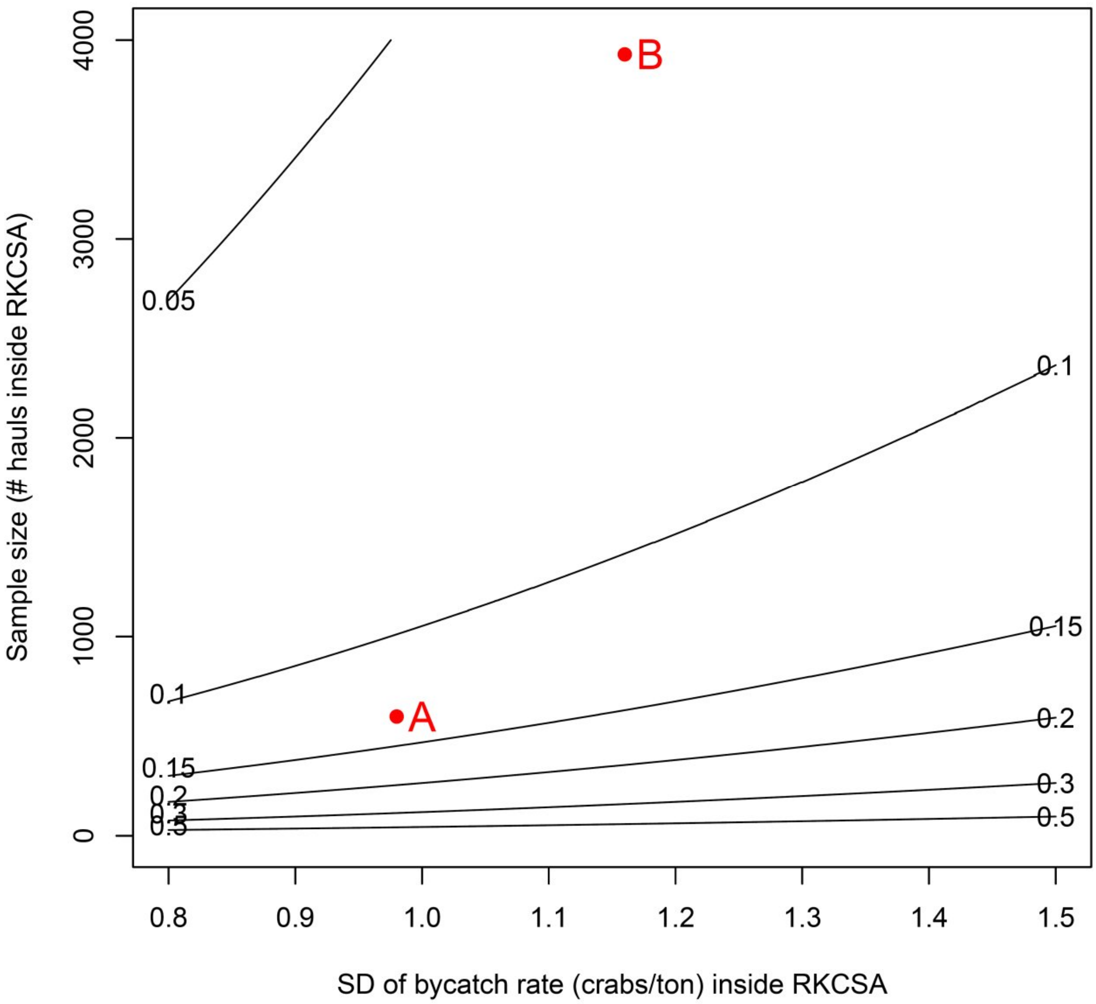

Figure 2. One sample t-test power analysis to assess ability to detect differences in the RKC bycatch rate (crab/ton of catch) against a reference bycatch rate level given a proposed sample size of hauls executed within the Savings Area (y-axis) and proposed bycatch rate sampling standard deviation expected for fishing within the Savings Area (x-axis; e.g. see Table 1). Contour lines give the magnitude of difference in bycatch rates (|?? ??? ? − ???????? ?? ?????|) that would be detectable, given a 5% significance level (Type I error rate) and with 90% power (1 – 10% Type II error rate). Point A (Table 2) represents the scenario in which the proposed sampling variability and bycatch rate for inside the RKCSA are equivalent to that experienced for rock sole targeted hauls from 2013 fishing (which occurred outside the Savings Area) and the reference (e.g. outside RKC Savings Area fishing) bycatch rate is equivalent to the average rate experienced in the 2014 rock sole targeted hauls from fishing outside the Savings Area. The y-axis indicates the number of hauls needed from fishing inside the reserve to detect the difference in the given bycatch rate, e.g. 0.28 red king crab / ton of catch vs. 0.41 crab/ton of catch, respectively. Point B represents the scenario in which proposed sampling variability and bycatch rate for inside the RKCSA are equivalent to that experienced for 2015 rock sole targeted hauls (which occurred outside the Savings Area) and the reference bycatch rate is equivalent to average rate experienced in the rock sole targeted hauls from 2013 fishing outside the Savings Area.

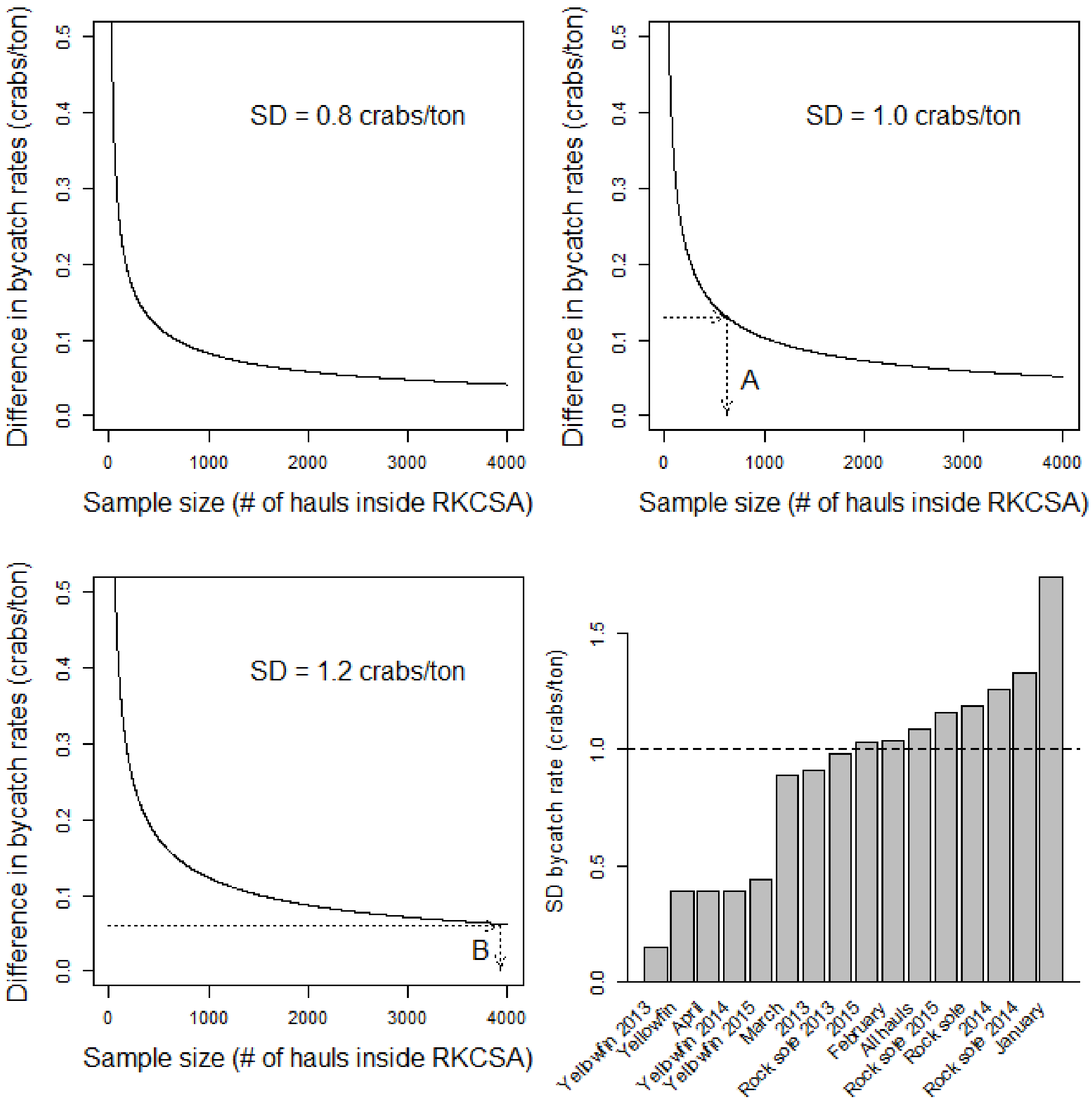

Figure 3. One sample t-test power analysis to detect the difference in proposed red king crab bycatch rates relative to a reference level in specific scenarios. Top row and bottom left panels show statistically significant detectable difference between a proposed bycatch rate for inside the Savings Area against a reference bycatch rate level (|?? ??? ? − ????????? ????|) across a range of sample sizes within the Savings Area. Each panel top row and left column panel represent a different proposed sampling variability level for the bycatch rate inside the Savings Area (sd = 0.8, 1.0, and 1.2 crabs/ton). Scenario A (top right panel; also see Table 2) shows the sample size needed for the scenario where the red king crab bycatch rate inside the Savings Area was similar to rock sole targeted hauls in 2013 (sd = 0.98 crabs/ton) and the reference bycatch rate (e.g. outside the RKCSA) was similar to rock sole targeted hauls in 2014. Scenario B (bottom left panel) shows the sample size needed for the scenario where the red king crab bycatch rate inside the Savings Area was similar to rock sole targeted hauls in 2015 (sd = 1.16 crabs/ton) and outside RKCSA was similar to rock sole targeted hauls in 2013. The bottom right panels demonstrates a suite of red king crab bycatch rates standard deviation for subsets of the 2013-2015 data from fishing outside the Savings Area (Table 1). The horizontal dashed line is the median of these standard deviations (= 1.005 crabs/ton).

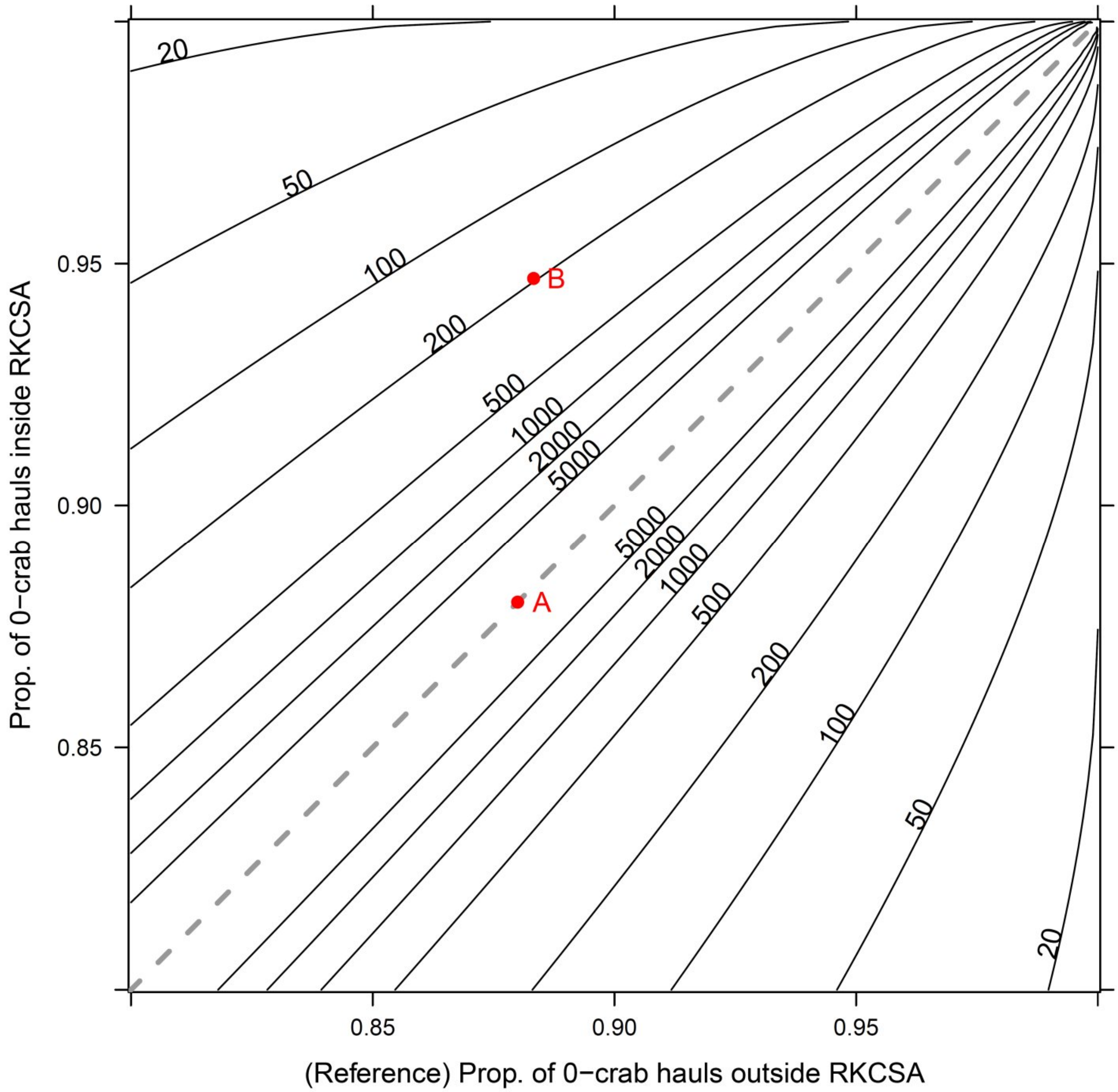

Figure 4. One-sample power analysis on the proportion of hauls with zero recorded red king crab bycatch. Contour lines give sample size (# of hauls) inside the Red King Crab Savings Area needed to detect a statistically significant difference in the proportion of zero-crab hauls from samples inside the Savings Area as compared to a reference proportion with 95% confidence and with 90% power (alpha, or Type I error rate, = 5%; 1-Type II error rate = 90%). Sample sizes rapidly increase to infinity as the difference between the proportion of zero red king crab hauls from sampling inside the Savings Area and the reference proportion (e.g. as informed by fishing outside the Savings Area) of zero crab hauls approaches zero (i.e. along the dashed gray 1:1 line). Point A (Table 2) represents the scenario in which the proposed proportion of zero crab bycatch hauls for inside the RKC Savings Area are equivalent to 2013 rock sole targeted hauls (which occurred outside the Savings Area) and the reference proportion of zero crab bycatch hauls is equivalent to average rate experienced in the rock sole targeted hauls from 2014 fishing outside the Savings Area; in this case both proposed proportions of zero crab hauls are equivalent at 88%. Point B represents the scenario in which proposed bycatch rates for inside the Savings Area are equivalent

to the proportion of zero crab bycatch hauls experienced for rock sole targeted hauls from 2015 fishing (which occurred outside the Savings Area) and the reference (e.g. outside RKC Savings Area fishing) proportion of zero crab bycatch hauls is equivalent to the average rate experienced in the 2013 rock sole targeted hauls from fishing outside the Savings Area.

Supplemental: Additional detail on power analyses

Cohen's one-sample proportion power analysis

Cohen (1970, 1988) defines the "effect size", h , i.e. the difference between the sample proportion $?_?$ and the reference proportion known with certainty, $?_?$, using the following acrsin square root transformation: h ÉÆ?????? ?? $\overline{?_?}$? $-$?????? ?? $\overline{?_?}$? . This transformation produces an effect size that is approximately distributed as a Standard Normal distribution, and Normal-based power analysis on h as a function of one-sample size, Type I error rate, and Type II error rate can proceed following standard approaches.

Appendix 2: Two-sample power analyses figures

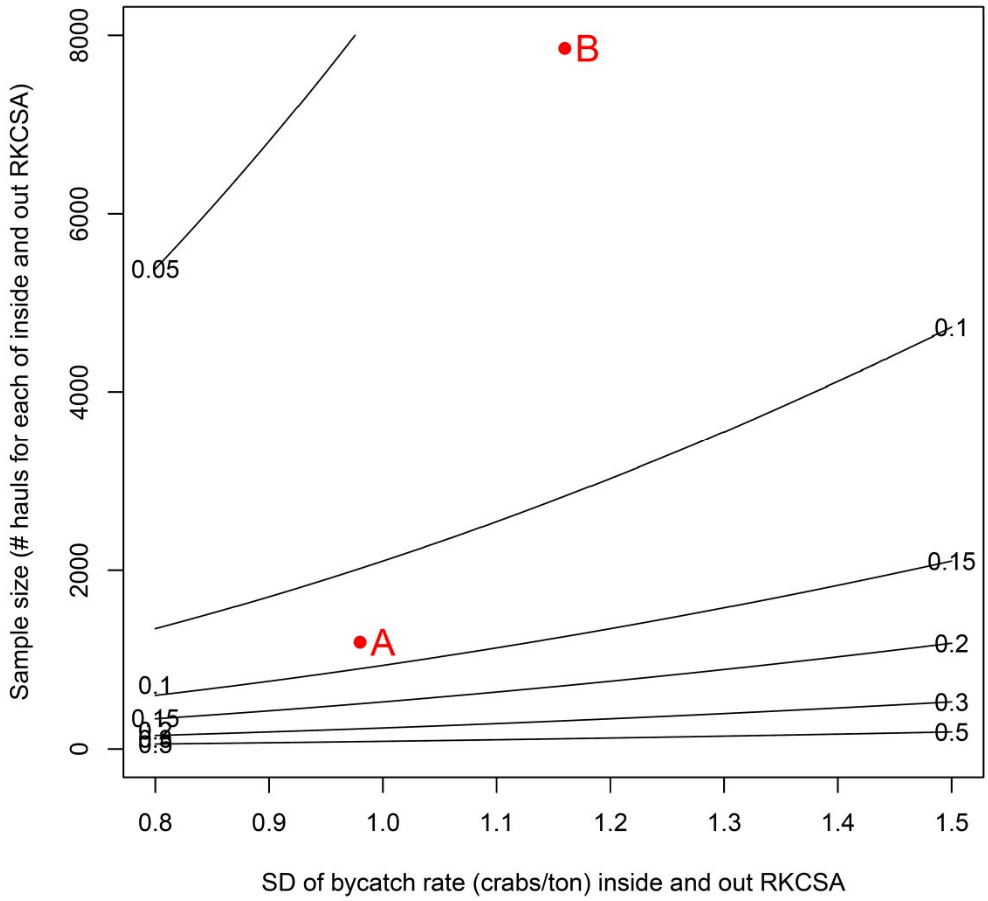

Figure A.1 Two sample t-test power analysis to assess ability to detect differences in the RKC bycatch rate (crab/ton of catch) from proposed sampling inside the Savings Area against proposed sampling outside of the reference area. In this analysis, it is assumed that bycatch sampling variability is equal inside and outside the reserve (x-axis; e.g. see Table 1), and the calculated required sample sizes (y-axis) are the amount of hauls required for each of fishing inside and outside the Savings Area. Contour lines give the magnitude of difference in bycatch rates (|?? ??? ? − ? ? ???? ? |) that would be detectable, given a 5% significance level (Type I error rate) and with 90% power (1-10% Type II error rate). Point A (Table 2) represents the scenario in which the proposed bycatch rate for inside the RKCSA is equivalent to that experienced for rock sole targeted hauls from 2013 fishing (which occurred outside the Savings Area) and the proposed outside bycatch rate is equivalent to the average rate experienced in the 2014 rock sole targeted hauls from fishing outside the Savings Area, with sampling variability inside and outside the reserve equivalent to that from 2013 Rock Sole fishing (see Table 1). The y-axis indicates the number of hauls needed from fishing inside the reserve to detect the difference in the proposed outside bycatch rate, e.g. 0.28 red king crab / ton of catch vs. 0.41 crab / ton of catch, respectively. Point B represents the scenario in which the proposed bycatch rate for inside the RKCSA is equivalent to that experienced for 2015 rock sole targeted hauls (which occurred outside the Savings Area) and the outside bycatch rate is equivalent to average rate experienced in the rock sole targeted hauls from 2013 fishing outside the Savings Area, with sampling variability inside and outside the reserve equivalent to that from 2015 Rock Sole fishing.

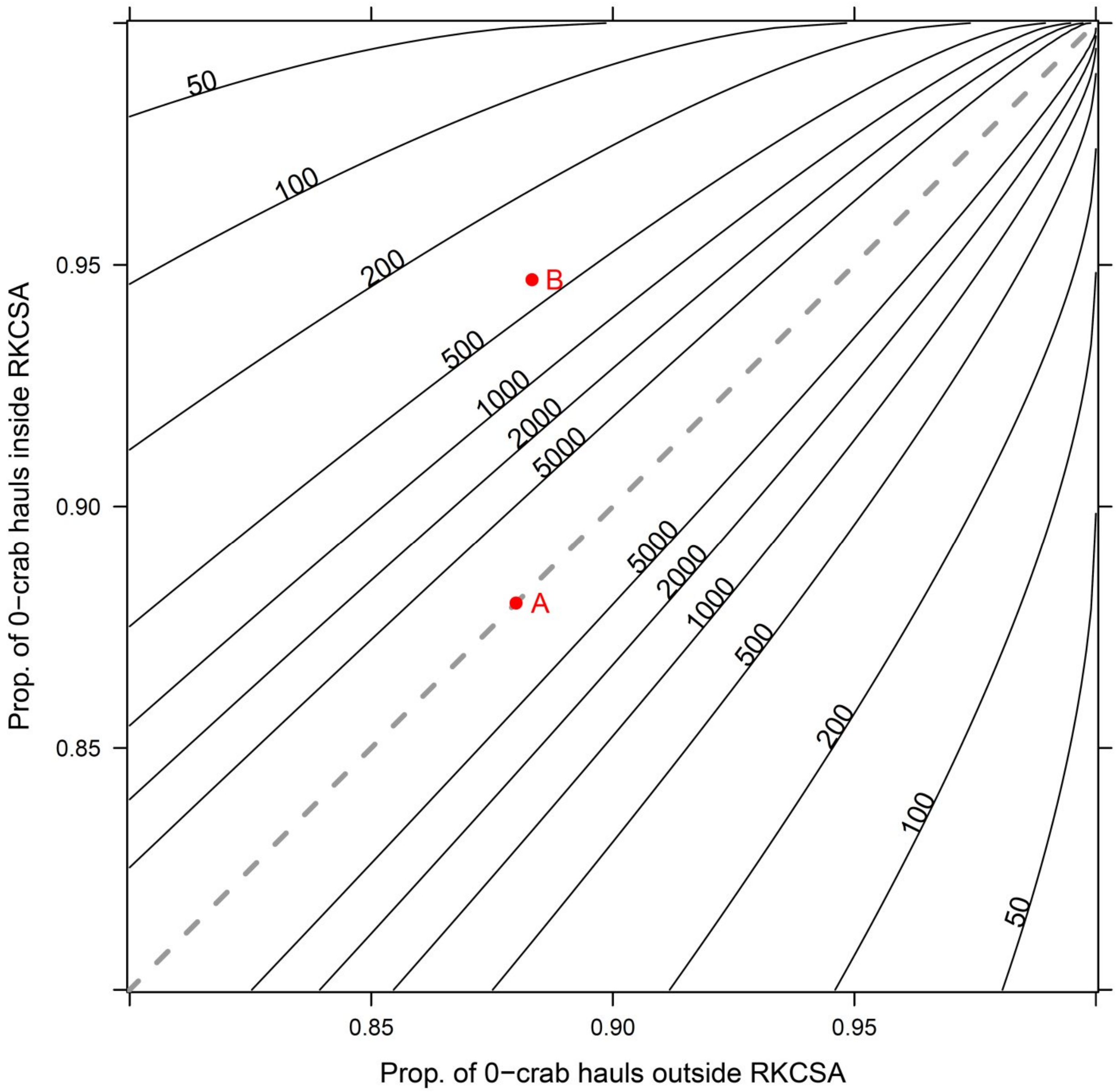

Figure A.2. Two-sample power analysis on the proportion of hauls with zero recorded red king crab bycatch. Contour lines give sample size required (# of hauls) for *each* of fishing inside the Red King Crab Savings Area needed and fishing outside the Savings Area in order to detect a statistically significant difference in the proportion of zero-crab hauls from samples inside the Savings Area as compared to a the proportion from samples outside with 95% confidence and with 90% power (alpha, or Type I error rate, = 5%; 1-Type II error rate = 90%). Sample sizes rapidly increase to infinity as the difference between the proportion of zero red king crab hauls from sampling inside the Savings Area and sampling outside approaches zero (i.e. the dashed gray 1:1 line). Point A (Table 2) represents the scenario in which the proposed proportion of zero crab bycatch hauls for inside the RKC Savings Area are equivalent to 2013 rock sole targeted hauls (which occurred outside the Savings Area) and the proportion outside of zero crab bycatch hauls is equivalent to average rate experienced in the rock sole targeted hauls from 2014 fishing outside the Savings Area; in this case both proposed proportions of zero crab hauls are equivalent at 88%. Point B represents the scenario in which proposed bycatch rates for inside the Savings Area are equivalent to the proportion of zero crab bycatch hauls experienced for rock sole targeted hauls from 2015 fishing (which occurred outside the Savings Area) and the outside proportion of zero crab bycatch hauls is equivalent to the average rate experienced in the 2013 rock sole targeted hauls from fishing outside the Savings Area.