Dividing up the Allowable Catch for Atlantic Butterfish between Landings and Discards in the Longfin Squid Fishery: A Discussion of Outcomes and Tradeoffs

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Executive Summary

In March 2010, the National Marine Fisheries Service implemented a Butterfish Rebuilding Plan recommended by the Mid Atlantic Fishery Management Council in order to rebuild the Atlantic butterfish stock. The primary action taken to improve the stock was to minimize bycatch of Atlantic butterfish by fishermen targeting longfin squid. For the first two years of the plan, 2011 and 2012, the amount of butterfish that could be caught (landings + estimated discards) by longfin fishermen was capped. During 2013, the program is expected to change by capping only estimated butterfish discards on the longfin fishery, while landings of butterfish would be subject to a separate quota. The rationale behind this change is that trip limits on butterfish have been increased for 2013, and more landings are expected to occur. By converting the catch cap into a discard cap, a trip landing large amounts of butterfish will not create an overestimation of the fleet's butterfish catch. However, as the butterfish discard cap and quota are both to be derived as percentages of the butterfish Annual Catch Target, there is potential for an allocation issue. Allotting more butterfish to the discard cap would favor longfin harvest and allotting more to the quota would favor butterfish harvest. This paper first examines when the allocation between quota and discard cap would be important and why. The second section looks at the 2013 thresholds for longfin and butterfish and what they could mean for the two fisheries. The third section shows how tradeoffs can be made and revenues may be increased by changing the method of dividing butterfish between allowable landings and discards. Finally, recommendations are made for use of the discard cap and allocation between the two fisheries in the future, particularly in the event of an expanded butterfish fishery.

Introduction

Longfin squid is a commercially valuable species along the Atlantic coast from Maine to North Carolina. In recent fishing seasons, ex-vessel revenues from longfin have been in the $20-$25 million range (Mid Atlantic Fisheries Management Council, 2012). Fishermen most commonly use bottom otter trawls to land longfin, which can be harvested year round. As is common with some trawl fisheries, the longfin fishery yields a significant amount of bycatch. One species that is caught in particularly high quantities by fishermen targeting longfin is the Atlantic butterfish. These two stocks often co-mingle along the continental shelf and can be caught by similar mesh sizes (Hendrickson, 2011).

Like longfin, Atlantic butterfish historically has been a species of commercial importance (fig. 1&2). In the 1980's and 90's, annual ex-vessel revenues from butterfish ranged from $2 million to $7 million (Mid Atlantic Fisheries Management Council, 2012). In recent years however, these numbers have dropped significantly to around $1 million annually.

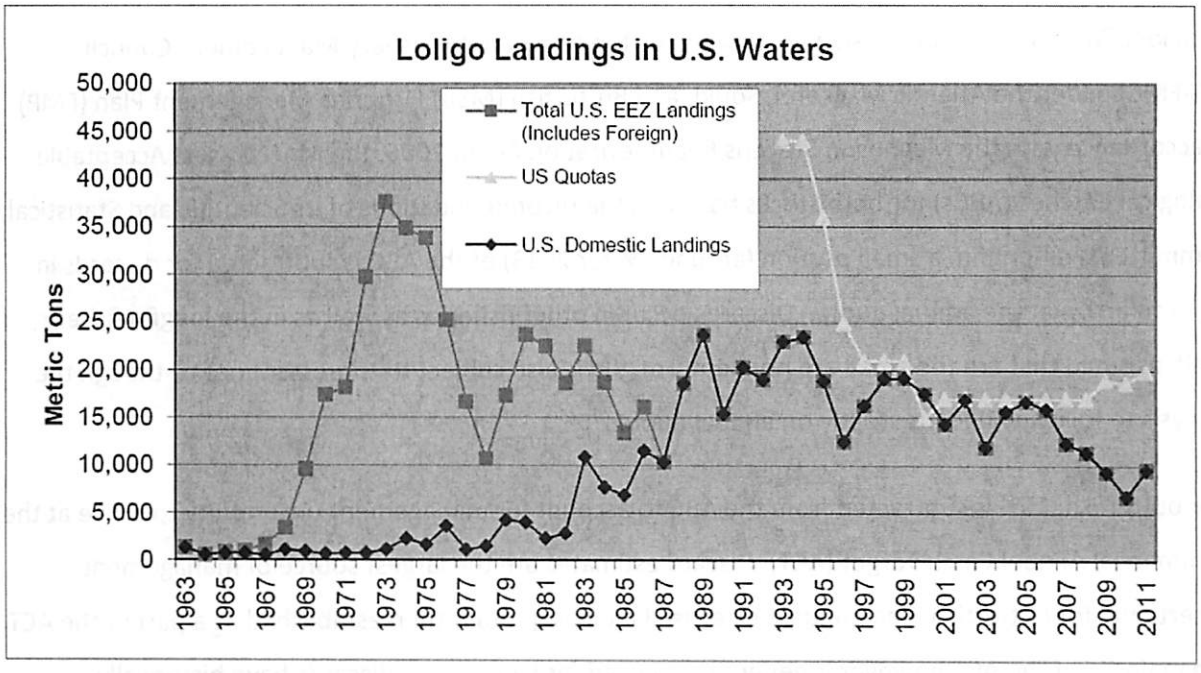

Figure 1. Loligo (Longfin) Squid Landings in U.S. EEZ
Source: MAFMC-Longfin AP Informational Document April 2012; NEFSC SAW/SARC 51

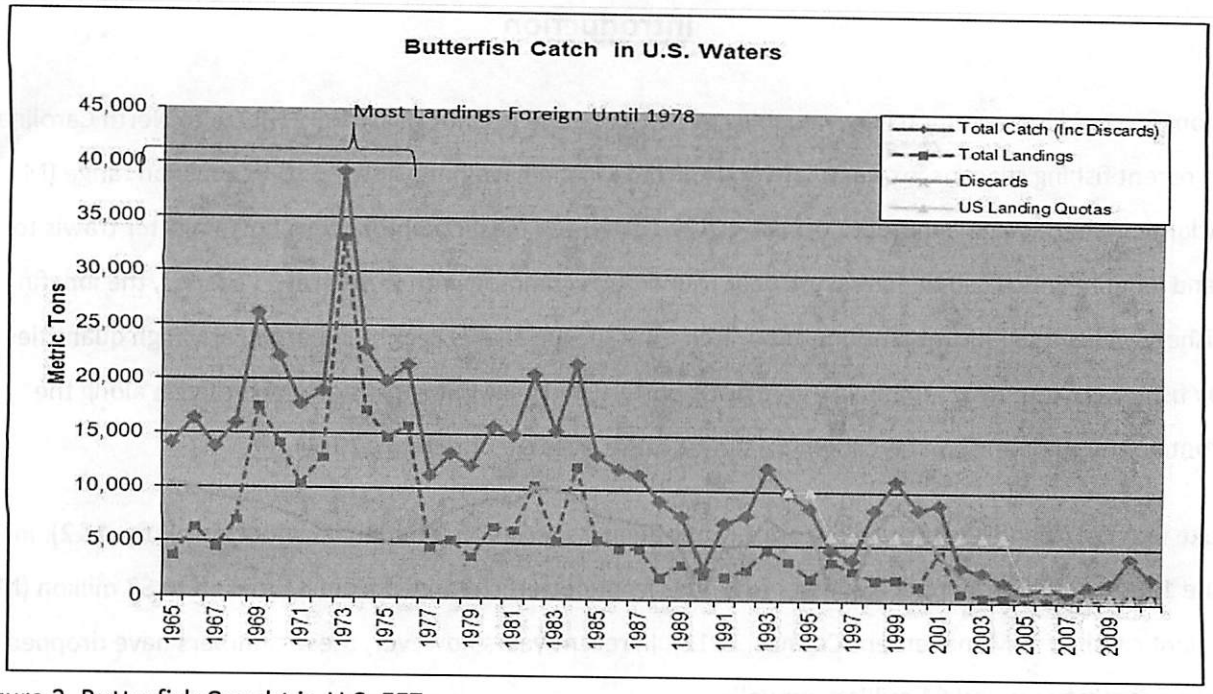

Figure 2. Butterfish Caught in U.S. EEZ
Source: MAFMC-Butterfish AP Informational Document April 2012; NEFSC SAW/SARC 49

Both longfin squid and butterfish are managed by the Mid Atlantic Fishery Management Council (MAFMC) under the Atlantic Mackerel, Squid, and Butterfish (MSB) Fisheries Management Plan (FMP). In accordance with the Magnuson Stevens Reauthorization Act of 2006, the MAFMC sets Acceptable Biological Catches (ABCs) for both stocks based on the recommendations of its Scientific and Statistical Committee. For longfin, a small portion (around 7% for 2013) of the ABC is subtracted for discards in order to arrive at the annual quota. Discards occur in other fisheries as well as in the longfin fishery itself, as squid that are too small are not kept. Longfin is also subject to trimester quotas, though the analysis to follow will focus strictly on annual quotas.

For butterfish, 10% is subtracted from the ABC to account for management uncertainty to arrive at the Commercial Annual Catch Target (ACT). Discard estimates are the largest source of management uncertainty for butterfish. The annual butterfish landings quota is then established as a part of the ACT. The majority of the ACT however is generally not used for landings, as discards have historically accounted for much of the catch (see fig. 2). If the total of landings and discards does not stay below the ABC, the overage must be deducted from the following year. The portion of the ACT that is specified for landings depends on the anticipated ratio of butterfish discards and landings, as well as the Council's goals for discard minimization. This will be discussed in greater detail later on.

A significant decrease in annual butterfish quotas from 5,900 metric tons (mt) in the late 1990's to 1,681mt in 2005 reflected the decline in the butterfish stock (MAFMC, 2012). This decline was confirmed in a 2005 stock assessment in which butterfish was designated an overfished stock. Lower trip limits on butterfish were put in place that year, effectively not allowing for directed fishing on butterfish to occur (from 2002-2004 there was already essentially no directed butterfish fishing). A few years later, in September 2010, the MAFMC passed Amendment 10 to the Atlantic Mackerel, Squid, and Butterfish FMP. This Amendment implemented a program to rejuvenate the butterfish stock, and included the following goals;

1) develop a rebuilding program that allows the butterfish stock to rebuild in the shortest amount of time possible (but not to exceed ten years) and permanently protects the long-term health and stability of the rebuilt stock; and

2) generally minimize bycatch and the fishing mortality of unavoidable bycatch, to the extent practicable, in the squid, Atlantic mackerel, and butterfish (SMB) fisheries;

Among the options that were contemplated in the butterfish rebuilding plan were the establishment of Gear-Restricted Areas (GRAs), and considerable increases in minimum codend mesh sizes for longfin vessels. These measures were not taken, mainly due to industry concern that longfin catch would be severely impacted. Some minor adjustments were made to minimum mesh requirements (48mm changed to 54mm), but the most significant development from Amendment 10 was the implementation of a butterfish mortality cap on the longfin squid fishery. The cap, also to be derived from the butterfish ACT, stipulated that the longfin fishery must close when the butterfish cap is reached. Like the longfin fishery, the cap is divided up between trimesters, though the analysis to follow will focus only on the annual cap. Furthermore, the combination of the butterfish quota and discard cap could not exceed the ACT. The cap was placed on the longfin fishery due to a greater amount of butterfish bycatch occurring in it than in any other directed fishery (MAFMC, 2009).

As the longfin fleet has always been sizable (around 150 active members in recent years), full observer coverage in monitoring butterfish bycatch was not deemed feasible. Instead, the MAFMC decided to estimate butterfish bycatch for all trips landing greater than 2,500 lbs. of longfin (hereafter called longfin trips) by extrapolating from observed longfin trips. This is done by taking the total observed butterfish catch and dividing it by the total observed kept catch for all species, from National Marine Fisheries Service (NMFS) observer data. This gives the percentage of catch that is butterfish compared to

landings on longfin trips. The percentage is then multiplied by total landings from dealer reports between all species on longfin trips to arrive at the total butterfish catch estimate. The formula is shown below (MAFMC, 2010);

(Observed Butterfish Catch/ Observed Kept Catch (all species)) * Landed Catch (all species, all longfin trips)

In 2011, there were 148 observed longfin cap trips, accounting for 11% of the 1,326 total trips landing at least 2,500 lbs. of longfin (MAFMC, 2012). The extrapolated butterfish catch was below the cap for all three trimesters, and the longfin fishery avoided any early closures. The annual cap for the 2012 season also was not binding; however the first trimester for longfin was briefly cut short due to the cap.

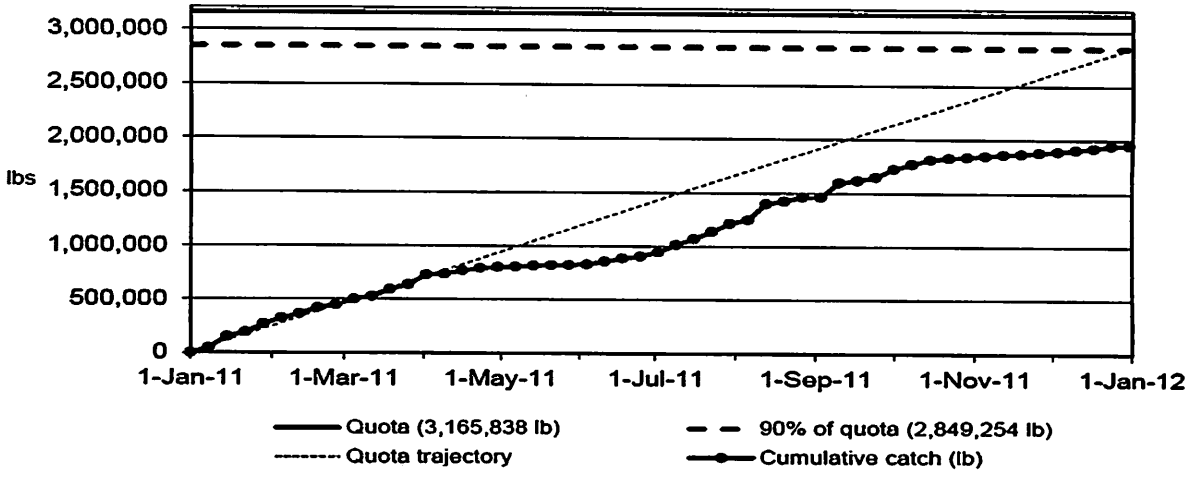

Figure 3. Butterfish cap performance in 2011
Source: MAFMC; NERO Quota and Landing Reports

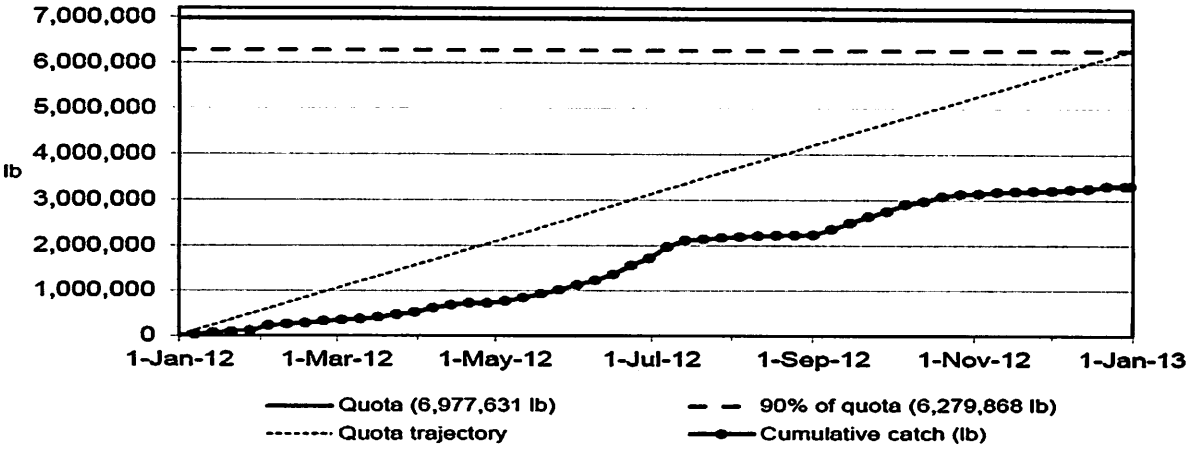

Figure 4. Butterfish cap performance in 2012
Source: MAFMC; NERO Quota and Landing Reports

It is too early to tell if the rebuilding program is affecting the butterfish stock compared to environmental conditions, but the ACT has increased from around 1,600mt in 2011 to over 7,000mt for 2013. The higher ACT is largely a reflection of improved indicators, and a better understanding, of butterfish abundance. As a result of the apparent ongoing stock recovery, the MAFMC has raised the butterfish quota for 2013, with the hope of allowing a limited directed butterfish fishery. The Council has also placed less stringent trip limits for longfin fishermen landing butterfish as well. Furthermore, the butterfish mortality cap, pending the approval of Framework 7 to the FMP by NMFS, will be converted into a discard cap in 2013. This simply means that only discarded butterfish will be counted against the cap on the longfin fishery, as opposed to the system used in 2011-2012 in which all butterfish mortality was counted. Landings of butterfish will continue to be counted against the landings quota. The rationale behind this change is that there will likely be an increase in butterfish landings relative to discards. Under the old system, if there was an observed longfin trip that also landed large amounts of butterfish, the predicted butterfish catch for the longfin fleet could become overestimated. This is because observer coverage is relatively low, and the high butterfish catch for that particular trip may have not been indicative of what is occurring with the majority of longfin trips. Under the proposed system, this overestimation will not be an issue, as butterfish landings from directed butterfish trips, that are also catching some longfin, will only be counted against the landings quota.

The increase in butterfish quota, combined with the discard cap on the longfin fishery, could create an allocation issue between these components of the butterfish ACT. Following Boyce (1996), the optimal allocation will be where the marginal value for an additional unit of butterfish is equalized amongst each use. Vessels in these fisheries are allowed to land both longfin and butterfish, so there are two "uses" for butterfish. The first is landing it, where the marginal value would equal the profit from an additional unit of butterfish kept. The second is discarding it, which holds a shadow value through longfin that can be caught with the butterfish cap.

There are two categories of permit holders involved in these fisheries. Moratorium permit holders land the vast majority of both species as part of their annual fishing portfolio. However, most butterfish have recently been discarded due to a lack of an available market and relatively strict trip limits. Incidental catch permit holders are open access members that generally target a variety of species. These fishermen are subject to different trip limits than the moratorium members, but have also typically discarded butterfish. Within these fleets, there is also a small group of vessels that historically have

landed large quantities of butterfish, many for export. However, with smaller butterfish stocks, and consequently, less catch, exports have fallen off. If a sizable directed butterfish fishery is to resume, these vessels are the most likely candidates to do so.

When allocating the butterfish ACT, maximizing economic yield is not the stated goal of the MAFMC. Currently the method of allocation from year to year is not specified in the FMP. However, with the longfin fishery being highly profitable, and the butterfish fishery in the rebuilding stages, the Council is first and foremost trying to protect the longfin fishery. For 2013, butterfish was allocated to the cap in a manner that should allow the longfin fishery to remain open throughout the season, as long as butterfish discards were not at significantly higher levels than recent seasons. Secondarily, the Council hopes to reestablish a directed butterfish fishery through a higher quota and more liberal trip limits than in past years. Potentially, the method of allocation could change over time, but the general goals of FMPs (Magnuson Stevens Act Section 301) are always used for guidance.

The butterfish ACT for 2013 is 7,560mt, although a small portion of this total is set-aside for discards in fisheries other than longfin. As these discards are not pertinent to this paper, they will not be considered when discussing allocation of the ACT hereafter. After eliminating these other discards, the effective ACT is 7,034mt. The selected allocation for 2013 was 2,570mt (36.5%) going to the landings quota, and the remaining 4,464mt (63.5%) going to the mortality cap. The conversion into a discard cap would lower the cap slightly, as butterfish landings would no longer be used to calculate butterfish discards in the longfin fishery. Currently, all observed butterfish catch is used to estimate total butterfish catch (see equation on page 5). Furthermore, recognizing that there is a great deal of variety in these fisheries year to year, NMFS will have the power to make transfers between the discard cap and quota near the end of the year. However, the initial allocation of the ACT still does dictate to a certain extent how tradeoffs will be made between longfin and butterfish harvest.

With a number of important management changes being made for the longfin and butterfish fisheries, and more changes likely to come, it is important that stakeholders are aware of the possible outcomes that may arise. The following analysis is done with the conversion of the mortality cap into a discard cap already being established, and any mention of the term "cap" will be referring to the discard cap. However, the 4,464mt cap figure will still be used moving forward. This paper will serve three purposes and will be divided up accordingly;

1. To make clear to stakeholders what conditions will result in early season closures for either fishery, or both, and how allocation of the butterfish ACT plays a role. Also, to show how eliminating the allocation issue and using only the ACT as a threshold would change the length of fishing seasons for both longfin and butterfish.
2. To show which scenarios are likely to occur in the 2013 fishing season based on the quota for longfin and the butterfish ACT.
3. To explain how tradeoffs can be made when there may be a binding butterfish ACT.

Part 1: Possible Season Outcomes in the Two Fisheries

I first consider the questions; when is the allocation of the butterfish ACT important, and why? The degree of accuracy in answering the "when" part essentially comes from how well the longfin and butterfish catch to occur during the season can be predicted. Clearly there will be year-to-year variability in these fisheries, but to answer the question theoretically, I assume here that there is perfect information regarding these predictions. Specifically, the assumption is that the landings of longfin to occur relative to the quota and the landings and discards of butterfish to occur relative to the butterfish ACT are known. From the known catch rates of the two fisheries, there are four distinct scenarios that can occur. The question of why the allocation of the ACT is important is answered for each of the four scenarios. Once again, discards set-aside for other fisheries are not considered in the ACT definition. Importantly, the components of the ACT can close the butterfish fishery (through the quota) and/or the longfin fishery (through the cap).

1. Longfin Quota: Not Binding **Butterfish ACT: Not Binding**	**2. Longfin Quota: Binding** **Butterfish ACT: Not Binding**	**3. Longfin Quota: Not Binding** **Butterfish ACT: Binding**	**4. Longfin Quota: Binding** **Butterfish ACT: Binding**

Scenario 1: Longfin Quota: Not Binding
Butterfish ACT: Not Binding

In this case, there is essentially no policy choice of importance. If it is known that both the longfin quota and butterfish ACT will not be binding, neither fishery will close. The initial allocation of the butterfish ACT can determine whether or not there may need to be an in-season transfer, but both fisheries will continue to operate throughout the season regardless. The in-season transfer is possible because there

is enough butterfish available to cover both allocation sources. For example, if the butterfish quota is about to be used up, but there are ample discards available for the longfin fishery for the rest of the season, the appropriate amount of butterfish can be transferred so that no early closure occurs.

Scenario 2: Longfin Quota: Binding
Butterfish ACT: Not Binding

When only the longfin quota will be a binding constraint, there again is not a real allocation issue. The longfin fishery will close regardless of how the butterfish ACT is divided up, as the longfin quota will not be sufficient to support a full fishing season. The butterfish fishery will not have an early season closure, as any unused butterfish discards from the longfin fishery can be transferred to the landings component.

Scenario 3: Longfin Quota: Not Binding
Butterfish ACT: Binding

When only the butterfish ACT will be a binding constraint, the issue of allocation is critical. Depending on how the ACT is utilized the longfin fishery can close, the butterfish fishery can close, or both can occur. If a large portion of the ACT is allocated to discards, it is likely the longfin fishery will not close, but the butterfish fishery will. If however more butterfish landings are allowed, the longfin fishery is more likely to close early, and the butterfish may remain open. Regardless of how the ACT is divided up, at least one of the fisheries will close early. Section 3 will give further details on how tradeoffs can be evaluated under this scenario. The importance of behavioral changes in vessels after the first closure occurs, in order to avoid the second closure, will also be discussed in section 3.

Scenario 4: Longfin Quota: Binding
Butterfish ACT: Binding

When both the longfin quota and butterfish ACT will be binding constraints, the issue of allocation is again very important. The longfin fishery will close early, but the closure may be due to its own quota or by meeting the discard cap. If most of the ACT is allocated to discards, the longfin fishery will likely close from its own quota. The unused butterfish would then be transferred to butterfish landings. If however the initial butterfish allocation is geared more towards landings, the cap may trigger an even earlier closure for longfin. It is also possible that both fisheries could close early. The tradeoffs and in-season changes in vessel behavior mentioned for scenario 3 are also relevant here.

Scenarios without separate allocation to butterfish landings and discards

The idea of not making an allocation between landings and discards of butterfish is presented below. Under this management practice, the longfin and butterfish fisheries will close simultaneously when the butterfish ACT is met. The four possible scenarios are given in table 1.

Scenario	Outcome
1. Longfin Quota: Not Binding Butterfish ACT: Not Binding	**1.** Both fisheries remain open.
2. Longfin Quota: Binding Butterfish ACT: Not Binding	**2.** Longfin closes early due to longfin quota; butterfish remains open until season ends.
3. Longfin Quota: Not Binding Butterfish ACT: Binding for both	**3.** Both fisheries close simultaneously as the butterfish ACT has been met. Even if there is remaining longfin quota remaining, the fishery cannot continue to operate. If butterfish fishing uses up a large portion of the ACT, longfin fishing could be heavily affected due to few discards being "available".
4. Longfin Quota: Binding Butterfish ACT: Binding for Butterfish	**4.** Longfin closes early due to longfin quota; butterfish remains open until ACT has been used up.

Table 1. There are four different scenarios that will result in unique outcomes. Without the issue of allocation, in-season transfers are not applicable.

Part 2: Which Outcome is most Likely?

As it is impossible to anticipate which thresholds may be binding at the start of the fishing season, a method of capturing the variability in these fisheries is presented. Data from 1982-2011 on longfin landings and active vessels in the fishery is used to examine the likelihood of the longfin quota being fully utilized in 2013. The catches for longfin are from the Northeast Fisheries Science Center (NEFSC, 2010) and the number of vessels active each year is from the Longfin Informational Document: Table 4 on the MAFMC website (MAFMC, April 2012). The table in the Council document has vessels divided into four categories based on longfin catch each year, and these categories were summed to get the total

fleet size. The longfin catch is divided by the number of vessels to get the average catch per vessel each year. Table 2 shows longfin landings, active vessels, and catch rates per vessel over the 30 year period. The table is in ascending order based on the catch rate per vessel, and the cumulative normal distribution based on these catch rates is shown in the final column.

Year	Longfin Landed (mt)	Active Vessels	Longfin Landed per Vessel	Normalized Distribution
2010	5,256	138	38	0.02
1987	10,369	189	55	0.10
1996	12,503	206	61	0.15
2009	9,306	151	62	0.16
2011	9,455	139	68	0.23
2000	17,540	252	70	0.25
2008	11,418	164	70	0.25
2001	14,345	206	70	0.25
1990	15,399	218	71	0.26
1997	16,270	220	74	0.31
1999	19,173	259	74	0.31
2003	11,941	156	77	0.35
2007	12,342	158	78	0.37
1998	19,145	241	79	0.39
1985	13,448	169	80	0.39
1986	16,123	199	81	0.42
1995	18,880	230	82	0.43
2002	16,868	204	83	0.44
1988	18,596	206	90	0.57
1984	18,720	201	93	0.61
2006	15,920	168	95	0.64
1991	20,299	212	96	0.65
2004	15,629	160	98	0.68
1993	23,020	218	106	0.79
1983	22,587	209	108	0.82
1992	19,018	163	117	0.90
1994	23,480	201	117	0.90
1989	23,738	201	118	0.91
2005	16,978	140	121	0.93
1982	18,653	118	158	1.00

Table 2. Longfin landings per vessel (mean=86; s.d=24) and normalized probabilities
Source: Longfin landings from NEFSC SAW/SARC 51; vessel data from Longfin Informational Document-April 2012

Using these average catch rates, the numbers are multiplied by two different estimations on the number of vessels that are likely to be active in 2013. A probability distribution is constructed from these estimations to illustrate the likelihood of the longfin quota being used up. It is assumed that the size of the fleet has no effect on the distribution of catch rates. While this assumption may seem extreme, figure 5 shows that historically there is little correlation, if any, between the size of the longfin fleet and catch rates. A larger fleet would be expected to have a higher total catch. Figures 6&7 show the cumulative catch distributions for the two fleet sizes, with n referring to the number of active vessels.

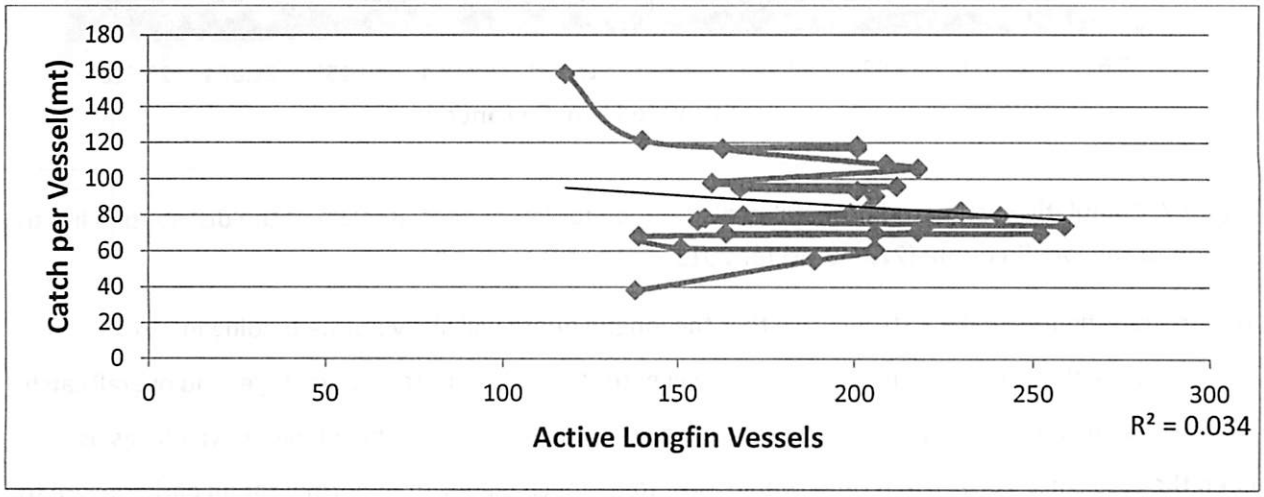

Figure 5. Effect of longfin fleet size on catch per vessel, with corresponding trend line. Notice the near-zero R^2 value.

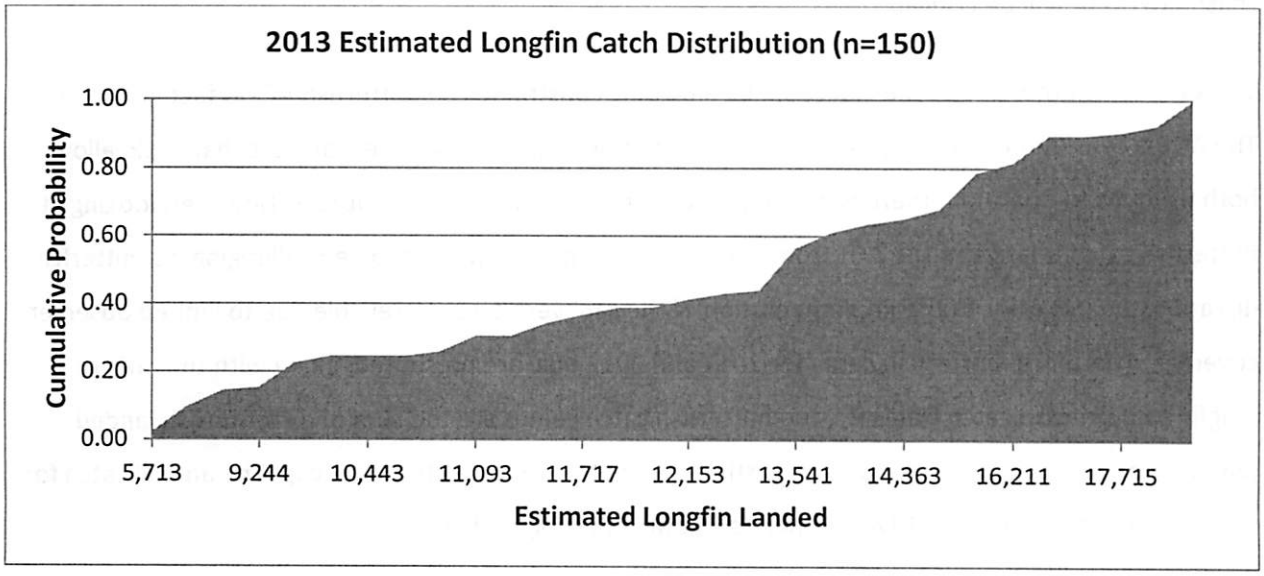

Figure 6. Cumulative estimated probability distribution for smaller fleet. 99.39% of the distribution lies to the left of the longfin quota (22,049mt) for 2013.

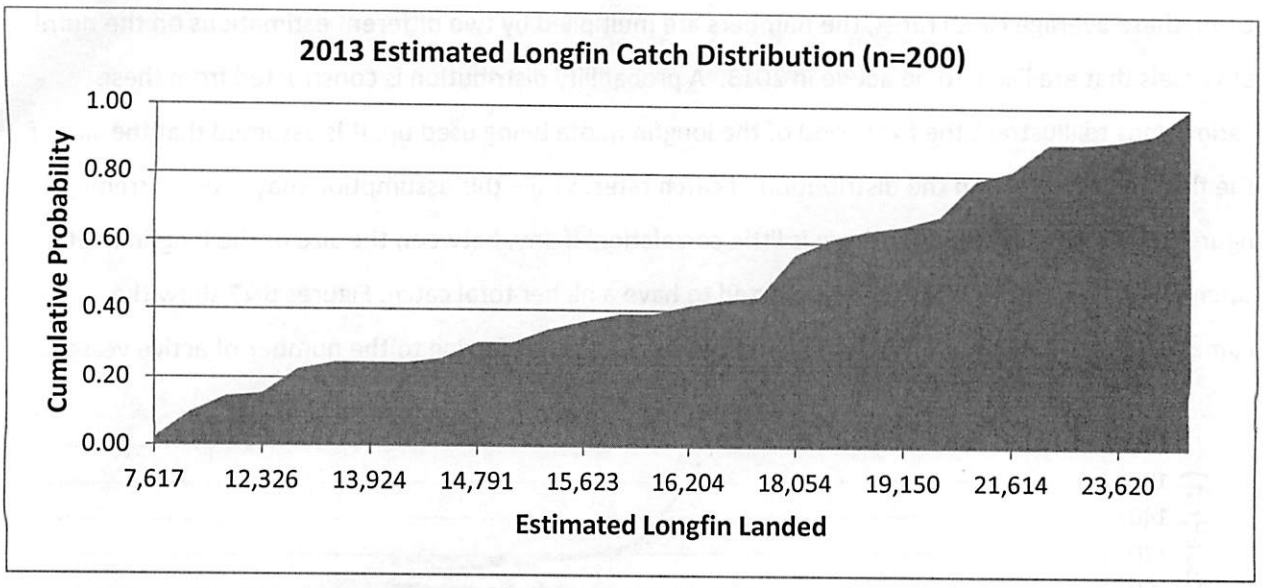

Figure 7. Cumulative estimated probability distribution for larger fleet. 83.92% of the distribution lies to the left of the longfin quota (22,049mt) for 2013.

The previous figures make a strong case that the longfin quota will likely not be binding in 2013. Certainly if catch rates are high, more vessels will enter the fishery to take advantage, and overall catch will increase further. However, even if there were 200 active vessels catching longfin, which has not been the case since 2002, catch rates would have to be much higher than normal for an early closure to occur. Furthermore, from 1997-2011, the entire annual longfin quota was only landed in 2000 (MAFMC, 2012). As the annual quota is not likely to be binding, avoiding the cap to allow a full longfin fishing season to occur will be critical.

To examine whether or not the cap could be a binding constraint, the butterfish ACT is first analyzed. The ACT is considered because, as established in part one, NMFS can make transfers that could allow both fisheries to operate if there is enough butterfish for both allocation sources. However, looking at butterfish catch relative to the ACT from a historical perspective proves to be challenging, as butterfish discard estimates prior to the implementation of the cap were often unreliable due to limited observer coverage. Therefore, butterfish catch for 2011 and 2012 only are presented, along with the ratio of longfin to butterfish catch (table 3). The butterfish catch values are the sum of all butterfish landed (whether or not on longfin trip) plus the estimate of butterfish catch from the cap. The annual catch for both species come from the NOAA Fisheries Quota Reporting Archives.

	2011	2012
Butterfish Landings+Discards (mt)	1,539	2,121
Longfin Landings (mt)	9,455	12,509
Longfin/Butterfish Catch Ratio	6.14	5.90

Table 3. Catch for both species since the butterfish cap was implemented.

The longfin quota for 2013 is 22,049mt, and the butterfish ACT (cap+quota only) is 7,034mt. If a longfin/butterfish catch ratio around 6 occurs again, fewer than 4,000mt of butterfish would be caught even if the longfin quota was met. However, as discussed earlier, some directed butterfish fishing is expected in 2013, which should lower the ratio. In theory, a longfin/butterfish catch ratio of 3.13 (22,049/7,034) or lower would be necessary for the cap to be met, and any higher ratio would mean sufficient butterfish is available to support both fisheries. In actuality, if there is enough butterfish to support both fisheries for the entire season, but the allocation between the landings quota and cap does not reflect what is occurring, a closure could occur. A transfer could be made between ACT components to allow the allocation to more accurately reflect what is happening in the fisheries. However, the decision to make a transfer likely would not be as easy as described in section one, where it is assumed that the butterfish catch relative to ACT is known beforehand.

Looking at the individual components of the ACT, in 2011 there was an estimated 885mt of the butterfish mortality cap caught, followed by 1,500mt in 2012. The cap of 4,464mt would not likely be met, considering longfin fishermen have the same incentive to avoid butterfish as in the past two years. For landings, 620mt occurred for butterfish in 2012. An increase of almost 2,000mt would be required to meet the quota of 2,570mt. Such an increase in a single year has only occurred on a few occasions in the history of the domestic butterfish fishery (see fig. 2). Furthermore, unless discards in the longfin fishery more than double in 2013, there would be butterfish available to transfer to the quota from the cap if need be.

Based on the above analysis, it would appear that the most likely outcome for 2013 would be scenario 1, in which case neither the longfin quota nor the butterfish ACT will be binding. Scenarios 2&4 seem improbable as the longfin quota has rarely been binding in recent history, and based on catch rate and fleet composition estimates, this trend should continue. Scenario 3 would likely only be possible if significant directed butterfish fishing occurs. Even if this is does not occur for some time, it is important to look at how tradeoffs can be made if there is not enough butterfish to support a full season in both

fisheries. The next section will use the 2013 butterfish landings quota and cap as starting points to examine how these tradeoffs can be made through altering the allocation of a binding ACT.

Part 3: Tradeoffs between Fisheries when changing the ACT Allocation

As discussed in part one, a binding butterfish ACT will result in at least one fishery having an early season closure. The lost revenue from an early closure would be undesirable for either fishery, but in this case, tradeoffs between longfin and butterfish harvest have to be made. The question of how to evaluate these tradeoffs is answered by analyzing if and when total revenue can be increased and ultimately maximized through allocation changes.

Evaluating tradeoffs is done by using a hypothetical fleet of vessels and the 2013 allocation of 2,570mt for the butterfish landings quota and 4,464mt for the discard cap as a starting point. From this point, the quota is first lowered 10% and then raised 10%, with the discard cap being changed in each case so that the sum of the quota and cap is always equal to the ACT. The fleet of vessels was assembled in a manner that would allow the starting point figures to be the revenue maximizing allocation when vessel behavior does not change during the season. This will be discussed in greater detail later. When vessel behavior does change, a different revenue maximizing allocation will be possible. For each of these examples, the longfin quota is not binding in order to best observe revenue changes that occur when the butterfish quota and cap are altered.

Before delving into the tradeoffs of reallocating butterfish, the importance of the starting point allocation must be established. As discussed earlier, there is variability in the fleet regarding the value of butterfish catch; some vessels primarily discard, others land. The starting point allocation is proportional to the predicted percentage of butterfish caught that will be retained amongst all vessels in the hypothetical fleet. For example, if 60% of butterfish caught by the fleet is predicted to be retained, 60% of the ACT would be given to the quota. By multiplying the ACT by the predicted fleet retention rate, the cap and quota would be used up at the same time, if the prediction is correct. As established, if butterfish catch (landings+discards) for the season is greater than the ACT, at least one fishery will close early. With a binding ACT, under the allocation based on fleet-wide retention rates, both fisheries would close together if the predicted retention rate is equal to the actual rate. For example, if there was an ACT of 1,000mt, with 100mt of butterfish being caught each month, and the predicted and actual retention rate was 60%, the two fisheries would close together after 10 months. The butterfish closure

would occur as 600mt (1,000*.6) are landed, and the longfin closure would occur at the same time with 400mt (1,000*.4) of butterfish being discarded. However, if the ACT was not binding, both fisheries would remain open until the end of the season.

This method essentially serves the same purpose as not making any allocation of the ACT. Each vessel is able to operate at full capacity until the cap and quota are met simultaneously; the same point at which the ACT would be met with no allocation made. However, if the rate of butterfish discards or landings is much higher than predicted, one fishery would close earlier than the other, if there is no butterfish available to transfer. Allocating based on the predicted fleet-wide retention rate is designed to effectively capture the current market for butterfish. Naturally, these markets will change over time and the retention rate likely will as well. What the adjustment to the predicted retention rate would be over time would depend on any number of factors. These may include trends not only in retention rate, but location changes of the butterfish stock in relation to longfin, and changes to fleet composition. Most importantly, as the predicted retention rate is increased, less butterfish is "available" for longfin-specialists to discard. This is when tradeoffs have to be made.

Fleet Characteristics and Starting Point

The process of making tradeoffs is illustrated via an Excel sheet consisting of a 52 week fishing season and a hypothetical fleet of 160 vessels. Within this fleet three categories of vessels are used. It is important to note that these categories of vessels represent the continuum of longfin and butterfish catch rates that exist amongst the actual fleet. As all fleet members have permits to land both species, vessels can be best categorized based on their catch portfolio. For simplicity, vessels that generate more revenue from longfin are classified as longfin vessels. Vessels that generate more revenue from butterfish are classified as butterfish vessels.

Category A consists of longfin vessels that generally treat butterfish as bycatch. These vessels are specified in the model as having a high longfin/butterfish catch ratio and a low retention rate on butterfish. Category B consists of longfin vessels that treat butterfish as a secondary species in some instances, and as bycatch in others. These characteristics are captured in the model through both an intermediate longfin/butterfish catch ratio and retention rate on butterfish. Category C consists of butterfish vessels that also land some longfin, but in significantly lower quantities than the first two. These butterfish vessels are representative of the group mentioned in the introduction that have

historically landed, and exported, substantial amounts of butterfish. In the model, these vessels are specified as having a very low longfin/butterfish catch ratio and a high retention rate on butterfish.

The catch and retention rates for all vessels are assumed to be linear when both fisheries are open. When vessel targeting behavior does not change during the season, the catch rates will be constant for the entire length of the seasons. When targeting behavior does change, catch rates will change after the first fishery closes. Finally, these vessels are assumed to be the entire fleet, so all catch rates are known. As discussed earlier, the discards of butterfish in the actual fisheries are estimated from observed trips, but this estimation method is not used for this analysis. Since the goal of this section is to best observe the consequences of changing the butterfish allocation, the assumption of perfect information is used. Table 4 shows the characteristics of the model fleet when both fisheries are open. Table 5 gives the total catch for both species per week and the catch ratio for the fleet when both fisheries are open. These tables will be referred to when allocation changes are made.

When assembling the fleet, the butterfish retention rates were set so that the fleet-wide retention rate was equal to 36.5%; the same percentage of the ACT that is allocated to the butterfish quota for 2013. As established, this allows for the longfin and butterfish fisheries to have equal length of seasons, and this allocation was used as the starting point in this analysis (table 6). Price estimates for longfin and butterfish are also included in table 6. These estimates are based on NMFS dealer report data included in the longfin and butterfish informational documents on the MAFMC website (MAFMC, 2012).

The starting point will be the revenue maximizing allocation when vessel behavior does not change during the season and there is perfect information for vessel catch rates. If there was a transfer from butterfish quota to cap, revenue from butterfish would decrease. Furthermore, revenue from longfin would remain the same. The reason for this is that once the butterfish quota is met, all butterfish caught then has to be discarded. The increase in discards after the quota is met will directly offset the higher cap, and the longfin season will be the same length as the starting point. To illustrate this, I revisit the numbers used earlier in this section when describing the fleet wide retention rate. The ACT is 1,000mt, with a starting point quota of 600mt, and a starting point discard cap of 400mt. Each month, 100mt of butterfish are caught, with 60% of it being retained, so that 60mt is landed each month and 40mt is discarded. This allows the butterfish fishery to operate for 10 months (600/60), and the longfin fishery to operate for 10 months (400/40). If the quota was lowered by 60mt to 540, the butterfish fishery could only operate for 9 months (540/60). The cap would be increase by 60mt to 460. When the

butterfish fishery closes after 9 months, 360 discards have been made (40*9). However, for the tenth month, all butterfish catch (100mt) must be discarded. This means that the cap will still be met after 10 months as the discard total when the butterfish fishery is open (360mt) plus the total when it is closed (100mt), equal the new cap.

In reality, butterfish discards are estimated, so even if the increase in actual discards would offset the cap gain, the estimates from observed discards may overestimate or underestimate the actual increase. An overestimation of the change in discard rates would actually cause the longfin fishery to close earlier than the starting point, even with the lower quota. An underestimation would cause the longfin fishery to be extended further than the starting point.

On the other hand if there was a transfer from the butterfish cap to the landings quota, there will be revenue changes. The revenue from longfin would decrease, as the discard cap would be met earlier in the season. Butterfish revenue would increase, but given current relative prices (table 6), it would be difficult to offset the losses from longfin. In order for total revenue to increase by raising the butterfish quota, the increase in butterfish landings would have to be greater than the decrease in longfin landings. As discussed earlier, longfin/butterfish catch ratios in recent seasons have been around 6:1. In earlier years, when significant directed butterfish fishing was occurring, this ratio was typically between 2:1 and 3:1. Given these facts, it would be extremely unlikely that raising the butterfish quota and lowering the cap from the starting point would yield revenue increases.

Category	Vessels	Longfin Landings (mt) per Vessel per Week	Longfin Landings per Butterfish Caught	Butterfish Caught (mt) per Vessel per Week	Butterfish Retention Rate
A	75	2.50	5	0.50	16%
B	75	2.50	2	1.25	30%
C	10	1.92	0.3	6.40	90%

Table 4. Starting point fleet characteristics. Vessels in category A&B are defined as longfin vessels and vessels in category C are defined as butterfish vessels. These values are used from the starting point in the season until the first fishery closes.

Total Longfin Landings (mt) per Week	Total Butterfish Caught (mt) per Week	Longfin/Butterfish Catch Ratio
382.69	156.89	2.44

Table 5. Catch rates when both fisheries are open.

	Butterfish	Longfin
ACT (mt)	7,034	N/A
Cap (mt)	4,464	N/A
Quota (mt)	2,570	22,049
Price (per mt)	$1,800	$2,500

Table 6. Starting point thresholds and prices for both species.

Changes in Allocation and Vessel Behavior

As established above, when vessel behavior does not change during the season, the current method of allocation maximizes revenue. However, while the assumption of fixed catch rates is useful to understand the implications of changing the allocation between butterfish quota and cap, such changes will likely create incentives to change targeting behavior. For example in the case where there is a reallocation from the butterfish landings quota (10%) to the cap, vessels will have incentives to lower their catch rate of butterfish, as they cannot be landed. If this does in fact occur, the effects on the relative and total net revenue of the various vessels and the total fleet will be different. To observe these changes, assume that after the butterfish season is closed, vessels change their behavior such that butterfish catch rates are decreased by 50% from the point the butterfish quota is met until the longfin quota is met. The values from table 4 will apply when both fisheries are open. Tables 7&8 show the characteristics of the fleet after the butterfish quota is met. The higher longfin/butterfish catch ratio allows for a longer longfin season and consequently, higher season catch.

Category	Vessels	Longfin Landings (mt) per Vessel per Week	Longfin Landings per Butterfish Caught	Butterfish Caught (mt) per Vessel per Week	Butterfish Retention Rate
A	75	2.50	5	0.25	0%
B	75	2.50	2	0.625	0%
C	10	1.92	0.3	3.20	0%

Table 7. Fleet characteristics from the point of the butterfish fishery closing until the longfin fishery also closes.

Total Longfin Landings (mt) per Week	Total Butterfish Caught (mt) per Week	Longfin/Butterfish Catch Ratio
382.69	78.45	4.88

Table 8. Catch rates when only the longfin fishery is open.

Next, consider what will likely happen if there is a transfer (equal to 10% of the quota) from the butterfish cap to the landings quota. Here it is again necessary to consider the incentives this transfer will have on the various vessels. The transfer will cause the butterfish cap to be met earlier in the season, prohibiting vessels from landing longfin. For simplicity, it is assumed that the longfin vessels will not find it profitable to operate once the cap is met. As they will also not land any butterfish after the closure, there will be more available for the butterfish vessels. Table 9 shows the characteristics of the fleet after the discard cap is met given these assumptions. The values from table 4 still apply when both fisheries are open.

Category	Vessels	Longfin Landings (mt) per Vessel per Week	Longfin Landings per Butterfish Caught	Butterfish Caught (mt) per Vessel per Week	Butterfish Retention Rate
A	75	0	0	0	N/A
B	75	0	0	0	N/A
C	10	0	0	3.20	90%

Table 9. Fleet characteristics from the point of the longfin fishery closing until the butterfish fishery also closes. Longfin vessels are no longer active, and butterfish vessels can no longer land longfin.

The results for the three categories of vessels for the decrease in quota, starting point, and increase in quota are presented in table 10. Consider first the transfer from the butterfish landings quota to the cap. Contrary to the case where catch rates stayed the same, the change in targeting after the butterfish closure lowers catch of butterfish and allows for a longer longfin season. Consequently, longfin vessels increase their net revenue, as the lost revenue from butterfish is minor compared to the increase longfin revenue. In terms of species-related revenue changes, butterfish vessels follow a similar trend; longfin revenue increases and butterfish revenue decreases. However, given the relative harvesting efficiency for the two species and the differences in relative prices, butterfish vessels will see decreases in net revenue.

Now consider what will happen if there is a transfer from the butterfish cap to the quota, shown in the third row in the table. The longfin vessels show a decrease in net revenue because there is a shorter season for longfin due to the reduced cap. In addition, butterfish revenues are reduced for longfin vessels, with the given assumption that they choose not to operate after the longfin fishery has closed because it is no longer profitable. The butterfish vessels show increases in revenue because of the

quota increase and because they are able to take more of the quota due to the reduced harvest by longfin vessels.

	Long Vessel (Cat A)			Long Vessel (Cat B)			Butter Vessel (Cat C)		
	Long Rev.	Butter Rev.	Total	Long Rev.	Butter Rev.	Total	Long Rev.	Butter Rev.	Total
Transfer from Quota to Cap	23.1	0.44	23.54	23.1	2.04	25.14	0.94	1.69	2.63
Starting Point	21.02	0.49	21.51	21.02	2.27	23.29	0.86	1.86	2.72
Transfer from Cap to Quota	19.8	0.46	20.26	19.8	2.14	21.92	0.81	2.16	2.97

Table 10. Species-related and total revenue (in million $) for each category of vessels when butterfish catch rates decrease by 50% after the quota is reached.

The fleet-wide revenues and closing dates for the three allocations are illustrated in table 11. The closure date is based on a season starting on Jan 1st. Given the assumptions about changes in targeting behavior, the fleet values indicate that transferring from the landings quota to the cap will increase total longfin revenue and decrease total butterfish revenue. Transferring from the cap to the quota will increase total butterfish revenue and decrease longfin revenue, for the reasons explained above. For this hypothetical fleet, with the assumed changes in targeting behavior, total fleet revenues increase significantly with the transfer from the butterfish landings quota to the cap.

	Fleet Totals				
	Long Rev.	Butter Rev.	Total	Closure Date Long	Closure Date Butter
Transfer from Quota to Cap	47.14	4.17	51.31	12/11	10/10
Starting point	42.9	4.62	47.52	11/10	11/10
Transfer from Cap to Quota	40.41	4.76	45.15	10/23	12/31

Table 11. Species-related and total revenue (in million $) for the fleet and closure dates when butterfish catch rates decrease by 50% after the quota is reached.

But an interesting policy question in this regard is if the goal is to maximize net revenue how much butterfish should be reallocated from the butterfish quota to the cap. The revenue maximizing allocation is shown in the second row of Table 12. In this case, if maximizing revenue in the season is the policy goal, the cap should be increased until the longfin season runs for the full year. With different assumptions of catch rates and abilities to change targeting behavior, the results would differ.

Nevertheless, the assumptions used here could provide guidance to the Council on maximizing single season revenue, if that is the goal.

	Butter Quota	Discard Cap	Long Rev.	Butter Rev.	Total	Closure Date Long	Closure Date Butter
Starting Point	2,570	4,464	42.9	4.62	47.5	11/17	11/17
Revenue Maximization	2,157	4,877	49.75	3.88	53.6	12/31	9/21

Table 12. Species-related and total revenue (in million $) for the fleet and fishery closure dates when butterfish catch rates decrease by 50% after the quota is reached. In order to maximize revenue, 413mt of butterfish is transferred from the landings quota to the cap.

Based on the above results, the ability of fishermen to change targeting behavior after the quota or cap is met is of critical importance. If the catch of butterfish decreases after the quota is met, an increase in the length of the longfin season could occur. The example of a 50% decrease in butterfish catch after the quota has been met is certainly a major change. To find the percentage decrease necessary to break even when the quota is lowered, the lost butterfish revenue is first considered. When the butterfish quota is lowered by 10%, revenue from 257mt of butterfish is lost. As the price of butterfish is 72% of the longfin price (1800/2500), 185mt of additional longfin landings would be necessary to offset the loss. For these additional landings to occur, the longfin season has to be extended by about half a week, as 383mt are landed each week. A decrease in butterfish catch of 11% after the quota is met would allow this to occur.

To summarize, if vessels cannot change their targeting behavior when the butterfish ACT is a binding constraint, the profit maximizing allocation of the ACT between butterfish quota and butterfish cap, is to set that quota equal to the expected retained butterfish catch. However, when vessels can change targeting behavior to reduce catch, there is the possibility that reallocations will increase net revenue. The minimum amount that the butterfish catch will have to be reduced in order to allow for a net revenue to increase (11%) in this hypothetical example is a function of the relative catch rates of the various vessels in the fleet.

The likelihood of this required decrease in butterfish catch would depend mostly on the actions of the butterfish vessels. If these vessels can change their fishing techniques when the butterfish quota is binding to better target longfin and avoid butterfish, the rate of butterfish catch may decrease. If these vessels are unable to change their targeting behavior, their butterfish catch will remain high, and will

now have to be discarded. Due to the coterminous nature of the stocks, behavior modification may be difficult. This analysis likely overestimates the targeting abilities of the different categories of vessels, seeing how there is great variability in catch rates (table 4). It is also possible that the butterfish vessels will stop operating when the quota is met. This action will almost assuredly allow for a longer longfin season than the starting point, but the vessels that are forced to stop operating will see large decreases in revenue. If this lost revenue were to threaten the long term viability of a sizable butterfish fishery, the policy would clearly have to be examined differently. Such a threat could force vessel operators to alter their behavior to improve landings of longfin, but also likely increasing butterfish discard totals to the fleet.

Discussion

The management of longfin squid and butterfish together is a complex and in some ways unique issue. Unlike the bycatch cap system being used for the Alaskan Groundfish fisheries (Holland and Ginter, 2001), there are not mandatory discards for the species being capped. To further complicate matters, some of the fishermen who do land butterfish are capable of doing so in large quantities. Certainly weighing the welfare of all members of the trawling fleet is a challenge when the value of a butterfish caught has so much variability amongst these members. This tradeoff issue is likely one that will remain for some time. With the continued emphasis on instituting ecosystem based management, the butterfish cap on the longfin squid fishery looks to be in place for a number of years.

As described in the possible scenarios, the issue of allocation is only of importance when the butterfish ACT will be binding. This is true whether or not the quota on longfin will be binding. Historical data shows that the longfin quota is rarely used up, and if the butterfish ACT is also not a binding constraint, there will be full fishing seasons for both. If the butterfish ACT is binding, there will be a tradeoff between longfin and butterfish harvest.

Obviously, regulators will not know whether or not the ACT for a season will be binding. If the ACT is allocated based on predicted retention rate, and butterfish catch is higher than expected, both fisheries could close early. However, if in-season vessel behavior cannot be modified, this allocation will maximize revenue. If it is believed that behavioral changes will occur, then the distributional effects and tradeoffs presented in section 3 should be considered. If vessels more geared towards butterfish are able to

adjust and lower their rate of butterfish catch when the butterfish quota is binding, then favoring the longfin fishery may become a more attractive option.

Competing short term and long term goals also have to be considered. In the short term, the longfin fishery is more profitable, and likely should be given priority consideration. In the long term, the potential for growth is much larger in the butterfish fishery. Growth in the market for butterfish may not occur however if quotas are kept relatively low at present. Three important considerations when deciding whether to raise the butterfish quota are; the affect the lower discard cap will have on the longfin fishery; the change in fleet-wide butterfish retention rate that could occur; and the change in the fleet's longfin/butterfish catch ratio. In response to the first point, if lowering the discard cap will threaten major losses to the longfin fishery, it may be a risky policy. The rewards in butterfish harvest would likely have to be substantial to justify such an action. The second and third questions would be difficult to answer, but both are critical. An increase in fleet retention rate is a reflection of the butterfish fishery improving without harming the longfin fishery. If raising the quota allows for this to occur in the long term, considerable revenue gains could be had for some vessels. However, an increase in retention rate also means there will likely be more butterfish caught. This could cause a decrease in the longfin/butterfish catch ratio, and once again cause loses to the longfin fishery. Modeling this multi-year approach was beyond the scope of this paper, but it may be worthwhile.

One consideration that has been put forth in how to address butterfish use is to do away with the allocation issue, as explained in results section 1. Essentially, the market for butterfish would determine how many are caught with the constraint being the ACT. The biggest issue with this method is the lack of control over butterfish harvest that could occur. Significantly large landings of butterfish could mean fewer "available" for discard, and longfin quota could be left on the table. As there is effectively no limit on how large the butterfish fishery can get in relation to the longfin fishery, a socially undesirable outcome may occur. As discussed in section 3, many vessels have different longfin/butterfish catch ratios and retention rates. A large increase in allowable landings could drive up the retention rates for some vessels, but could cut short the season for vessels that are efficient at targeting longfin. On the other hand, if there is not a sharp increase in the market for butterfish, this concern may not be realized. In that case, not having to make a butterfish allocation would save some time and effort in the management process.

Another issue that may be raised is under the current management system, no matter what the allocation of butterfish is; longfin fishermen do not have as large an incentive to avoid butterfish bycatch as under a catch share or ITQ system. While this may be true to some extent, there have been significant efforts between industry and researchers to develop strategies, including gear modifications and notifications of butterfish-dense areas, to reduce bycatch (Northeast Cooperative Research Program, 2012). Other fisheries have also had some degree of success in fleet communication to avoid high bycatch areas (Gilman, Dalzell, et al., 2006). There are however some adjustments to the cap methodology that may be warranted;

Recommendation #1: Continue improving butterfish discard estimates.

The estimation of butterfish discards is a source of uncertainty in the management process. While Amendment 10 resulted in significant increases in observer coverage, 10-15% trip coverage can yield variable results. Having reliable discard estimates is crucial not only in tracking during the season, but also in allocation, especially if the Council is to continue to divide up butterfish based on the fleet retention rate. It may be wise to consider increased coverage even for a portion of a season to test any differences that may occur in the discard trajectory.

Recommendation #2: Explore using the butterfish ACT only as a threshold.

As explained, this method of allocation can lead to losses in longfin harvest, if a sizable butterfish fishery is present. However, this is likely not an issue with the current state of the butterfish fishery. A modest increase in butterfish landings could bring in extra revenue and may not harm the longfin fishery. However, every butterfish that is landed would reduce the longfin fishery's ability to discard. As 2013 has higher than trip limits than the previous seven years, the current performance of the butterfish fishery could be indicative of what the next few years could bring. If the increase in butterfish fishing is modest, using the ACT only could simplify the management process, although the longfin fishery must be given fair representation in this decision.

Recommendation #3: Continue to protect the more valuable longfin fishery.

While an increase in directed butterfish fishing could certainly bring in additional revenue to the fleet, a serious impact on longfin fishing would not be advised. Even if substantial increases in butterfish harvest occur, it is unlikely that the fishery will become more valuable than the longfin. Furthermore, if there is a

binding ACT, a lower butterfish quota and higher cap will not protect the longfin fishery if in-season behavior changes are not made. Limiting the size of the butterfish fishery should prevent the binding ACT from occurring.

Recommendation #4: Consider spatial trends in butterfish catch.

Butterfish discard estimates are calculated from all observed trips throughout the entire fleet. Some areas will have larger butterfish aggregations than others, and this should be considered, particularly in the event where the remaining cap for the season is low. In such a situation, it may be worthwhile to allow for more longfin fishing in areas that are believed to have smaller butterfish populations.

With these recommendations in mind, the current methods of managing butterfish and longfin have produced some encouraging results. The butterfish stock is appears to be growing and the longfin fishery has been minimally harmed by the cap. An expanded directed butterfish fishery in the future could also bring in additional revenue. However, if the expansion is large, the ability of vessel operators to change targeting behavior will be the critical factor in how allocation tradeoffs can be made.

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