International Pacific Halibut Commission

Compiled by IPHC Staff
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Item 1. Effect of reducing bycatch limits in the Gulf of Alaska on the halibut exploitable biomass and spawning potential, including downstream effects from halibut migration

Bycatch Impacts

The impact of halibut bycatch on lost yield and lost spawning biomass has been reported recently by Valero and Hare (2011). That report also estimated the effects of migration on the areas of impacts of under 32 in (U32) bycatch mortality, with migration separated into two components – juvenile (under 26 in, U26) and adult (over 26 in, O26) migration. The effect of migration on the relative area-specific losses due to U32 bycatch is not very sensitive to estimated rates of migration within each component, although we note that the proportion of each component and the relative rates by each component are more sensitive input parameters.

In general, migration of halibut in the Gulf of Alaska (GOA) occurs as a west-to-east process that diminishes with size and age. The major shift in Commission treatment of halibut migration in recent years arose from the results of a major tag and recapture program from 2003-2009. Those results indicated that halibut continue to migrate throughout their lives, whereas the Commission had previously considered that halibut migration effectively ceased after recruitment to the sizes exploited in the commercial fishery (currently about age 8 yr or 32 in). Migration rates are estimated based on the return rate of tags, which vary by area, hence the precision with which migration rates are estimated also varies by area. However, the total impact of bycatch mortality on the coastwide halibut stock is not subject to any of the concerns about migration rate estimation. Instead, the total losses in yield, spawning stock biomass, or egg production can be estimated with confidence because they are functions of the size composition of the bycatch and the known biological parameters of growth, mortality, and fecundity.

Estimates of the lifetime lost yield to the halibut fishery and lost spawning stock biomass arising from one pound of bycatch mortality in the Gulf of Alaska vary, depending on the area of origin of the bycatch (Valero 2011, Valero and Hare 2011). We used the average observed U32 size/age composition of 1996-2008 bycatch, by area, and the target halibut fishery harvest rate in calculating the impacts of U32 bycatch mortality on the coastwide halibut stock. Assuming that both juvenile and adult movement is considered, the cumulative lifetime estimated per lb impacts of U32 halibut bycatch mortality by area are as follows:

Area of One Pound of Bycatch Origin	Lost Yield	Lost Spawning Stock Biomass
Area 3B	0.9 lb	1.6 lb
Area 3A	1.1 lb	1.7 lb
Area 2C	1.1 lb	1.5 lb

The loss of spawning stock biomass has become a more significant portion of the impact of bycatch mortality as halibut size at age has decreased over the past decade (Hare 2011). While smaller size at age means that yield loss per lb of bycatch mortality is lower than in previous decades, this is not the case for losses to spawning stock biomass. Even with smaller sizes at age, female halibut mature into the spawning biomass near the same ages as usual and while many fish may not be vulnerable to the fishery until older ages than in past decades, they still contribute to the spawning biomass from the age of first maturity (8-11 yr). This is a reason why halibut spawning stock biomass can increase even when the exploitable biomass may decrease. The Commission's harvest policy is based on conservation of spawning stock biomass per recruit and the continued impact of bycatch mortality on this metric is of great concern to the Commission.

Timing of bycatch impacts

The variation in losses estimated for different areas of bycatch origin is accounted for by the both the sizes of halibut comprising the bycatch and the differences in growth and mortality that would be experienced by halibut in those areas. It should be noted that the lifetime losses resulting from U32 bycatch occur over an extensive time period, even with current exploitation rates. Valero and Hare (2011) estimated that only about 42% of lost yield occurs during the first eight years following the bycatch occurrence and about 87% after 16 years. The long period over which bycatch impacts are manifested renders migration patterns of significance to the areas of impact, though not to the total impact on the stock.

Bycatch estimation and levels in the Gulf of Alaska

In 1991, the Commission constituted a bilateral Halibut Bycatch Work Group as a response to concerns about bycatch mortality impacts on the halibut stock. The report of this group (Salveson et al. 1992) identified measures to address bycatch mortality, as well as targets for bycatch reduction and timelines for its achievement. The recommendations of this Work Group were adopted by the Commission at an extraordinary meeting in 1991 and forwarded for action by the U.S. and Canadian governments. Success at achieving the goals identified by the Work Group has been mixed and while monitoring of bycatch and some reductions have been achieved in the Bering Sea/Aleutian Islands (BSAI), bycatch in the GOA remains poorly estimated. Observer coverage is only partial (30%) for a substantial portion of the groundfish fleet and not required for the remainder. Recent proposed restructuring of the National Marine Fisheries Service (NMFS) observer program which will place control of observer deployment under the authority of the NMFS could provide potential improvements to bycatch estimation. In the GOA, the ratio of halibut mortality to groundfish catch is more than twice as high as that in the BSAI fisheries and renders improved estimation of halibut bycatch mortality of greater importance. In recent years, the Commission has been forced to reduce both the harvest rate (Area 3B) and the harvest levels of GOA catch (Areas 3A and 3B) as the stock biomass has not responded to management measures based on the harvest policy. The Commission's action to reduce harvest rates in Area 3B is based on a lack of response to these mitigative management measures and the inadequate knowledge of bycatch mortality in this area is a primary source of uncertainty in understanding stock dynamics and determination of appropriate yield.

The existing GOA Prohibited Species Cap (PSC) limits have been in place for trawl fisheries since 1986 and for fixed gear fisheries since 1996. The Commission staff believes that these limits were based on inadequate data, that monitoring of both historical and current bycatch mortality is similarly inadequate, and that the PSC limit for trawl fisheries should be reduced as a precautionary measure until the improved observer procedures are implemented, at which time the estimated bycatch mortality levels can be re-evaluated in the context of halibut stock dynamics.

Item 2: Recent changes in stock assessment methods, harvest policies, and catch limit setting

Coastwide assessment

Since 2006, the IPHC stock assessment model has been fitted to a coastwide dataset to estimate exploitable biomass. For many years, the staff assessed the stock in each regulatory area by fitting a model to the data from that area, i.e., a closed area (CA) assessment. This procedure relied on the assumption that the stock of fish of catchable size in each area was closed, meaning that net migration was negligible. A growing body of evidence from both the assessments (Clark and Hare 2007) and a coastwide mark-recapture experiment (Webster and Clark 2007, Webster 2010) showed that there is a continuing and predominantly eastward migration of catchable fish from the western area (Areas 3 and 4) to the eastern area (Area 2). The effect of this unaccounted for migration on the closed-area stock assessments was to produce underestimates of abundance in the western areas and overestimates in the eastern areas. To some extent this has almost certainly been the case for some time, meaning that exploitation rates were well above the target level in Area 2 and a disproportionate share of the catches have been taken from there.

In order to obtain an unbiased estimate of the total exploitable biomass (EBio), beginning with the 2006 assessment, the staff built a coastwide data set and fitted the standard assessment model to it. Exploitable biomass in each regulatory area was estimated by partitioning, or apportioning, the total EBio in proportion to an estimate of stock distribution derived from the IPHC setline survey catch rates (WPUE). Specifically, an index of abundance in each area was calculated by multiplying weighted survey WPUE by total bottom area between 0 and 400 fm (Hare et al. 2010). The logic of this apportionment is that survey WPUE can be regarded as an index of density, so multiplying it by bottom area gives a quantity proportional to total abundance.

The current halibut assessment model has remained essentially unchanged since 2003. It has been thoroughly described in an IPHC Scientific Report (Clark and Hare 2006) and was subjected to a peer review by two external scientists from the Center for Independent Experts (Francis 2007, Medley 2007). Since the Commission's acceptance of a coastwide stock assessment model, much of the focus of the staff and the industry is now on how the coastwide estimate of exploitable biomass is apportioned among regulatory areas. For both these reasons, the assessment model for 2010 is identical to that used for the 2008 and 2009 assessments. In the interest of brevity, details of the model can be found in Clark and Hare (2006, 2007, and 2008).

Survey WPUE adjustments

Hook competition (catchability)

The IPHC setline assessment survey extends from Oregon northward to British Columbia and west to the Bering Sea and out the Aleutian Island chain. The survey catch of halibut is reduced by the number of baits taken by other species and regional differences in the strength of this effect would result in differences in survey catchability among areas. Clark (2008) developed an analytical method for determining the level of hook competition and an adjustment factor to the survey WPUE indices. The fraction of baits returned on the survey in each regulatory area is used to compute an adjustment factor. If a smaller than average proportion of baits are returned, an area's WPUE index is adjusted upwards because higher competition for baits in that area would have had a negative effective on the halibut catch and therefore on that area's WPUE. Conversely, an area with more than the average rate of baits returned will have its WPUE index adjusted downwards. Calculation of the hook adjustment is done in the same manner each year, using the results from that year's survey. The Commission's approach to this problem has also been independently validated by another research team (Etienne et al., in press).

Effect of survey timing

The amount of commercial catch taken prior to the IPHC setline survey varies with both regulatory area and time (Webster 2009). It is plausible that survey WPUE is affected by the proportion of removals taken prior to the survey, as exploitable biomass is decreased by commercial and sport fishing and other forms of removals, leaving fewer fish for the survey to catch. In areas where removals are greater early in the season, survey WPUE could be expected to be lower on average than in areas where removals are spread evenly across the fishing season. Concern about the effect of commercial catch on survey WPUE is high in Area 2A, where typically over 80% of the catch is taken prior to the mean survey date, much higher than all other areas (Webster 2009, Webster and Hare 2010).

The IPHC staff's approach (Webster and Hare 2010) is to estimate what WPUE would have been for each area had 50% of removals been taken prior to the mean date of the setline survey in that area. Thus, for removals greater than 50%, survey WPUE is adjusted upwards; for removals less than 50%, survey WPUE is adjusted downwards.

Survey WPUE weighting

With the advent of the coastwide assessment approach, the IPHC has used the most recent three years' setline survey index values to apportion the estimated biomass among regulatory areas. The initial methodology employed an equal weighting of the three most recent years but the IPHC staff sought to develop a more statistically defensible approach.

Survey catch rates are more variable than commercial catch rates, for a number of reasons that may be unrelated to underlying stock abundance. While the surveys are spatially extensive, this variance is an inevitable consequence of the limited period in the year over which the surveys are conducted. To provide some stability to the mean catch rate index and make it less susceptible to sampling variance, the survey index can be, and has been for the past several years, averaged over the most recent three years in the data set. In 2010, the Commission followed a staff recommendation to continue with a three-year simple average of adjusted survey WPUE until the staff completed a proper statistical analysis of the survey data, to determine a time-averaging procedure which is appropriate for these data. That analysis (Webster 2011), which examined several methods for weighting of survey WPUE over recent years, used a Kalman filter approach to develop a reverse-weighting procedure for survey data, wherein more recent data receives greater weight than older data. The weighting scheme adopted for 2011 used a 75:20:5 ratio for averaging the past three years' data, with the most recent year receiving the highest weight.

Harvest Policy

Slow Up - Fast Down and Slow up - Full Down

One component of the Commission's harvest policy is the Slow Up – Fast Down (SUFastD) harvest control rule. This rule, in which 33% of increases or 50% of reductions in FCEY are captured in the staff's catch limit recommendations, has been generally applied since 2001. Following the 2006 Center for Independent Expert review (Francis 2007, Medley 2007), the SUFastD adjustment was formally investigated as part of the harvest policy and became official IPHC policy in 2008 (Hare and Clark 2009). The SUFastD was designed to avoid rapid increases or decreases in catch limits, which can arise from a variety of factors including true changes in stock level as well as perceived changes resulting from changes in the assessment model, as well as to apply a more precautionary approach to catch limit setting. The SUFastD approach is estimated to leave approximately 3% more stock biomass in the water, over the long term, than a straight FCEY approach to catch limit setting.

Over the past few years, however, as biomass declines have persisted, there has been a growing concern by the staff about continued use and application of the SUFastD adjustment because some of the current stock conditions were not included in the original evaluation of the SUFastD. The effect of its application on a declining stock is that the target harvest rate is never achieved. Instead, the procedure of taking only 50% of the identified reductions in FCEY has meant that the target harvest rate is consistently exceeded and the stock cannot realize the benefits of the harvest policy. The Commission's adopted catch limits have often resulted in even greater departures from the target harvest rates.

Staff analysis of the effect of using SUFastD, when biomass and size at age are declining and when the policy is initiated at a harvest rate that is well above target, shows exaggerated biomass declines and realized harvest rates continuing to be above targets (Hare 2011). This is the case for any combination of biological and management processes which results in removals exceeding surplus production. Considering the recent history of the stock, the application of the SUFastD harvest control rule and the subsequent Commission decisions on catch limits has resulted in a failure to achieve the Commission's stated harvest policy goals. For 2011, the IPHC staff recommended modifying the SUFastD policy to specify an adherence to the FCEY values for identified reductions in yield, i.e., a Slow Up – Full Down (SUFullD) policy. This means that 100% of any identified decreases in yield (i.e., when the current FCEY is lower than the previous year's catch limit) are recommended compared with only 50% of identified decreases under a SUFastD policy. The staff recommendations for 2011 catch limits and the Commission's adopted catch limits incorporated this change for 2011.

Accounting for U32 bycatch and wastage

Starting in 2011, the Commission adopted a standardized process for treatment of removals of halibut that are less than 32 inches but over 26 inches in length (U32/O26). Hare (2011) analyzed the impacts of various treatments of bycatch and wastage mortality (BAWM), motivated by a Commission directive to staff concerning how U32/O26 removals by different sectors were accounted for in the Commission's harvest policy. This analysis identified a procedure whereby there could be direct deductions from Total CEY for all U32/O26 removals, regardless of which sector gave rise to the removals, with no negative impact on the current spawning biomass per recruit level. While the previous procedure of accounting for this BAWM through harvest rate reduction achieved the same goal, the revised procedure provides more transparent and consistent accounting for this BAWM.

Item 3. Possible causes of low growth rates and the effects on future exploitable biomass and spawning biomass

Halibut size-at-age has been declining since the mid-1980s. The cause(s) behind the ongoing decline are not well understood. First, some perspective on the scope of the changes in size-at-age. In the central Gulf of Alaska, a 15 year old female averaged approximately 100 (net) lbs in weight in the 1980s. In the late 2000s, a 15 year old female halibut in the central Gulf have averaged 28 pounds – a decline of 70% in 30 years. Similar, though slightly smaller, declines have been noted in all IPHC areas. The declines in size at age occur at all ages and for both sexes; the declines increase markedly with age.

A number of hypotheses for the decline have been suggested, and a few analyzed (Clark et al. 1999, Clark and Hare 2002). The timing of the decline in size-at-age correlates very strongly with the increase in halibut numbers that began following the environmental regime shift of the late 1970s. By the mid-1980s, several strong year classes had increased the total number of halibut in the ocean by at least a factor of two. At the same time, increased numbers of other flatfish, in particular arrowtooth flounder (*Atherestes stomias*), also occurred in the Gulf of Alaska and Bering Sea (Walters and Wilderbuer 2000). The most generally accepted cause of the decline in size-at-age has been a density-dependent decline in growth rate resulting from the greatly increased numbers, and biomass, of flatfish. It is worth noting here that, although the exploitable biomass of halibut has declined by 50% since the late 1990s, the **total** biomass of halibut has continued to increase. Additionally, the biomass of arrowtooth flounder estimated to be several times greater than the halibut biomass, has remained very high.

Other potential factors include: environmental effects (temperature, salinity), diet changes, fishery induced evolution, and size-selective fishing. No strong environmental correlate has been found. The possibility of fishery induced evolution, i.e., that halibut capable of producing fast-growing progeny have been "fished out" of the population is both unlikely over such a short time frame and is also countered by the observation that the current halibut size-at-age is similar to that of the 1930s. In other words, a cycle of change from small to large size-at-age has already been observed, and the increase in size-at-age occurred at a time of very low halibut abundance. The change in halibut size-at-age could, theoretically, be produced by the effects of size-selective fishing and not by a change in growth rate. Since larger halibut are targeted, a progressively smaller size-at-age would result in a fishery that systematically removed the larger individuals. Such an effect however, would be expected in a fishery imposed on a previously unfished stock, which has not been the case for halibut in 80+ years. Additionally, halibut size-at-age increased greatly through the 1960s and 1970s, a time when the stock was (and long had been) fully exploited.

The effects of reduced size-at-age are rather predictable. Given the commercial size limit and selectivity of both the harvesters and the gear, a continued reduction in size-at-age leads to a lowered exploitable biomass (EBio) for a given number of halibut. It has been conclusively demonstrated that EBio is a function of halibut size, not halibut age. Female spawning biomass, on the other hand, is a function of both age and size. Female spawning biomass has also declined over the past decade, but appears to have begun increasing starting in 2007-2008. This results from the several large year classes now entering the age at which a substantial fraction contribute to spawning (age of 50% maturity in halibut is around 12 years). Thus, the increase in biomass from addition of new (though small) mature females now outpaces the declines from losses due to fishing and natural mortality as well as the decrease in size-at-age.

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