Collaborative Pacific Halibut, *Hippoglossus stenolepis*, Bycatch Control by Canada and the United States

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Introduction

Bycatch of Pacific halibut, *Hippoglossus stenolepis*, in nontarget fisheries has been a major resource removal since the 1960's (Williams et al., 1989). Although targeted by directed commercial setline and recreational fisheries, bycatches of halibut occur in many other fisheries involving various gears. The magnitude of bycatch mortality relative to removals from directed fisheries has caused bycatch to be the subject of much research and management control. The International Pacific Halibut Commission (IPHC), the agency charged through a treaty between Canada and the United States with management of the halibut resource, lacks authority and jurisdiction over nondirected fishing, including bycatch. Thus, management of halibut bycatch falls under the purview of the national governments.

Until relatively recently, direct controls over halibut bycatch had been achieved through bilateral agreements enacted by the United States and Canada with other nations. The agreements provided general stipulations for foreign fishing: observers, seasons, closed areas, and limits on the amount of halibut taken as bycatch by each country. International fora, such as the International North Pacific Fisheries Commission (INPFC), served mainly as a venue for discussion and data sharing. Implementation of extended fisheries jurisdiction in the late 1970's passed the development of bycatch controls to agencies of the Canadian and U.S. governments

In this article, we review bycatch of Pacific halibut by nontarget fisheries, the actions that led to the initial international control and resulting measures, the development of bycatch controls by the United States and Canada for their respective fisheries, and the role of the IPHC in discussions between Canada and the United States. We also evaluate approaches and methods to bycatch control and discuss potential future developments.

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ABSTRACT—Bycatch mortality of Pacific halibut, Hippoglossus stenolepis*, in nontarget fisheries is composed primarily of immature fish, and substantial reductions in yield to directed halibut fisheries result from this bycatch. Distant-water bottom-trawl fleets operating off the North American coast, beginning in the mid 1960's, experienced bycatch mortality of over 12,000 t annually. Substantial progress on reducing this bycatch was not achieved until the of extension fisheries jurisdictions by the United States and Canada in 1977. Bycatch began to increase again during the expansion of domestic catching capacity for groundfish, and by the early 1990's it had returned to levels seen during the period of foreign fishing. Collaborative action by Canada and the United States through the International Pacific Halibut Commission has resulted in substantial reductions in bycatch mortality in some areas. Methods of control have operated at global, fleet, and individual vessel levels. We evaluate the hierarchy of effectiveness for these control measures and identify regulatory needs for optimum effects. New monitoring technologies offer the promise of more cost-effective approaches to bycatch reduction.*

Bycatch History

Bottom trawl nets were introduced on the Pacific coast of North America in the mid 1910's (Williams et al., 1989). The IPHC prohibited set-nets for halibut in 1938 and the use of any nets in 1944, primarily due to concerns about the harvest of halibut below optimum harvesting size (Hoag, 1971; Skud, 1977). This gear restriction resulted in the retention of trawl caught halibut being prohibited, and the mandatory discarding, with minimal additional injury, of all halibut.

Growth in halibut bycatch followed development of groundfish[1] fisheries, which began in the early 1960's. Up through the 1950's, trawling by U.S. and Canadian vessels for groundfish in the North Pacific was relatively limited. Fishing by vessels from foreign nations, which began in the early 1960's, was more fully developed. Halibut bycatch mortality was relatively small until the 1960's, when it increased rapidly due to distant-water trawl fisheries by Japan, Korea, the U.S.S.R., Poland, and other nations. Total bycatch mortality is estimated to have peaked in 1965 at about 12,800 metric tons (t) (Fig. 1). Bycatch mortality declined during the late 1960's as some of the first bycatch restrictions (e.g. observers and catch accounting) were put into place by the United States, but increased to about 11,900 t in the early 1970's when new areas and species (e.g. walleye pollock) were exploited. During the late 1970's and early 1980's, halibut bycatch dropped to roughly

[1] Primary species included Pacific cod, *Gadus macrocephalus*; rockfishes, *Sebastes* sp.; English sole, *Pleuronectes vetulus;* Dover sole, *Microstomus pacificus;* and petrale sole, *Eopsetta jordani.*

7,100 t, as foreign fishing off Alaska came under increasing control. By 1985, bycatch mortality had declined to 4,600 t, the lowest level since the IPHC began its monitoring nearly 25 years earlier. Bycatch mortality then increased through the late 1980's, due to the growth of the U.S. groundfish fishery off Alaska and the lack of restrictions on that developing fishery. Bycatch mortality peaked at 12,240 t in 1992 but it declined to 7,417 t in 2003. The decline can be attributed to management regulations that encouraged more efficient fishing practices and the introduction of individual quota management programs for the sablefish, *Anoplopoma fimbria,* longline fishery in Alaska and the groundfish bottom trawl fishery in British Columbia.

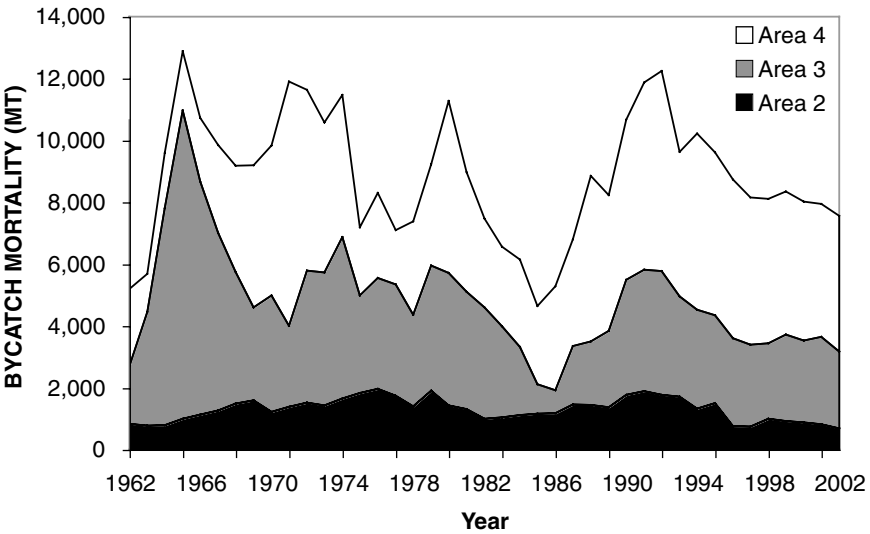

Figure 1.—Historical trend in bycatch mortality of Pacific halibut by IPHC regulatory area, 1962–2002 (Source: Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2002:175–186).

International Prohibition

During the late 1960's and early 1970's, regulation of foreign fishing fleets in U.S. waters resulted from bilateral agreements between the United States and the national government of the foreign fleet (e.g. Japan, U.S.S.R., etc.). The agreements identified specific areas and time periods when the foreign fishery was not allowed to operate. This often resulted in a "patchwork" of areas within the Gulf of Alaska and the Bering Sea/Aleutian Islands closed to groundfish fishing at various times of the year. Agreements formulated in the late 1960's were directed at reducing gear conflicts between the North American halibut longline fishery and foreign trawl operations. Typically, foreign trawling was prohibited during the 5–15 day period surrounding the halibut fishery seasons established by IPHC (Fredin[2]). Time/area closures also provided some minor reduction in the halibut bycatch by certain fisheries.

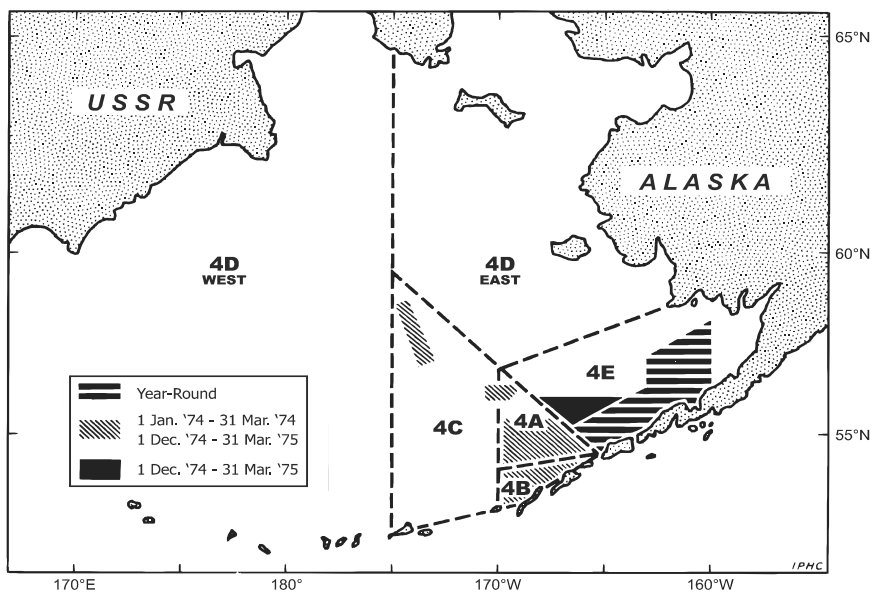

Figure 2.—Areas closed to trawling by Japanese vessels in the eastern Bering Sea during 1 Dec. 1973 to 31 Nov. 1974 (IPHC, 1974: Fig. 2).

The first direct attempt to control the halibut bycatch in a foreign fishery off Alaska began in 1973, when the IPHC proposed to its member governments that foreign trawling be prohibited in certain areas of the Bering Sea when the incidence of halibut was high (Skud, 1977). Japan responded by voluntarily refraining from trawling in certain areas within the eastern Bering Sea from 1 Dec. 1973 through 31 Nov. 1974. These time/area closures, and similar measures for the Gulf of Alaska, were part of subsequent bilateral agreements between the United States and Japan, the U.S.S.R., the Republic of Korea, and Poland during 1975 and 1976 (Fredin[2]). Figure 2 illustrates the extensive nature of the time/area closures enacted on the Japanese fishery operating off Alaska during that time.

[2]Fredin, R. A. 1987. History of regulation of Alaskan groundfish fisheries. NOAA/NMFS/NWAFC Proc. Rep. 87-07, 63 p.

Of relevance is that only time/area closures were used to control halibut bycatch. Bycatch limits were not part of the measures employed, probably because of the lack of a comprehensive observer program that would be needed to monitor compliance. A few observers were placed on foreign vessels as part of a joint program by IPHC, NOAA's National Marine Fisheries Service (NMFS), and INPFC to obtain better information on the magnitude of the halibut bycatch (Hoag and French, 1976), but coverage was limited. Managing bycatch with limits was thought to be impractical at that time.

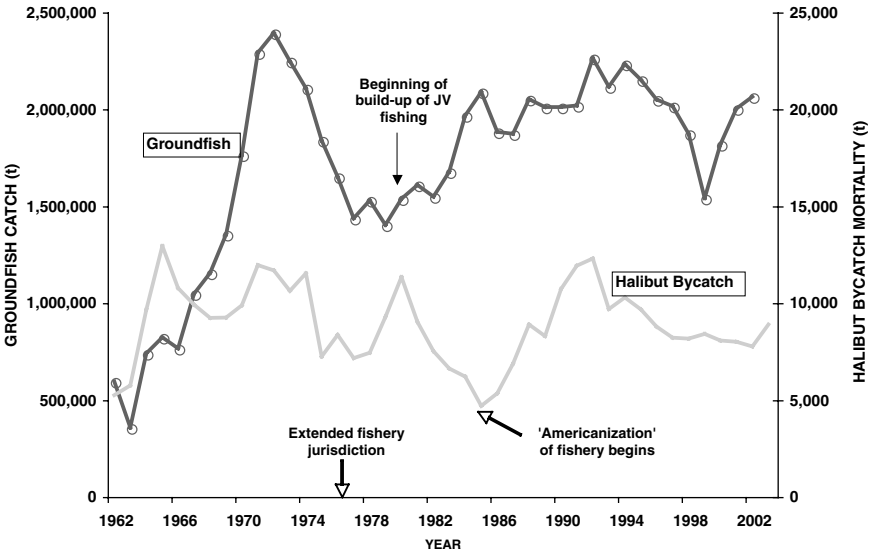

Figure 3.—Groundfish catch and halibut bycatch mortality for Alaska fisheries, 1962–2002 (Source: NPFMC, 2004a, NPFMC 2004b, and Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep of Assessment and Research Activities 2002:175–186).

Impacts of Extended Jurisdiction and the Role of the IPHC

The adoption of exclusive economic zones (EEZ) out to 200 n.mi. in 1977 by the United States and Canada mandated the development of fishery management plans that contained many of the bycatch control measures imposed on foreign fisheries. With the exclusion of foreign bottom-trawler fleets from fishing within the EEZ's of the United States and Canada beginning in 1977, the outlook for lower halibut bycatch mortality should have improved substantially. Initially, this proved to be the case as purely foreign fishing was replaced with joint-venture fishing, with domestic catcher vessels delivering to foreign processors (Williams et al., 1989). Observers aboard the joint-venture processors ensured that the restrictions on halibut bycatch mortality that applied previously to foreign catcher vessels also applied during joint venture fishing. By 1985, the halibut bycatch mortality had fallen to 4,644 t from an initial level of over 11,000 t at the beginning of the joint-venture fishing (Fig. 3).

The perception of increased economic opportunity, together with government encouragement, spawned a major initiative on domestic participation in the fisheries formerly dominated by foreign processors. This "Americanization" of the Alaska trawl fisheries began in earnest around 1985, and fully domestic operations quickly became able to harvest the total available catch. This assumption of catching and processing capacity was largely complete by the early 1990's. Domestic harvesters should have been expected to exercise more conservation-oriented harvesting policies concerning halibut bycatch mortality, since the benefits of such policies would accrue directly to the domestic industry. However, controls and monitoring applied to foreign and joint-venture fisheries were not mirrored by similar measures for the newly-domesticated fisheries (Salveson et al., 1992). Bycatch mortality of halibut in domestic fisheries increased steadily from 1985 through 1992, peaking at over 12,000 t (Salveson et al., 1992).

The increasing halibut bycatch mortality and the impact of U.S. halibut bycatch on catch limits for the halibut fishery off Canada led to a confrontation at the 1991 IPHC Annual Meeting between U.S. and Canadian representatives (IPHC, 1992). The high bycatch levels, which were causing decreases in yield to the directed fishery, were of great concern to IPHC. Following much discussion and negotiation, the Commission passed a resolution addressing bycatch mortality (Salveson et al., 1992). Through the resolution, the Commission created a Halibut Bycatch Work Group (HBWG) to review scientific issues and to:

1) Review management measures being implemented in each country to control and reduce bycatch, and advise the Commission on their adequacy,
2) Recommend additional measures which could be taken to reduce bycatch, and
3) Determine appropriate target levels for bycatch mortality reduction.

The recommendations of the HBWG were adopted formally by the two countries in 1991 (IPHC, 1992). Although many recommendations of the group were to the IPHC itself, the major recommendation by the HBWG was for a 10% per year reduction in bycatch mortality off Alaska, beginning in 1993.

Bycatch Control in U.S. and Canadian Domestic Fisheries

The recommendations adopted in the 1991 agreement between Canada and the United States established both reduction milestones and a target for halibut bycatch mortality. Controlling

Table 1.—2002 Pacific halibut prohibited species catch (PSC) limits (t) implemented by the North Pacific Fishery Management Council for Alaska waters. Source: NPFMC (2002a, 2002b).

Area	Trawl PSC	Longline/Pot PSC
Bering Sea/Aleutian Islands	3,675	900
Gulf of Alaska	2,000	300
Total	5,675	1,200

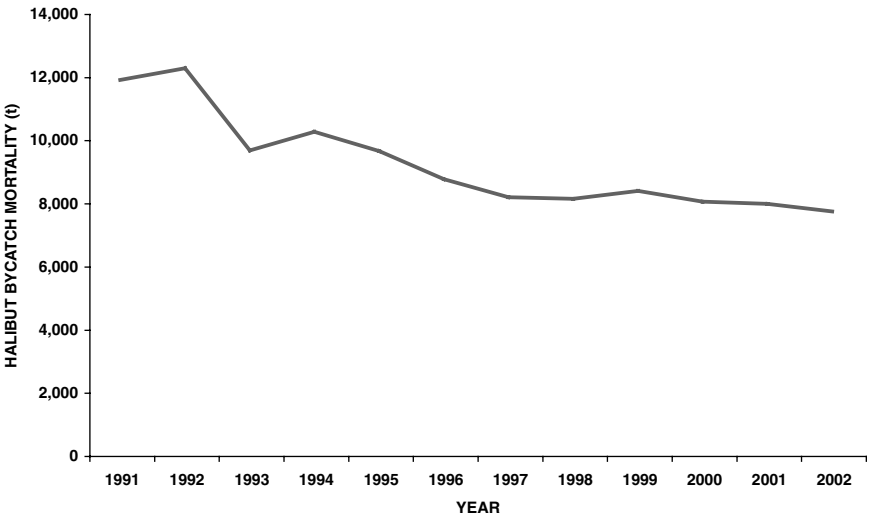

Figure 4.—Halibut bycatch mortality in Alaska trawl fisheries, 1991–2002 (Source: Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2002: 175–186).

and reducing halibut bycatch mortality in waters off Alaska is regulated by the North Pacific Fishery Management Council (NPFMC) and similar authority for waters off Canada is vested in the Canadian Department of Fisheries and Oceans (DFO). While both countries implemented a number of similar measures to achieve the bycatch reduction goals, there was a significant difference in one specific measure and the subsequent results achieved.

For Alaska waters, the NPFMC adopted a number of Prohibited Species Catch (PSC) caps for halibut, by target fishery and gear (Table 1). These measures were accompanied by requirements for onboard observer validation, which were scaled to vessel size. Vessels greater than 38 m in length are required to have 100% observer coverage, while vessels between 19.8–38 m in length are required to have observer coverage for 30% of sea days (U.S. Dep. Commer.[3]). Although the IPHC has transmitted the reduction goal and milestones to the NPFMC, the Council has been unable to reconcile this goal completely with its own goals for groundfish fishery development. The NPFMC has also instituted other measures such as careful release programs to reduce discard mortality rates. A vessel incentive program involving penalties for exceeding particular bycatch rates in selected target fisheries was also introduced but was ineffective because vessel crews were able to hide halibut from observers, and the observer catch sampling did not have the statistical properties to allow for prosecution (Renko, 1998). Bycatch mortality declined 17% from 1993 to 2000, as domestic fleets improved gear, employed better release practices when discarding halibut, conducted fishing seasonally to avoid high halibut bycatch, and were managed by bycatch mortality limits (Fig. 4). However, there have been only modest reductions in bycatch mortality in Alaskan fisheries since 2000 (Williams[4]).

For the waters off Canada, the primary source of bycatch mortality is the groundfish bottom-trawl fishery. While the HBWG did not identify specific reduction targets for the Canadian fishery, the DFO began to institute measures to control and reduce bycatch mortality following the 1991 agreement. The most significant measure introduced by the DFO was an Individual Bycatch Quota (IBQ) for each trawl vessel participating in outside water fisheries in 1995. This measure was accompanied by a requirement for 100% observer validation of all trawl hauls and was specific for fishery management areas. If the IBQ for an area was caught, further fishing by that vessel in that area for the remainder of the fishing year was prohibited (Trumble and Leaman[5]). Reduction in halibut bycatch mortality was a remarkable 85% by 1997, and mortality has remained near this level since that time (Fig. 5) (Williams[4]). This reduction was achieved primarily through changes in fishing patterns by time and area, as well as through reductions in fishing effort for some target species, such as Pacific cod, *Gadus macrocephalus*. The effectiveness of the IBQ process is underscored by the fact that vessels consistently catch <60% of their vessel IBQ for a given year (Trumble and Leaman[5]).

Methods of Bycatch Mortality Control: What works?

On an individual vessel basis, the reduction of bycatch mortality can be divided into three major elements: decrease the encounters of the gear and the bycatch species, decrease the retention of encountered fish by the gear, and increase the survival of fish that are retained but subsequently dis-

[3] U.S. Dep. Commer., NOAA, NMFS, Commercial Fishing Regulations, 50 CFR 679.50.

[4] Williams, G. H. 2005. Incidental catch and mortality of Pacific halibut, 1962–2004. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2005:213–224.

[5] Trumble, R. J., and B. M. Leaman. 1997. Status of 1996 bycatch management planning. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 1996:201–207.

carded. These elements are presented by increasing probability of mortality, so it is clearly desirable to effect bycatch reduction primarily through reduction of encounters between the fishing gear and the bycatch species.

Decreasing Encounters

Decreasing encounters with bycatch species is knowledge-based, i.e. the harvesters must have knowledge of the distribution and/or behavior of the species in order to avoid encounters. This knowledge can be gained through both personal and collective experience. For example, in Alaska this collective experience is employed in a formalized way through a cooperative agreement among some harvesters, conducted by the industry group Groundfish Forum (Gauvin et al., 1996). In the program called Sea State, observers aboard these trawl vessels estimate catch and bycatch. These data are submitted electronically to a centralized repository, where they are checked and extrapolated to include unsampled hauls. Vessel-specific bycatch rates are faxed to participating vessels within 24 h. Similarly, the IPHC has analyzed halibut size frequency data obtained by observers on Bering Sea trawlers to identify areas of consistently high abundance of juvenile size classes of halibut (Adlerstein and Trumble, 1998). These data sources provide knowledge that allows harvesters to avoid areas of high halibut abundance, thereby minimizing the rate at which the PSC caps are approached and allowing greater harvest of the target species.

Knowledge of fish behavior may also allow harvesters to minimize encounters. For example, in the Pacific cod bottom trawl fishery in Alaska, halibut bycatch rates increase nocturnally because the target species (cod) rises off the bottom during darkness. Avoiding fishing during the night can reduce the halibut capture rate relative to the target species. While this knowledge has been useful during parts of the year, a great deal of Pacific cod fishing in this northern area occurs during the winter months, when the hours of darkness are a substantial proportion of the total hours in the day.

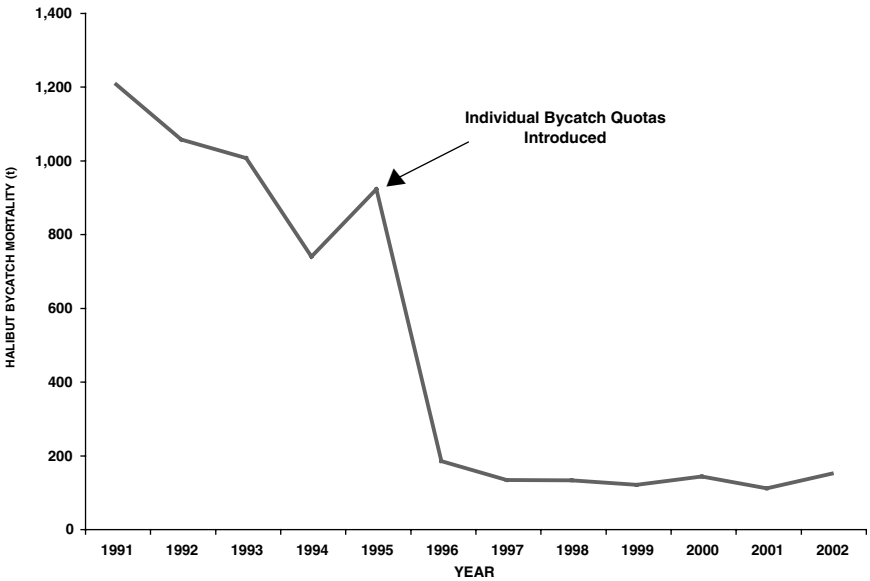

Figure 5.—Halibut bycatch mortality in Canadian trawl fisheries, 1991–2002 (Source: Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2002:175–186).

Decreasing Retention

Decreasing retention of halibut encountered by the fishing gear has been an area of considerable research. The development of gear modifications to either avoid capture or allow escape of halibut from trawl gear has employed the collective expertise of both harvesters and agency scientists (Rose, 1996; Stone and Bublitz, 1996). In the waters off Alaska, industry groups such as the Groundfish Forum have worked cooperatively with the NMFS to test devices in trawls that allow escape of halibut but retain a large proportion of the groundfish target species catch. Rose and Gauvin (2000) showed that, in tests of flexible halibut excluder panels, only 6% of the halibut were retained while 62% of the aggregate deepwater flatfish[1] were retained. The retention rates for individual flatfish species ranged from 48–79%. This work is especially significant because flatfish-flatfish separation is a far more difficult task than flatfish-roundfish separation. A second significant component of this work is the willingness of the NPFMC to grant an Experimental Fishing Permit (EFP) for the project, allowing cost reduction through retention and sale of the target species by the vessels conducting the experiment (Karp et al., 2001). In the absence of such an EFP, the work would have exceeded both government's and industry's funding ability.

Increasing Survival

If halibut or other bycatch species has been retained by the gear during fishing for other target species, bycatch mortality can still be reduced through increasing the survival of incidentally caught fish. In general, increasing this survival means releasing the fish quickly and carefully. The major issues to be dealt with include either releasing the undesired species before it encounters subsequent damage during the catching or sorting process, or rapidly sorting the bycatch species from the target species to allow subsequent release.

Smith (1996) describes the development and application of three NMFS-mandated methods of careful release of halibut captured incidentally to the Pacific cod longline fishery in Alaska. The three methods—careful shaking, hook straightening, and gangion cutting—all improve halibut survival

compared with the traditional practice of "horning" or "crucifying" the fish (essentially, ripping the hook from the mouth of the fish). The adoption of this careful release program resulted in a 36% reduction in the discard mortality rate for halibut in this fishery (Trumble, 1996). However, a significant feature of measures aimed at increasing survival of discarded halibut is the need for observations on the relative condition of fish, in order to assign a discard mortality rate. Discard mortality rates are calculated from fish condition factors, as assessed by observers using objective criteria, and validated through tag-recovery experiments using the same criteria for assessing the condition of tagged fish at release (Hoag, 1975).

Rapid sorting of halibut from mixed-species groundfish catches can also reduce the discard mortality rate of halibut. Trumble et al. (1995) tested the use of grid sorting grates on groundfish trawlers to speed the extraction of halibut from mixed species catches of roundfish. The grates were highly effective at reducing the time required to return incidentally caught halibut to the sea. Again, the use of this measure requires the presence of observers to monitor the condition of halibut returned to the sea and to validate changes in the discard mortality rate. In the case of factory trawlers, this activity conflicted directly with other priority monitoring and sampling duties of the observers, and the measure was not implemented in the fishery (Trumble et al., 1995).

Hierarchy of Effectiveness

The effectiveness of bycatch mortality reduction measures is also related to the level at which they are applied. A hierarchy of this effectiveness runs from global mortality control, through sector or fleet control, to individual vessel control. Global mortality control is the only option when a regulatory or cooperative framework for more specific control and monitoring does not exist.

For example, restrictions on halibut bycatch mortality in foreign fisheries off the west coast of North America occurred initially at the nation level. That is, each nation participating in the fishery was assigned a total halibut mortality cap, to which it had to adhere. This global level of control was effective primarily because the penalty for noncompliance (exclusion from fishing) was severe and the nations involved exercised control over the individual fishing companies comprising their national fleets. However, the benefits of compliance (access to fishing) accrued at the nation level, rather than at the vessel level.

Sector or fleet level control typifies the present approach to halibut bycatch control in the waters off Alaska. PSC caps are assigned to sectors or fleets that target particular species or species aggregates, e.g. deepwater flatfish, (Dover sole, *Microstomus pacificus*; Greenland turbot, *Reinhardtius hippoglossoides*; and deep-sea sole, *Embassichthys bathybius*), rockfish (*Sebastes* spp.), pollock (*Theragra chalcogramma*), etc. These PSC caps are effective control measures because they limit the activities of these fleets as a function of halibut bycatch. Similar PSC caps exist for other species such as herring, *Clupea pallasii pallasii;* Chinook salmon, *Oncorhynchus tshawytscha;* and red king crab, *Paralithodes camtschaticus*. However, again, the benefits of compliance accrue at the fleet level, rather than at the individual vessel level. Responsibilities and rewards are thus distributed functions.

The final and most effective level of control is demonstrated by the Canadian IBQ experience described previously. These individual controls are applied universally and provide both economic penalties and incentives based on actions by each vessel. The value of individual incentives lies in the direct feedback for vessel bycatch. Compared with the other two levels of control, vessels cannot be penalized and lose economic opportunity through the actions of other vessels.

The Future of Halibut Bycatch Mortality Reduction

Bycatch mortality of Pacific halibut in fisheries off the west coast of North America has not yet achieved the targets agreed upon by the United States and Canada in 1991. However, there has been substantial progress in some areas, including innovative and cooperative research initiatives by industry and fishery management agencies. The future of bycatch control and reduction will be determined by progress on two major issues.

The first issue is the creation of a U.S. regulatory environment that will permit the development of incentives and penalties at the third, or individual, level of control we have described. Achievement of bycatch reduction targets will require translation of policy into economic benefits. These benefits will need to accrue at the level of the individual vessel, since that is the basic level of economic expression for most U.S. fisheries.

In the absence of such a regulatory environment, it is likely that the fishing industry will be required to continue its independent efforts to reduce bycatch and access the additional economic benefits of higher catches of target species. This action will also be necessary to avoid imposition of judicial controls on fishing activities, which are likely to occur as bycatch issues attract greater attention and intervention by nontraditional stakeholders such as environmental groups.

The second issue upon which progress on bycatch reduction may depend concerns the development of new technologies for monitoring the compliance with bycatch control measures. Many measures currently considered require monitoring and validation through at-sea observer programs (ASOP). The average daily cost of an ASOP for each vessel can be US$300–400 or higher if multiple observers are on the vessel. Expansion of bycatch controls into sector, fleets, or vessels not currently covered by ASOP may tax both the capabilities of observer providers, as well as the economic viability of the fisheries.

New technologies, such as digital video cameras linked with geo-positioning, shipboard equipment monitoring software, and tamper-proof installations provide potential for some forms of data acquisition, at substantially lower cost than a traditional ASOP. These new technologies cannot fulfill all functions presently conducted by an ASOP; however, they may provide

a means to focus observer activities on functions that can only be human-based, while other monitoring functions are assumed by technology-based applications. We see this as a major area of development and progress in halibut bycatch reduction.

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