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Performance of federally managed catch share fisheries in the United States

Ayeisha A. Brinson[a,*], Eric M. Thunberg[b]

[a] NOAA Fisheries, Office of Science and Technology, 1315 East-West Highway, Silver Spring, MD 20910, United States
[b] NOAA Fisheries, Office of Science and Technology, 166 Water Street, Woods Hole, MA 02540, United States

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ABSTRACT

In 2011 the National Marine Fisheries Service began a systematic collection of performance indicators for U.S. fisheries managed under catch shares. Catch shares are a fishery management tool that dedicate a secure share of quota allowing individual fishermen, fishing cooperatives, fishing communities, or other entities to harvest a fixed amount of fish. Catch share design varies widely across different programs and regions. Many programs share similar biological, social, and economic management objectives even though these design features are tailored to accommodate particular fishery characteristics. This paper evaluates fisheries using standardized indicators to measure the basic economic performance, regardless of catch share program design. Data collected were used to evaluate the economic and distribution effects of U.S. catch share programs. Catch share fishery performance is compared to a baseline period prior to implementation of the catch share program. Overall, the majority of objectives to improve the economic performance of catch share fisheries were achieved. Catch share programs have been effective in reducing fishing capacity. However, catch share programs have had distributional consequences as there are indications that consolidation is occurring in a number of programs. For example, there have been considerable reductions in the number of active vessels and entities holding quota share in the Alaska Halibut and Sablefish and the Mid-Atlantic Surfclam and Ocean Quahog catch share programs. However, it is important to note that the accumulation of ownership share may be less of a concern than consolidation in the use of quota. Thus, to the extent that consolidation is considered a management problem, it may be more effective to consider caps on the use of quota than by imposing more restrictive ownership caps.

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1. Introduction

Catch share programs are management tools that dedicate a secure share of a quota, allowing individual fishermen, fishing cooperatives, fishing communities, or other entities to harvest a fixed amount of fish. These management tools are known as Limited Access Privilege Programs or Individual Fishing (or Transferable) Quota (IFQ/ITQ) Programs. The goals of these programs vary based upon the individual needs of the associated fishery, but generally catch share programs are designed to reduce overcapacity, promote safety at sea, and provide social and economic benefits (Anderson and Holliday, 2007; National Research Council, 1999, p. 33). Catch share programs also include a number of biological goals (e.g., reduction in bycatch, adhering to annual catch limits, etc.). However, these biological goals would have been required in the United States whether or not a catch share program was implemented as they are required by the Reauthorized Magnuson Stevens Act (MSA, 2007). The performance of catch share programs relative to biological goals has been evaluated in many studies, including Essington et al. (2012). Our focus is on the social and economic performance of catch share fisheries.

Catch share management is not unique to the United States as the management regime has been implemented in several other countries. Some of the early adopters of ITQs include The Netherlands (Salz, 1996), Iceland (Arnason, 2002, 2008; Haraldsson, 2008), Canada (Dupont and Grafton, 2000; Marsden and Sumaila, 2005), and Australia (Campbell et al., 2000; Grafton and McIlgorm, 2009). Bonzon et al. (2013) estimated that catch shares in one form or another have been implemented in 40 countries, covering over 900 species in about 200 programs. In the United States, catch share management was first introduced in the surfclam and ocean quahog fisheries in 1990 (Wang, 1995) then in

* Corresponding author.
E-mail address: ayeisha.brinson@noaa.gov (A.A. Brinson).

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Table 1
U.S. federal catch share programs, implementation year and respective Fishery Management Council.

Catch Share Program Name	Year	Council
Surfclam & Ocean Quahog ITQ[a,b]	1990	Mid-Atlantic
Wreckfish ITQ[a,c]	1992	South Atlantic
Western Alaska Community Development Quota[d]	1992	North Pacific
Alaska Halibut & Sablefish IFQ[a,b,e]	1995	North Pacific
American Fisheries Act (AFA) Pollock Cooperatives[e]	1999	North Pacific
Pacific Sablefish Permit Stacking[f]	2001	Pacific
Bering Sea and Aleutian Islands (BSAI) Crab Rationalization	2005	North Pacific
Red Snapper IFQ[a]	2007	Gulf of Mexico
Central Gulf of Alaska Rockfish Cooperatives[e]	2007	North Pacific
Amendment 80 Non-Pollock Trawl Catcher/Processor Groundfish Cooperatives	2008	North Pacific
Golden Tilefish IFQ[a]	2009	Mid-Atlantic
General Category Atlantic Sea Scallop IFQ[a]	2010	New England
Northeast Multispecies Sectors	2010	New England
Grouper-Tilefish IFQ[a]	2010	Gulf of Mexico
Pacific Groundfish Trawl Rationalization (Shoreside Whiting and Shoreside Non-whiting)[b,e,g]	2011	Pacific

[a] Refers to Individual Transferable/Fishing Quota (ITQ/IFQ).
[b] The two components of the Program will be presented separately as singular fisheries.
[c] Not included in forthcoming analyses due to confidentiality issues.
[d] The Community Development Quota Program is a unique program with the goal of preserving Alaska Native and community involvement in Alaskan fisheries. For this reason, it is not included in the forthcoming analyses.
[e] These indicators only cover the harvesting sectors because the inclusion of the mothership or catcher-processor sectors would confuse comparison across all of the catch share programs.
[f] Pacific sablefish permit stacking was only partially implemented in 2001; data from 2002 represent the first full year of the program and will be used as year 1 in the forthcoming analyses.
[g] The 2011 implementation of the Trawl Rationalization combines the non-whiting and whiting components of the fishery. The whiting component has three sectors: shore-based harvesters, catcher-processors and motherships. The shoreside whiting and shoreside non-whiting components will be treated as separate fisheries for comparison sake.

the wreckfish fishery in 1992 (Gauvin et al., 1994) and in the Alaska halibut and sablefish fisheries in 1995 (Hartley and Fina, 2001). Citing a number of concerns over the social and economic effects of IFQ programs, the U.S. Congress included a moratorium on the adoption of any new IFQ programs with the passage of the 1996 reauthorization of the Magnuson Stevens Act. With this Act, the Ocean Studies Board of the National Research Council was commissioned to study the impacts of IFQs and make recommendations toward a national policy on the use of IFQs (National Research Council, 1999). During the moratorium, the Alaska Pollock Cooperatives were created by the American Fisheries Act in 1998 and a program that allowed the stacking of Pacific sablefish permits was developed in 2000. The moratorium expired in 2000, but was extended through a Congressional appropriations bill to 2002 with an exception that allowed the implementation of the Pacific Sablefish Permit Stacking Program to move forward. Nine additional catch share programs have been implemented since the moratorium was lifted in 2002 (Table 1).

As with other management tools, there are both supporting and opposing arguments for managing fisheries using catch shares. These differing viewpoints have been thoroughly reviewed by others (see for example, Yandle and Dewees, 2008; Abbot et al., 2010), which we do not repeat in detail here. A sample of studies on the economic benefits or performance of individual catch share fisheries includes efficiency gains (Wang, 1995; Weninger, 1998), productivity (Felthoven et al., 2009; Walden et al., 2012), employment (Abbot et al., 2010), transferability (Criddle and Strong, 2013), capacity (Felthoven, 2002), markets and prices (General Accounting Office, 1999; Herrmann, 1996; Lee, 2014), welfare analysis (Lee and Thunberg, 2013), and effects on processors (Matulich, 2008; Matulich and Clark, 2003). The negative effects, particularly those of ITQs, include economic inefficiencies associated with highgrading (Anderson, 1994), excessive consolidation (Yandle and Dewees, 2008) or changes in bargaining power due to vertical integration (Dawson, 2006). Other researchers have called for a comprehensive review of the different dimensions of catch share fisheries to complete an impact assessment (Thébaud et al., 2012), while others have noted distributional consequences among individuals (Bromley, 2009; Macinko, 2014) and communities following implementation of catch share programs (Carothers et al., 2010; Olson, 2011).

Typically, the social science literature comprises studies on the evaluation of catch share program performance based upon expectations from economic theory or social dislocations. In this paper, we depart from this approach and evaluate catch share program performance based on the stated goals, objectives and anticipated impacts as they were articulated by the Fishery Management Councils, following Clay et al. (2014). The majority of social and economic studies on catch share fishery performance focus on specific programs with far fewer studies of multiple catch share programs using a common set of metrics. Grafton and McIlgorm (2009) reviewed seven Australian catch share programs using a mix of quantitative and qualitative criteria. More recently Grimm et al. (2012) used publicly available data to evaluate 15 major U.S. and Canadian catch share fisheries. In this paper, we build on Grimm et al. (2012) for U.S. catch share programs by using a set of quantitative indicators with more recent data. Additionally, we apply these indicators to U.S. catch share program subcomponents that were not covered in Grimm et al. (2012) and we include recently implemented programs. We also provide updates to the catch share indicators reported in Brinson and Thunberg (2013) as well as recently completed estimates of multi-factor productivity (MFP) change (a measure of changes in quantities of inputs used to harvest fish and outputs produced) in U.S. catch shares fisheries (Walden et al., 2014).

2. Methods and data

We depart from the approach of evaluating catch share program performance based upon economic theory or social dislocation. Instead we develop indicators based on the stated goals, objectives and anticipated impacts as they were articulated by the Fishery Management Councils at the time the programs were designed and implemented (Clay et al., 2014). While there is considerable variability in the stated objectives of all of the catch share programs, the interest here is on goals and objectives that are common

Table 2
Common program goals, objectives, or expected impacts at the time a catch share program was developed by Fishery Management Councils.

Goals/Objectives/Impacts	Surfclam & Ocean Quahog	Golden Tilefish	General Category Scallop	Multispecies Sectors	Red Snapper	Grouper-Tilefish	Pacific Sablefish	Pacific Groundfish Trawl Rat.	Alaska Halibut & Sablefish	AFA Pollock	Crab Rat.	Amen. 80	Rockfish Coops
Reduce capacity	x	x	x	x	x	x	x	x	x	x	x	x	x
Lengthen fishing season	x	x			x	x	x		x	x	x		x
Increase product quality				x	x			x	x	x			x
Increase ex-vessel price		x		x	x	x	x		x	x			
Lower costs	x	x			x	x		x	x	x		x	
Increase efficiency				x	x			x	x	x	x	x	x
Improve profitability	x	x	x	x	x	x		x	x	x	x	x	
Improve vessel safety	x	x			x	x	x	x	x	x	x	x	x
Maintain diverse fleet/small vessels		x	x	x	x	x	x	x	x		x	x	
Share consolidation		x		x			x		x	x			x
Community impacts		x		x			x	x	x	x			x
New entry/windfall profits		x			x	x	x	x					
Effects on support sectors							x	x	x		x		x
Impacts on other fisheries	x			x					x	x	x		x
Reduce gear conflicts				x	x				x				
Use of quota by non-fishers		x			x		x		x	x			

among multiple programs across regions. These commonalities were determined by reviewing the Fishery Management Plan (FMP) documents prepared the first time each catch share program was implemented. For each program, the identified purpose and need, goals, objectives and impacts were tabulated and commonalities across programs were grouped into categories or themes. While all catch share programs emphasize biological objectives such as maintaining healthy stocks, rebuilding depleted stocks, and reducing discards, in this paper we focus on the economic and social considerations in the design of 16 U.S. federal catch share programs. These themes are identified in Table 2.

The themes noted in Table 2 are not necessarily common to all programs, do not fall into mutually exclusive categories and are not hierarchically ordered. Rather, the themes reflect the differing problems that Councils sought to address through catch share management and the myriad tradeoffs that are inevitably confronted in shaping design specifications. In a general sense, the themes noted in Table 2 fall into two broad categories: economic effects and distributional impacts. It is from these categories that performance indicators were selected where measurement was influenced by the availability of data common to all programs. All of the indicators were compiled for the catch share programs for the baseline period (the average of the three years prior to program implementation) until 2013 except for MFP, which was estimated through 2012. These indicators also only cover the harvesting sectors. Therefore, for many fisheries, particularly those on the West Coast and in Alaska, indicators for motherships or catcher processors are excluded. Also, all price and revenue related metrics have been adjusted by the GDP deflator indexed for 2013. The specific indicators and their measurement follow.

2.1. Economic effects

2.1.1. Reduce capacity

Reducing capacity was noted as a management objective or expected effect in all catch share programs. Formally, capacity may be defined as the maximum amount of fish over a period of time that can be produced by a fishing fleet if fully utilized, given the biomass of the fish stock and the present state of the technology (Greboval, 2003). Kirkley et al. (1999) and Kirkley and Squires (2003) outline alternative approaches to estimate capacity output for fisheries that would have required data that were not available for all catch share programs. However, conditional on technology and resource conditions, capacity output depends on fleet size. For this reason, the number of active vessels was used as a proxy for reduction in capacity, where an active vessel was defined as any vessel that takes one or more trips on which catch share program species were landed.

2.1.2. Season length

Season length may be adjusted for several reasons including spawning protection, interaction with protected species, or to reduce bycatch. Here we focus on the length of the season over which a species may be landed. Prior to implementation of catch shares, several fisheries experienced early closures of fishing seasons due to reaching or exceeding target species and/or bycatch quotas. In most cases, extension of the fishing season was not necessarily an explicit goal or objective for the program. Instead, extension of the fishing season was seen as an ancillary outcome to economic effects such as improved prices or product quality or to improved vessel safety. In this study, we defined the season length as the total number of days in a year or defined fishing season in which the fishery was not closed to landing catch share species. However, in Alaska, we used the season length index, which is defined as the ratio between active fishing days and the regulatory season length. For the Alaska programs, the season length index accounts for catch share programs with multiple stocks that are spatially distributed with different regulated season lengths as well limitations on fishing activity due to weather or participation in other fisheries.

2.1.3. Increased price

Improvements in ex-vessel price or product quality, or both, were noted as expected economic effects of catch share programs, particularly for catch share programs where an extended season length was an anticipated outcome. Ex-vessel prices were expected to be higher through the dual effects of alleviation of market gluts and improved product quality due to better handling of harvested fish as well as changes in product form at the processor level. In this study, we use ex-vessel price as an indicator of catch share program performance. However, since data were not available in all regions to measure change in product quality, it is not possible to disentangle supply effects associated with reduced market gluts from demand effects due to improved product quality. Note that changes in quotas as well as changes in international prices or prices for market substitutes further complicate attribution of changes in ex-vessel prices to catch shares.

Table 3
The number of active vessels by catch share program.

Catch Share Program	Baseline period	Year 1	Average years 1–3	Average years 1–5	Last 5 year average	2013
Red Snapper	482	319	308	333	353	360
Grouper-Tilefish	631	480	468	458		430
General Category Scallop	271	158	151			138
Multispecies Sectors	417	295	290			231
Surfclam	137	128	87	73	38	40
Ocean Quahog	67	57	82	76	32	27
Golden Tilefish	14	11	10			10
Pacific Sablefish	135	101	97	90	93	91
Shoreside Non-whiting	115	94	90			86
Shoreside Whiting	36	26	25			24
Alaska Halibut	3432	2060	2485	2196	1033	937
Alaska Sablefish	1101	581	742	640	341	320
AFA Pollock	114	117	107	102	87	85
Crab Rationalization	264	101	152	126	78	75
Rockfish Cooperatives	34	38	35.3	38.3	41.8	52
Amendment 80	22	22	22	21	20	18

2.1.4. Catch share trip revenue

Profitability was expected to improve in nearly all of the catch share programs through a combination of improved prices and cost savings. Although several catch share programs implemented mandatory cost data collection to be used for tracking program performance, cost data were not available for all catch share programs so it was not possible to develop a measure of profitability for each catch share fishery. Even for programs that implemented a cost data collection program there are substantive differences among regions and programs in terms of what data are collected that confound development of a comparable estimate of profitability across programs. In this study, we use total revenue from catch share species coupled with revenue per active vessel as a proxy indicator of change in profitability. That is, improvements in revenue per vessel will be related to profitability to the extent that reductions in fleet size represent cost savings (either capital or operating expenses).

2.1.5. Multi-Factor productivity change

Productivity is the relationship between outputs and inputs, and productivity change is a deconstruction of profitability change into its price and quantity components (O'Donnell et al., 2008). As such, productivity change, more specifically MFP change, captures multiple dimensions of economic change associated with catch shares that were identified by Councils, (changes in product value and mix, costs and efficiency), in a single metric. In a recently completed study of MFP change, NOAA Fisheries' economists used a Lowe index adjusted for biomass change to estimate MFP change for the catch share fisheries included herein (Walden et al., 2014). We use these estimates of MFP change in this paper. For a detailed treatment of methods and data see Walden et al. (2014).

2.2. Distributive effects

It was recognized by the Councils that some consolidation of the fleet was inevitable even though most catch share programs sought to reduce or control capacity (see for example Amendment 16 to the Northeast Multispecies Fishery Management Plan, available at: http://www.nefmc.org/management-plans/detail/northeast-multispecies). Consolidation was noted as leading to beneficial effects such as cost reductions and efficiency gains, but concerns over potential adverse effects of excessive consolidation were also noted. These potential effects included the loss of small vessels as well as a loss of diversity in terms of fleet structure and landing ports, which are coincidental to issues related to impacts on shoreside infrastructure and community impacts.

Although one or more of these distributive effects of consolidation was noted in the majority of catch share programs, available data are lacking to develop indicators for effects such as community impacts or fleet diversity across all programs. Instead we use the number of entities holding share and the Gini coefficient as measures of consolidation that may serve as proxies for the distribution effects that could not be measured. We also note which catch share programs have implemented an excessive share limit, which places a limit on allowable consolidation.

2.2.1. Entities holding share

The number of entities holding share was defined as the number of unique owners or ownership groups receiving a share of the quota at a point in time. For catch share programs that included an excessive share limit, the number of entities was based on how ownership was defined in the catch share program for purposes of monitoring the share cap. Since most programs allow shares to be traded during the year, the number of entities holding share was measured either at the beginning or the end of the year to provide a consistent year-to-year indicator of share consolidation.

2.2.2. Gini coefficient

We use the Gini coefficient to measure changes in the distribution of the use of quota in terms of catch share revenue among active vessels. The Gini coefficient is a measure of the difference between the cumulative distribution of catch share revenue and the cumulative distribution of the uniform distribution. Since revenue data were available for all active vessels in each catch share program, the Gini coefficient for a census can be calculated as follows:

$$G = \frac{\sum (2 \times i - n - 1)x_1}{n^2 u},$$

where $i = 1$ to n; i is the vessel's rank order in ascending order; x is the annual catch share species revenue for vessel i; n is the number of active vessels; u is the mean revenue (Bellú and Liberati, 2006).

A Gini coefficient of 0 means that catch share revenues are the same for all active vessels, and a value approaching 1 means that catch share revenues are highly concentrated in a single or among a small number of vessels. The absolute value of the Gini coefficient is not of interest here, but rather how it is changing over time is of interest. A decreasing Gini coefficient is indicative of increasing evenness or equality in catch share revenues, whereas an increasing Gini coefficient indicates decreasing evenness, or its opposite increasing inequality among participating vessels.

Table 4
Season length for catch share programs with a shortened season length.

Catch Share Program	Baseline period	Year 1	Average years 1–3	Average years 1–5	Last 5 year average	2013
Red Snapper[a]	121	365	365	365	365	365
Grouper-Tilefish[a]	124	124	365	365	365	121
Pacific Sablefish[a]	8	214	214	214	214	214
Shoreside Non-whiting[a]	365	355				365
Shoreside Whiting[a]	141	200	200			200
Alaska Halibut [b]	0.01	0.72	0.51	0.61	0.72	0.72
Alaska Sablefish[b]	0.07	0.96	0.67	0.78	0.96	0.98
AFA Pollock[b]	0.36	0.61	0.66	0.70	0.79	0.80
Crab Rationalization[b]	0.13	0.77	0.50	0.60	0.62	0.61
Rockfish Cooperatives[b]	0.06	0.85	0.78	0.82	0.82	0.77
Amendment 80[b]	0.75	0.94	0.86	0.89	0.93	0.97

[a] Season length represents the total number of days in a calendar or fishing year when the fishery is open to landing catch share species.
[b] Season length represents the season length index, which is the ration between active fishing days and the regulatory season length.

3. Results

3.1. Economic effects

3.1.1. Active vessels

Across all programs, the number of active vessels decreased by an average of 24% in the first year of the catch share program compared to the baseline period (Table 3; see online supplement for annual data for all catch share programs). Some programs (Alaska Halibut IFQ, Alaska Sablefish IFQ, Crab Rationalization, Red Snapper IFQ, General Category Scallop IFQ, Northeast Multispecies Sectors, Pacific Sablefish Permit Stacking and Shoreside Whiting) had large reductions in active vessels (greater than 24%) in the first year, while other programs saw no change (Amendment 80) or increases (Rockfish Cooperatives and AFA Pollock Cooperatives) in the number of active vessels. The number of active vessels has continued to decrease for most catch share programs at an average rate of 5.1% per year; in 2013, there were more than a third fewer active vessels across all catch share programs when compared to the baseline period. The Surfclam ITQ (71% reduction) and Alaska Halibut IFQ (73% reduction) programs have seen the largest reductions in active vessels over the history of the programs. However, in these and most other programs, much of the reductions in active vessels occurred in the first year, as active vessels declined through 2013 by a lower average annual rate of 2.4% when compared to the change in active vessels in the first year In contrast to these trends, the number of active vessels has increased in the Rockfish Cooperatives Program (Table 3).

3.1.2. Season length

During the baseline years, 11 of the 16 catch share programs were subject to closures as quotas were reached prior to the end of the regulated length of the fishing season (Table 4). These closures resulted in season lengths ranging from extremes of 1–7% of the current active fishing days in the Alaska Halibut IFQ (1%), Pacific Sablefish Permit Stacking (4%), Alaska Rockfish Cooperatives (6%) and Alaska Sablefish IFQ (7%) to longer seasons of 75% of active fishing days in the Amendment 80 Cooperatives program and 85% (310 days) in the Golden Tilefish IFQ program. Many other fisheries experienced shortened seasons in the baseline periods. The season length averaged one-third of the allowable season in both the Red Snapper and the Grouper-Tilefish IFQ programs, which currently operate on a year round basis. Similarly, the season length index for the Crab Rationalization and AFA Pollock Cooperatives programs were 37% and 36% of the current season length index, respectively. In the first year of full catch share implementation, the season length expanded significantly in the 11 programs that previously had shortened seasons. For example, the Pacific Sablefish Permit Stacking season went from 8 days to 214 days; the full length of the regulated season and has remained at 214 days in every year since implementation. Similarly, the season length index went from 0.01 to 0.72 in the Alaska Halibut IFQ and increased from 0.07 to 0.96 in the Alaska Sablefish IFQ programs. In these two fisheries and nearly every other, the season length remained at levels similar to that of year 1 in all subsequent years through 2013 (Table 4).

There were seven catch share programs that remained open during the full length of the regulatory season both before and after catch shares were implemented. However, with the exception of the General Category Scallop IFQ that had no quota assigned to the fishery during the baseline period, a number of regulations were needed in the other seven fisheries that were designed to spread landings throughout the year. These measures included, but were not limited to trip limits, limits on effort, area closures and gear restrictions (Table 4).

3.1.3. Prices

Across all programs, average ex-vessel prices for all of the catch share program species increased by an average of 19% in the first year of the catch share program when compared to the respective baseline periods (Table 5). A few catch share programs saw decreases in average ex-vessel prices in the first year; ex-vessel prices decreased by 22%, 17% and 9% in the Ocean Quahog ITQ, Amendment 80 Cooperatives and Surfclam ITQ programs, respectively (Table 5). Among these three programs, average prices were lower than the baseline period in all but three of the 24 years for Surfclam ITQ and were lower in all but two of six years for Amendment 80 catch share species. Ocean quahog prices were below the baseline period in all but one year from 1990 to 1999, but have been above the baseline period in all but one year since 2000 (Table 5).

For the 13 programs where prices improved during year 1, the increase in average price ranged from 3% in the Grouper-Tilefish IFQ to a high of 70% in the Crab Rationalization programs (Table 5). The average catch share species prices in 2013 were also above each program's baseline period in 12 of these 13 programs. In 2013, average prices were lower than the baseline period in Northeast Multispecies Sectors. However, average prices were greater than the baseline period in each year from 2010 to 2012 (Table 5).

In programs where average prices improved in the first year, the average price remained above the baseline period in all subsequent years through 2013 in nine catch share programs and was above the baseline period in all but one year in each of the other four catch share programs including Northeast Multispecies Sectors as noted above. For example, average sablefish prices were above the baseline period in 11 of the 12 years of the Pacific Sablefish Permit Stacking program (Table 5).

3.1.4. Catch share trip revenue

Compared to the baseline periods for each respective catch share program, total catch share species revenue declined in six programs and increased in 10 programs during the first year (Table 6).

Table 5
Average price for catch share program species.

Catch Share Program	Baseline period	Year 1	Average years 1–3	Average years 1–5	Last 5 year average	2013
Red Snapper ($/lb)	3.48	3.88	3.89	3.78	3.86	4.30
Grouper-Tilefish ($/lb)	3.32	3.41	3.42	3.50		3.73
General Category Scallop ($/lb)	7.04	9.25	10.12			12.19
Multispecies Sectors ($/lb)	1.26	1.30	1.31			1.20
Surfclam ($/bushel)	13.85	12.66	12.51	12.42	12.40	11.72
Ocean Quahog ($/bushel)	6.37	4.98	5.74	5.79	7.27	7.34
Golden Tilefish ($/lb)	2.70	2.70	2.90			3.18
Pacific Sablefish ($/lb)	1.94	2.20	2.17	2.21	3.11	2.41
Shoreside Non-whiting ($/lb)	0.60	0.85	0.74			0.66
Shoreside Whiting ($/lb)	0.09	0.12	0.13			0.12
Alaska Halibut ($/lb)	1.91	2.95	2.68	2.58	5.05	4.86
Alaska Sablefish ($/lb)	1.97	2.91	2.60	2.64	3.81	2.78
AFA Pollock ($/mt)	245.01	283.03	279.24	283.28	365.40	296.22
Crab Rationalization ($/mt)	3389.05	5750.53	4935.13	5308.08	6805.53	6555.49
Rockfish Cooperatives ($/mt)	459.08	559.72	551.37	563.71	589.76	598.33
Amendment 80 ($/mt)	1220.98	1011.92	1061.33	1091.00	1083.98	932.21

Table 6
Catch share revenue (million $) for each catch share program.

Catch Share Program	Baseline period (million$)	Year 1 (million$)	Average years 1–3 (million$)	Average years 1–5 (million$)	Last 5 year average (million$)	2013 (million$)
Red Snapper	13.96	11.12	9.51	10.26	13.37	21.11
Grouper-Tilefish	22.77	15.12	20.91	22.06		25.50
Scallop	28.37	21.14	27.70			29.45
Multispecies Sectors	86.31	86.02	83.46			57.24
Surfclam	39.63	39.83	35.82	35.66	29.09	28.78
Ocean Quahog	29.41	23.54	26.48	26.76	24.19	23.88
Golden Tilefish	4.71	5.20	5.44			5.72
Pacific Sablefish	6.70	5.51	7.51	8.44	10.14	5.36
Shoreside Non-whiting	30.35	32.25	28.81			27.33
Shoreside Whiting	9.64	23.10	23.58			26.54
Alaska Halibut	91.80	95.35	100.25	109.02	152.30	101.16
Alaska Sablefish	81.59	100.14	88.49	79.68	83.45	64.47
AFA Pollock	127.53	143.67	163.18	184.29	198.98	195.14
Crab Rationalization	174.71	143.44	151.12	174.92	224.70	190.03
Rockfish Cooperatives	3.92	4.83	4.66	4.89	5.67	5.83
Amendment 80	244.62	256.85	239.67	252.47	258.03	220.40

Among the 10 programs with higher first year revenues, the change relative to the baseline period ranged from 0.5% for the Surfclam ITQ program to a high of 140% in the Shoreside Whiting IFQ program. In most cases where first year revenue declined, it was due to lower landings as a result of reduced quotas, and while prices were higher, they did not increase enough to offset the lower quotas. In two of these programs (Northeast Multispecies Sectors and Ocean Quahog IFQ), total catch share species revenue during 2013 was also below the baseline period, while 2013 revenues were above the baseline period in the other four programs (Red Snapper IFQ, Grouper-Tilefish IFQ, General Category Scallop IFQ and Crab Rationalization). However, there also were four catch share programs in which first year catch share species revenues were greater than the baseline periods, but were lower than the baseline period in 2013. These programs include Surfclam ITQ, Shoreside Non-whiting IFQ, Pacific Sablefish Permit Stacking and Amendment 80 Cooperatives (Table 6).

With the exception of Grouper-Tilefish IFQ and Ocean Quahog ITQ, catch share species revenue per vessel improved in the first year of all other catch share programs (Table 7). In the Grouper-Tilefish IFQ, revenue per vessel was higher than the baseline period in 2013 and was above the baseline period in all other years after year 1. Similarly, revenue per active vessel in the Ocean Quahog fishery was higher than the baseline period during 2013 and with the exception of 2005 has been above the baseline period in every year from 2001 to 2013.

Among the 14 catch share programs where catch share species revenue per vessel was above the baseline period in the first year, revenue per vessel was also above the baseline period during 2013 in all programs but the Rockfish Cooperatives (Table 7). The latter was one of the few programs where the number of active vessels had increased relative to the baseline period. Although aggregate catch share species revenue was above the baseline period, the number of active vessels increased proportionally more than revenue resulting in lower revenue per vessel. In the remaining 13 programs where 2013 catch share species revenue per vessel was above that for the baseline period, revenue per vessel was more than twice that of the baseline period in eight programs and was above baseline period levels in every year in all programs but the Red Snapper IFQ and Amendment 80 Cooperatives Programs (Table 7).

3.1.5. *Multi-factor productivity change*

Data limitations on input quantities used by catcher vessels in five Alaskan catch share programs (Halibut IFQ, Sablefish IFQ, AFA Pollock Cooperatives, Amendment 80 Cooperatives and Rockfish Cooperatives) as well as the Sablefish Permit Stacking program meant that the baseline period was a single year instead of the three-year average pre-catch share baseline period used for the other fisheries and for the other metrics. Since MFP change was measured using a Lowe index, the results are interpreted as the percent change in each year relative to the baseline period. For example, the Lowe index value of 1.19 in 2012 for the Red Snapper IFQ Program means that MFP was 19% higher in 2012 than it was during the pre-IFQ baseline period (Table 8). Of the ten catch share programs that included a pre-catch share baseline period,

Table 7
Catch share revenue (thousand $) per active vessel for each catch share program.

Catch Share Program	Baseline period (thousand$)	Year 1 (thousand$)	Average years 1–3 (thousand$)	Average years 1–5 (thousand$)	Last 5 year average (thousand$)	2013 (thousand$)
Red Snapper	28.96	34.84	30.85	30.78	37.66	58.63
Grouper-Tilefish	36.09	31.50	44.88	48.48		59.30
Scallop	206.99	291.60	287.56			247.78
Multispecies Sectors	104.67	133.83	185.28			213.42
Surfclam	289.23	311.15	445.71	549.82	770.41	719.41
Ocean Quahog	438.91	413.03	333.84	361.28	768.83	884.44
Golden Tilefish	336.26	472.77	532.58			572.48
Pacific Sablefish	206.99	291.60	287.56			247.78
Shoreside Non-whiting	263.87	343.11	319.77			317.79
Shoreside Whiting	267.67	888.35	957.65			1105.74
Alaska Halibut	26.75	46.28	43.65	53.57	146.44	107.96
Alaska Sablefish	74.11	172.37	133.37	134.13	244.28	201.47
AFA Pollock	1118.69	1227.97	1559.94	1847.33	2286.97	2295.75
Crab Rationalization	661.77	1420.23	1189.31	1676.60	2878.54	2533.79
Rockfish Cooperatives	115.36	127.09	131.71	129.13	136.50	112.13
Amendment 80	11118.99	11675.06	11050.88	12064.22	13205.34	12244.25

Table 8
Multi-factor productivity (MFP) trends for each catch share program.

Catch Share Program	Baseline period	Year 1	Average years 1–3	Average years 1–5	Last 5 year average	2012
Red Snapper[a]	1.00	1.04	1.12	1.11	1.14	1.19
Grouper-Tilefish[a]	1.00	1.07	1.14		1.14	1.19
General Category Scallops	1.00	1.21	1.44		1.44	1.57
Multispecies Sectors	1.00	1.24	1.16		1.16	0.97
Surfclam	1.00	1.34	1.50	1.64	2.28	2.14
Ocean Quahog	1.00	0.92	0.96	0.97	1.74	1.82
Golden Tilefish	1.00	1.56	1.70		1.70	1.75
Pacific Sablefish[b]	1.00	1.26			1.68	2.32
Shoreside Non-whiting	1.00	1.32	1.31			1.29
Shoreside Whiting	1.00	1.02	0.83			0.64
Alaska Halibut[c]					0.98	0.88
Alaska Sablefish[d]					0.90	0.88
AFA Pollock[d]	1.00				0.80	0.73
Crab Rationalization	1.00	0.78	1.10	1.27	1.52	1.73
Rockfish Cooperatives[e]		1.00	0.95	1.01	1.06	1.26

[a] Data represent unadjusted productivity.
[b] Data are only available for 2003, which will be treated as the baseline. Data are also available for 2004–2010.
[c] Data are only available for 2008–2012.
[d] Data are only available for 2007–2012.
[e] Data are not available for the baseline period.

MFP change was higher in 2012 in all but two programs. In each of the eight fisheries where MFP was higher in 2012, MFP change was above the pre-catch share baseline periods in all years except for the Ocean Quahog ITQ and the Crab Rationalization catch share programs. However, MFP in the former has been above the baseline period in every year since 1995 and in all years except year 1 (2005) in the latter.

The two programs where MFP was lower in 2012 include Northeast Multispecies Sectors and Shoreside Whiting programs (Table 8). MFP in the Northeast Multispecies Sectors program was 3% lower during 2012 than it was during the baseline period after having been 24% and 26% higher during 2010 and 2011, respectively. In the case of the Shoreside Whiting fishery, biomass-adjusted MFP was 36% lower in 2012 even though the ratio of output to inputs (unadjusted MFP) was higher than it was during the baseline period. However, the change in biomass as measured by the Lowe biomass index was more than twice that of the change in unadjusted MFP, which resulted in much lower MFP in 2012 for this fishery when adjusted for biomass.

In programs where data were not available to construct a pre-catch share baseline period for catcher vessels, MFP change in 2012 was above the selected baseline period in the Sablefish Permit Stacking, Amendment 80 Cooperatives and the Rockfish Cooperatives programs (Table 8). By contrast, MFP was either at or below the selected baseline period in all years for the Alaska Halibut IFQ, Alaska Sablefish IFQ and AFA Pollock Cooperatives programs (Table 8).

3.2. Distributive effects

3.2.1. Entities holding share

Compared to the first year of program implementation, the number of entities holding share declined in nine of the catch share programs evaluated (Table 9). The decline in number of entities holding share averaged 57% in three programs (Surfclam ITQ, Ocean Quahog ITQ and Alaska Halibut IFQ), but the rate of decline was lower (21%) in six programs (Red Snapper IFQ, Grouper-Tilefish IFQ, General Category Scallop IFQ, Golden Tilefish IFQ, Sablefish Permit Stacking and Alaska Sablefish IFQ). In most of these programs, at least 50% of the reduction in entities holding share occurred within the first two to five years of program implementation.

The number of entities holding share increased after the first year in both the Northeast Multispecies Sectors and the Crab Rationalization programs. The increase in entities holding share in Northeast Multispecies Sectors program is a reflection of increased participation in the program and not necessarily a reflection of an increase in the dispersion of shares among more owners since participation in this program is voluntary (Table 9).

Table 9
The number of entities holding share in each catch share program.

Catch Share Program	Baseline period	Year 1	Average years 1–3	Average years 1–5	Last 5 year average	2013
Red Snapper	N/A	497	470	451	418	399
Grouper-Tilefish	N/A	743	702	678		604
General Category Scallop	700	321	289			262
Multispecies Sectors	1401	762	813			851
Surfclam	N/A	154	129	122	60	64
Ocean Quahog	N/A	117	94	84	42	41
Golden Tilefish	30	15	13.3			12
Pacific Sablefish	154	144	139	135	116	111
Shoreside Non-whiting	N/A	128	128			128
Shoreside Whiting	N/A	78	78			78
Alaska Halibut	4829	4829	4731	4484	2766	2570
Alaska Sablefish		1004	982	952	778	772
AFA Pollock	N/A		111	111	109	106
Crab Rationalization	491	491	489	483	494	501
Rockfish Cooperatives	N/A	44	45	45	46	46
Amendment 80	28	27	27	27	27	27

N/A = Not applicable.

There were five catch share programs in which the number of entities holding shares has remained constant or nearly constant. In both the Shoreside Whiting and Non-whiting IFQ fisheries, transfer of quota share was not allowed during the first three years of the program. The number of entities holding share may be expected to change once permanent trades are allowed. For the remaining three programs, the number of entities holding share has been constant at 27 entities in the Amendment 80 Cooperatives; has increased by 2 entities from 44 in year 1 to 46 in 2013 in the Rockfish Cooperatives (Table 9).

3.2.2. Gini coefficient

The Gini coefficient was used to evaluate the equality of revenue distribution among active vessels in each catch share program. Compared to the baseline period, the Gini coefficient increased by an average of 12% during the first year of program implementation in nine programs but declined in three (Table 10). For the older catch share programs, when we compare the average Gini coefficient for the first five years with the most recent five-year average, we find that most of the change in the Gini coefficient occurred early in the history of these longer term programs and that the differences between the first and most recent five-year average Gini coefficient are modest.

When we compare the Gini coefficient for 2013 to the baseline period, we find that the Gini coefficient decreased in eight of the sixteen catch share programs (Table 10). This means that for these eight programs catch share revenue was more evenly distributed among active vessels during 2013 than it was during the baseline period. Among the eight remaining catch share programs where 2013 revenues were more concentrated compared to the baseline period, there were four fisheries (Grouper-Tilefish IFQ, Northeast Multispecies Sectors, Pacific Sablefish Permit Stacking and Alaska Halibut IFQ) in which the largest change in the Gini coefficient occurred during year 1. In these four fisheries, the Gini coefficient was relatively stable afterward (Table 10).

3.2.3. Excessive share caps

Most of the catch share programs had regulations in place to limit the accumulation of excessive shares. Excessive quota share caps are designed to prevent individual shareholders (or entities) from controlling harvesting or processing as well as achieving management objectives. The share cap in place for each catch share program is listed in Table 11. Excessive share caps are in place for all catch share programs except Surfclam ITQ, Ocean Quahog ITQ and Northeast Multispecies Sectors (Table 11). At the time that the Surfclam and Ocean Quahog Programs were established, the Reauthorized Magnuson Stevens Act (MSA, 2007) was not in place and therefore establishing accumulation limits were not required. The Mid-Atlantic Council has considered an Amendment to the FMP to address accumulation limits in the surfclam and ocean quahog ITQ programs but did not take action (Walden, 2011). Accumulation limits are not required for Northeast Multispecies Sectors due to the specific legal framework that established this program (Amendment 16 to the Northeast Multispecies Fishery Management Plan, available at: http://www.nefmc.org/management-plans/detail/northeast-multispecies). However, the New England Fishery Management Council recently submitted Amendment 18 to the Northeast Multispecies Fishery Management Plan that would establish share accumulation limits as well as a limit on the total number of permits that could be owned by any one individual (Draft Amendment 18 to the Northeast Multispecies Fishery Management Plan, available at: http://www.nefmc.org/library/amendment-18-information).

4. Discussion

The results presented above reveal a number of trends regarding the economic and distributive effects of catch share management. The majority of the objectives to improve the economic performance of catch share fisheries were achieved. However, the distributional effects of catch share programs may indicate that consolidation is occurring in many fisheries.

Economic effects from catch share fisheries have generally improved. Capacity reduction was an objective for all of the catch share programs, and this objective (as measured by the proxy, number of active vessels) was achieved for all but one catch share program. Catch share revenue was greater in 2013 than the baseline period for 9 of the 16 catch share fisheries. In the most recent year, catch share revenue per vessel was above the baseline periods in almost all catch share fisheries.

Nine programs had explicit objectives to lengthen the fishing season and this was achieved for 11 catch share programs. A longer season was not necessarily the end goal for this objective. Rather, it is an outcome that would facilitate other economic improvements, such as increased prices or product quality and improved safety at sea. As many of these fisheries were open for longer periods of time, average ex-vessel prices also increased (Tables 4 and 5). For example, as the Pacific Sablefish Permit Stacking program was open for 196 more days during the year, ex-vessel prices increased by 13% (Tables 4 and 5). All of the fisheries in Alaska were subject to short season lengths prior to introduction of the catch share programs. Perhaps the most dramatic increase in season length occurred in

Table 10
The Gini coefficient for each catch share program.

Catch Share Program	Baseline period	Year 1	Average years 1–3	Average years 1–5	Last 5 year average	2013
Red Snapper	0.81	0.76	0.76	0.75	0.76	0.79
Grouper-Tilefish	0.83	0.87	0.88	0.88		0.89
General Category Scallop[a]	Not available	0.55	0.49			0.45
Multispecies Sectors	0.55	0.63	0.63			0.65
Surfclam	0.32	0.37	0.45	0.46	0.49	0.50
Ocean Quahog	0.51	0.48	0.61	0.61	0.61	0.59
Golden Tilefish	0.61	0.51	0.49			0.52
Pacific Sablefish	0.39	0.45	0.46	0.44	0.47	0.49
Shoreside Non-whiting	0.35	0.39	0.43			0.47
Shoreside Whiting	0.39	0.24	0.24			0.19
Alaska Halibut	0.59	0.66	0.64	0.65	0.67	0.64
Alaska Sablefish	0.62	0.68	0.65	0.65	0.58	0.56
AFA Pollock[b]	Not available	Not available	Not available	0.37	0.36	0.35
Crab Rationalization	0.37	0.40	0.39	0.37	0.31	0.31
Rockfish Cooperatives	0.45	0.51	0.51	0.55	0.58	0.65
Amendment 80	0.25	0.22	0.25	0.24	0.21	0.15

[a] Data are not available for the baseline period.
[b] Data are only available for 20013–2013.

Table 11
Catch share program and harvesting share cap for program species, if applicable0.

Name	Harvesting Share Cap
Surfclam & Ocean Quahog ITQ	Not Applicable
Alaska Halibut & Sablefish IFQ	0.5%, 1.5%
AFA Pollock Cooperatives	17.5%
Pacific Sablefish Permit Stacking	No more than three permits on one vessel
Bering Sea and Aleutian Islands (BSAI) Crab Rationalization	1–20% of initial harvester quota share, 2–20% for crew quota share
Red Snapper IFQ	6.0203% of quota share. No cap on quota pounds
Central Gulf of Alaska Rockfish Cooperatives	4-60% of quota share depending on sector
Amendment 80 Non-Pollock Trawl Catcher/Processor Groundfish Cooperatives	30% of quota share for an individual and 20% of quota share for a vessel
Golden Tilefish IFQ	49% of quota shares
General Category Atlantic Sea Scallop IFQ	2.5% for any one vessel. If an entity owns more than vessel, the entity cannot hold more than 5% of the allocation
Northeast Multispecies Sectors	Not Applicable
Grouper-Tilefish IFQ	2-14% depending on species
Pacific Groundfish Trawl Rationalization	2.5–17.7% depending on species, but ownership cap of 10%

the Alaska Halibut IFQ program, where fishing occurred for as few as four days in the baseline period (season length index = 0.01) and went to near full utilization of the fishing year (average season length index for 2009–2013 = 0.72; Table 4). In the last five years, ex-vessel prices were 165% greater (average $4.80) than the baseline period ($1.81; Table 5). Once the catch share programs were implemented, there was little variation in the season length, with the exception of Halibut IFQ, Crab Rationalization and AFA Pollock where there were some fluctuations in the season length index in the early years of the catch share programs (Tables 4 and 5).

It is important to note that there is not a strict linear relationship between a longer fishing season and increased prices. Fluctuations in supply, i.e., changes in landings will affect demand for fishery products and as a result, ex-vessel prices may change. Furthermore, some fisheries that did not experience fishery closures needed other regulatory instruments to ensure that the season is spread throughout the year. For example, quarterly limits on the number of trips that could be taken by each vessel were utilized in the Surfclam ITQ so that fishing occurred year-round.

The performance measures used to track the distributional effects of catch share programs illustrate a trend that bears further scrutiny. The number of entities holding share and Gini coefficients, proxies for consolidation, indicate that consolidation is occurring in many fisheries. However, the Gini coefficient results indicate that some level of consolidation may have been occurring before catch share management tools were implemented in certain fisheries (e.g., Red Snapper IFQ, Grouper-Tilefish IFQ, or Northeast Multispecies Sectors). To further examine the possible extent of consolidation to date, we compared the current number of entities holding share to the minimum number of entities that could exist based on accumulation limits (Table 12).

The minimum number of entities that would be present is equal to the inverse of the share limit. For example, the share limit for the General Category Scallop IFQ is 2.5%, which means that the minimum number of entities would be 40. For programs that included at least one aggregate accumulation limit as reported in Table 11, the associated minimum number of entities that would exist if the accumulation limit were reached is shown in Table 12. Note that programs not shown in Table 12 had ownership caps for multiple stocks or stock components, or were associated with limits on ownership for specified components of the fishery. In these cases, it was not possible to attribute ownership in 2013 to these subcomponents. The minimum possible number of entities ranged from 3 (49% ownership cap) in the Golden Tilefish IFQ to 200 entities (0.05% ownership cap) in the Alaskan Halibut IFQ program. The actual number of entities during 2013 was 4 times and 12.9 times the minimum in the Golden Tilefish IFQ and Alaska Halibut IFQ programs, respectively. In 2013, the Pacific Sablefish Permit stacking was the closest to being at the minimum as the 111 entities was twice the minimum possible number of 55. The next closest was the Shoreside Non-whiting program, which was 3.4 times more than the minimum. The number of entities in the Red Snapper IFQ was furthest away from the minimum as the 399 entities in 2013 were 23.5 times larger than the minimum possible of 17 (Table 12).

Table 12
Number of entities in 2013 compared to the minimum possible number of entities in catch share programs.

Catch Share Program	Minimum Number of Entities	Entities in 2013	Multiples Above Minimum for 2013
Red Snapper	17	399	23.5
General Category Scallop	20	262	13.1
Golden Tilefish	3	12	4.0
Pacific Sablefish	55	111	2.0
Shoreside Non-whiting	38	128	3.4
Shoreside Whiting	10	78	7.8
Alaska Halibut	200	2570	12.9
Alaska Sablefish IFQ	67	845	12.6

Our results provide further support to many others' findings that catch share programs achieve economic efficiency but with these efficiencies there may be increased consolidation (Bromley, 2009; Hannesson, 2013; Macinko, 2014; Olson, 2011). As the number of catch share programs increase, Councils and stakeholders may need to adopt novel regulations that can balance the need for capacity reduction while avoiding excessive consolidation. For example, when the Pacific Trawl Rationalization Program was implemented there was a moratorium on quota trading within the first three years of the program to avoid early changes in quota holdings (50 CFR § 660.140(b)(3)(ii)(B)(2), available at http://www.westcoast.fisheries.noaa.gov/publications/fishery_management/groundfish/regulations.pdf).

5. Conclusion

We developed a set of indicators to measure the performance of 16 catch share fisheries implemented in the United States. Data limitations mean that some of these indicators serve as proxies for several outcomes that could not be directly quantified. Our focus is on evaluating program performance in terms of the objectives and anticipated outcomes as stated by regional Fishery Management Councils. Within this context, we find that many of the expectations for economic performance of catch shares have been met. Capacity as measured by reductions in active vessels has been reduced. Prices have improved, a result that is particularly pronounced for fisheries subject to early closures. Average revenue per vessel has increased in the majority of catch share programs, as has MFP. Season length has been restored in fisheries that were subject to derbies as well as fisheries where effort controls were required to spread out landings. For these reasons, catch shares seem to be an effective tool to increase the economic performance of fisheries, however, there are distributional consequences related to this management tool.

While not unanticipated, consolidation seems to be an issue for fisheries managed with catch shares, although there may be an important distinction to be made between accumulation of ownership share and the use of quota. Although the minimum number of entities that may be possible ranges from 3 to 200 depending on the share limit, the actual number of entities for the programs that could be evaluated is significantly larger than the theoretical minimum. By contrast, the Gini coefficient, which we use to measure the use of quota, has been increasing in most catch share programs. As previously noted, the increase in the Gini coefficient has not been large and there were no cases in which the Gini coefficient started out low then became relatively high. Our findings indicate that accumulation of ownership share may be less of a concern than consolidation in the use of quota, which would include the use of quota owned by entities as well as any quota leased from other share owners. Thus, to the extent that consolidation is considered a management problem, it may be more effective to consider caps on the use of quota than by imposing more restrictive ownership caps.

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Appendix A. Supplementary data

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