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EDITED BY
Tsz Leung Yip,
Hong Kong Polytechnic University, Hong Kong SAR, China

REVIEWED BY
Devran Yazir,
Karadeniz Technical University, Türkiye
Scott Crosson,
Southeast Fisheries Science Center (NOAA), United States

*CORRESPONDENCE
Julia Livermore
julia.livermore@dem.ri.gov

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Beyond discards: cascading socio-economic and environmental effects of a commercial aggregate landings program in Rhode Island

Julia Livermore[1,2]*

[1]Rhode Island Department of Environmental Management, Division of Marine Fisheries, Jamestown, RI, United States, [2]Department of Marine Affairs, College of the Environment and Life Sciences, University of Rhode Island, Kingston, RI, United States

Flexible approaches to commercial fisheries harvest have been designed to meet management objectives. Rights-based management tools have been problematic for fishing businesses in certain scenarios, whereas aggregate landings approaches may offer similar flexibility while avoiding pitfalls like industry consolidation. This study evaluates a Rhode Island pilot aggregate landings program for summer flounder (*Paralichthys dentatus*) and black sea bass (*Centropristis striata*) from the perspective of the pilot program participants. Semi-structured interviews were conducted with participating commercial harvesters. Fishery-dependent data were also analyzed to supplement harvesters' responses. Interview respondents overwhelmingly supported the aggregate landings approach and described benefits directly from the program, including cost savings, reduced discards, and improved safety. The program also led to increased average weekly harvest of both species and a slight increase in the price of catch for black sea bass for program participants. The aggregate landings approach encouraged fishers to take on less risk through added flexibility in when they chose to fish, while still maximizing their utility. Although the original goals of the program were to reduce regulatory discards and make businesses more efficient, it also resulted in improvements to fishers' well-being, suggesting that aggregate landings approaches should be considered for other fisheries.

KEYWORDS

aggregate landings, possession limit, regulatory discards, safety, well-being, summer flounder (*Paralichthys dentatus*), black sea bass (*Centropristis striata*)

Introduction

Overfishing, defined here as removing a species at a rate greater than the population can replenish itself, presents a variety of threats to coastal ecosystems and the fisheries that rely upon them. Overharvesting can reduce biomass of the target species but may also lead to reductions in biodiversity and the sustainability of fisheries and coastal livelihoods (Halpern et al., 2012; Sumaila and Tai, 2020). Marine fish stocks are overfished in many parts of the world, which also decreases stocks' resilience to climate change (Sumaila and Tai, 2020). Consequently, limiting overfishing through effective fisheries management is essential to sustain fisheries in the long-term (Hilborn et al., 2020).

To avoid overfishing, fishery harvest is traditionally managed using three general approaches: 1) limiting possession, 2) limiting effort, and 3) spatial access controls. Limiting possession involves regulating who can fish and what they can catch (species and amount); these controls can include limited access entry into the fishery, setting a total allowable catch, and implementing market-based regulations. Limiting effort can be used when monitoring harvest is challenging or cost-prohibitive, so managers may opt for input controls with or without guideline harvest levels. Input controls may consist of seasonal closures, gear restrictions, or days-at-sea limitations. Finally, spatial access controls might include restricted access to certain fishing grounds (e.g., rotational scallop management in the US northeast) or overall area closures (Anderson et al., 2019).

Trip, or possession, limits are catch control methods for managing a fishery's quota allocation of a particular species by limiting the total amount of fish that can be landed by or possessed by a vessel in one trip. Trip limits can also be coupled with limiting the days of the week that fishers can harvest and/or limiting the length of the season. Generally, when annual or seasonal quota is reached, the fishery will be shut down to preclude overfishing. This approach can be highly effective in preventing a fishery from exceeding the quota allocation, but it may not enable harvesters to operate efficiently. Furthermore, single species daily possession limits or trip limits may not be well suited to preventing bycatch of other, non-target species, as well as the target species in the event of exceeding the possession limit. The rate of discarded fish has been found to be significant in trawl fisheries regulated using single species trip quotas. For example, Pikitch et al. (1988) contended that single species trip quotas led to program failure to conserve key species and maintain a year-round fishery for West Coast groundfish; they suggest that discards actually increased as trip regulations became more restrictive. Management programs that limit flexibility through restrictive measures may also have sobering social and economic impacts on the future viability of commercial fishing (Colburn and Clay, 2012). To limit these impacts, new approaches that allow for more flexibility are being explored.

Market-based environmental regulations are a newer tool to manage resources, including commercial fishery harvest. Creating markets for fishing quota creates an economic incentive to avoid overfishing, because market mechanisms link firms' and individuals' self-interest to environmental outcomes (Anderson et al., 1997; Mansfield, 2006). These approaches can also reduce regulatory discards by reducing the time harvesters spend fishing. One such market-based approach is sector management (a rights-based management tool), in which vessels or cooperatives are given an allocation of the yearly total allowable catch as individual fishing quotas (IFQs) (Clay et al., 2014; Birkenbach et al., 2017). In theory, sector management could help to extend fishing seasons by allowing harvesters to fish flexibly over the season and improve safety at sea (Birkenbach et al., 2017). However, sector management has raised consolidation and equity issues in certain cases (Birkenbach et al., 2019); one key example is the New England groundfish fishery in the United States (Brewer et al., 2017).

Aggregate landings programs also serve to increase flexibility in the timing of landings and are expected to increase economic rents through improved efficiency of harvest. The primary difference between aggregate landings and sectors is that aggregate landings approaches are not rights-based and do not allocate quota to individuals; fishers in the program are granted more temporal flexibility to land their catch. Instead of a daily commercial possession limit, aggregate participants are given a weekly aggregate limit (e.g., 7 days x 100 lbs./day daily possession limit = 700 lbs./week aggregate limit). Aggregate participants have no ownership over any portion of the quota and may have the same total possible weekly harvest as the rest of the fleet. The difference is that participants can land their weekly aggregate limit at any time during the week, without needing to abide by the daily possession limit.

Any proposed fishery management measure has the ability to influence job characteristics, including safety, which in turn can affect job satisfaction and well-being (Pollnac et al., 2015). Breslow et al. (2016) defined well-being as "a state of being with others and the environment, which arises when human needs are met, when individuals and communities can act meaningfully to pursue their goals, and when individuals and communities enjoy a satisfactory quality of life (p. 2)." Therefore, improved safety has the ability to increase overall well-being among fishers, as could management techniques that reduce uncertainty stressors, which may lead to improvements in mental health (King et al., 2021). Management changes have the ability to restructure a person's work, which in American culture plays a strong role in the psychological, economic, and social aspects of well-being (Pollnac and Poggie Jr, 1988). It is also essential to note that fishing and interacting with marine resources is much more than an economic activity alone (Anderson, 1980; Smith, 1981; Bunce et al., 2000; Pollnac et al., 2006). Managers should consider all the disparate facets of fisher well-being when designing management measures.

In theory, an aggregate program could improve safety by reducing temporal constraints on when catch may occur. Commercial fishing is one of the most dangerous professions in the United States (Center for Disease Control and Prevention, 2021). In spite of this, fishers are known to experience high levels of job satisfaction (Smith, 1981; Apostle et al., 1985; Pollnac and Poggie, 2008; Pfeiffer and Gratz, 2016; Holland et al., 2020). As described above, managers have a variety of management tools at their disposal to restrict harvest to sustainable levels. These tools restrict decisions that can be made by fishers, which can lead to market failures and escalate physical risks for fishers (Pfeiffer and

Gratz, 2016). One of the most persistent decisions fishers must make is whether to fish given weather conditions (Jin and Thunberg, 2005). In over 61% of fatal vessel accidents in the United States between 2000 and 2009 severe weather was a contributing factor (Lincoln and Lucas, 2010). The choice a fisher must make when weather is poor is between delaying a trip until conditions have improved and losing the marginal value of a day of fishing (Pfeiffer and Gratz, 2016). While Pfeiffer and Gratz (2016) argue that individual fishing quota programs (rights-based management) transition fishers' incentives and constraints such that that they choose to take on less risk while still maximizing their utility, other tools like less restrictive landing periods may also help.

While aggregate programs theoretically offer a variety of benefits to commercial harvesters, questions remain about whether landing in aggregate limits may exhaust fishing quotas more rapidly than management using daily possession limits. If such programs change the rate at which landings occur over the course of a fishing season, the price of ex-vessel catch could potentially change in response.

To make fishing more economical and reduce negative impacts of traditional harvest controls, the state of Rhode Island (US) recently tested both sector and aggregate landings approaches. The state of Rhode Island is home to a robust commercial fishing industry, with industrial activity dating back to the 1630s. Over 1,700 commercial licenses allowing finfish harvest were issued in 2021. The commercial and recreational fishing industries are integral to the state's economy, with the commercial fleet landing over $103 million in ex-vessel value in 2021 alone (RIDEM, 2022b).

The Rhode Island Department of Environmental Management (RIDEM) implemented a summer flounder, or fluke, (*Paralichthys dentatus*) sector pilot program in 2009 and part of 2010, where eight participating vessels were selected based on average annual landings of those vessels over a prior four-year period. The sector pilot program allowed participating vessels to harvest outside the standard management program. They were not required to abide by daily possession limits or seasonal closures, as long as catch did not exceed their allocation within the sector, but discard reporting and observer coverage were dramatically increased for participating vessels (Division of Marine Fisheries (RI), 2011). An economic analysis of the program using a counterfactual approach revealed that participating vessels avoided harvesting summer flounder during seasonal derbies, instead focusing fishing effort on other times of year when prices for fluke were higher (Scheld et al., 2012). Scheld et al. (2012) suggest that the pilot program increased fleetwide revenues for both program participants and non-participants. Nevertheless, some members of the broader Rhode Island commercial fishing community expressed strong opposition to the program due to philosophical objection to a catch share approach where the public resource is allocated to individuals (or a sector). This ultimately led to discontinuing the program (Scheld et al., 2012).

Due to a lack of support for a catch share approach, and consistently low state quotas for fluke and black sea bass (*Centropristis striata*), the state conducted a more recent pilot aggregate landings program for commercial fisheries harvesting these two species in Rhode Island. The aggregate landing model is not new for Rhode Island, as it has been used without issue for fluke during a winter season sub-period (January through April), scup, and bluefish. The commercial quotas for fluke and black sea bass have traditionally been managed through season-specific quotas, changes in possession limits throughout the year, and in some cases closures during certain days of the week. Both fluke and black sea bass are targeted by a large proportion of the commercial fleet (particularly in summer) due to their high demand and relatively high prices at dealers. As such, the daily possession limit of both species is generally low with state quota allocations also contributing to low limits. Given the variability of fish stocks, low quotas, and subsequently low possession limits, combined with rising fuel prices, vessel maintenance costs, safety at-sea concerns, and global pandemics, fisheries managers are striving to provide more flexible fishing programs to the fishing industry.

At the recommendation of certain commercial fishing industry representatives, the Rhode Island Department of Environmental Management (RIDEM) Division of Marine Fisheries (DMF) brought forth a proposal for a summer pilot fluke and black sea bass aggregate program in the fall of 2018 to the Rhode Island Marine Fisheries Council (RIMFC), which was passed and implemented in 2019. The goal of the Pilot Aggregate Program was to collect data for assessing the viability of an aggregate program for fluke and black sea bass from May 1 to December 31, where participants would be held to a weekly aggregate limit in lieu of a daily limit. With the support of the 2019 Pilot Aggregate Program fishing participants, the program was extended through the 2021 fishing year in hopes of better understanding the interannual variability associated with the program that is imperative to understand before any form of the program can be formally adopted. Increasing the number of participants using each respective gear type was also essential to capture variability among harvesters.

To ensure that the pilot program would not lead to overfishing or premature season sub-period closures, it included a variety of existing fishery management measures used on both species in Rhode Island. Both species were subject to fishing seasons (with sub-period allocations to distribute catch over the full fishing season), minimum size limits, and live tracking of sub-season and annual harvest (e.g., https://dem.ri.gov/natural-resources-bureau/marine-fisheries/commercial-fishing-dealer-resources/ri-quota-monitored) to ensure that Rhode Island did not exceed its state quota allocation of the coastwide total allowable catch (TAC) in any program year. Further, the program was only active in the summer fishing season and had a trigger in place that would terminate participants' ability to land in aggregate once 80% of the quota had been harvested. Participants could continue to fish under daily possession limits for the rest of the open season. In addition, all participants had to have active Vessel Monitoring Systems (VMS) installed on their vessels, which is not required to harvest via a daily possession limit.

The goal of the aggregate program was to allow harvesters more flexibility in fishing practices by harvesting a weekly possession limit unconstrained by daily possession limits. Such a program would theoretically decrease harvester operating costs by reducing

required days at sea (e.g., less fuel and vessel maintenance required) while also increasing safety as fishers could pick which days were the best to fish based on weather. While not monitored by the program, it was hoped that the aggregate program would also decrease regulatory discards, and thus, discard mortality in some fisheries, by reducing the total number of needed fishing trips to maximize possession limits. Gillis et al. (1995) and Hilborn (2007) explain that fishermen's decisions regarding discarding are driven by maximizing the economic value of their fishing trips, A similar hypothesis was postulated for benthic habitat, as fewer days trawling would theoretically reduce benthic disturbances. The aggregate possession limits also had the opportunity to reduce illegal fishing behavior by increasing flexibility and therefore reducing the incentive to harvest over the daily limit. Overall, this pilot program represented an attempt to create incentives that align fishing fleet dynamics and fisher behavior with intended societal goals (e.g., Branch et al., 2006).

One challenge of any proposed management approach is that assessment of the management program depends directly on the quality of the data reported by fishing industry participants. Research has shown that resource users frequently behave in a manner that is unintended by the designers of the management system, which increases uncertainty and may lead to unintended management outcomes (Fulton et al., 2011). As described by Clay and McGoodwin (1995), not all members of a fisheries user group may behave the same way, or have the same impact on marine ecosystems. Decisions may be driven by economic and ecological considerations, as well as family and community variables.

Therefore, fishery-dependent data in the form of state logbooks, vessel trip reports, fishery observer reports, and dealer reports (often called landings) all serve as essential sources of information to monitor catch and effort, but these datasets do not address all socioeconomic indicators of a management strategy's impacts. Harvest and effort data collection (via dealer reporting and state logbooks or federal vessel trip reports) occurred during the pilot aggregate program and all aggregate participants were also required to install a VMS onboard for real-time vessel location monitoring. However, no data collection on the economic and safety components of the program took place initially, limiting state managers' ability to assess program performance in terms of socioeconomic impact. This information is necessary to determine whether this pilot aggregate program resulted in improved economic efficiency and safety, as intended. Discerning the human behavioral response in terms of changes to fishing activity and business operations is pivotal to understanding what drives changes in harvest. This information is necessary to make informed recommendations about management options that will achieve desired positive impacts for harvesters, specifically stable and predictable harvest to maximize quota utilization.

Here, we use a mixed-methods (qualitative and quantitative) approach to address this data gap by examining business information (fuel, bait, ice, grocery, and labor costs, number of days fished, etc.), perceived impacts of the program from participating harvesters, changes in behaviors, and attitudes towards the program.

Materials and methods

Interviews

Participants' perceptions of the pilot aggregate program's impacts were obtained through semi-structured interviews, with both structured and open-ended questions (refer to Supplementary Information for interview instrument). Prior to contacting potential interviewees, a semi-structured interview instrument was developed and approved by the University of Rhode Island's Institutional Review Board. Interview questions focused on perceptions of impacts (i.e., changes to number of trips targeting fluke or black sea bass or costs associated with fuel and bait, whether the program affected the number of discards), behavioral responses (i.e., changes to number of days at sea or other business decisions), and attitudes towards the program (e.g., positive or negative, what could be done to improve the program). Gender neutral language is utilized throughout this manuscript, as pronouns were not asked about explicitly during interviews.

Sampling efforts attempted to reach all pilot aggregate program participants using purposive sampling, a common practice for studying individuals of a particular demographic group (Bernard and Ryan, 2010). Data collection was focused exclusively on participants of the aggregate programs to allow for assessment of changes to their businesses since joining the program. Management decisions on behalf of the RIDEM DMF must meet requirements set forth through the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan cooperatively managed by the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC). This effort aimed to improve upon the RIDEM DMF's understanding of how aggregate programs may impact fishing businesses, and to supplement management measures designed to prevent exceeding the state's quota, established through regional management.

In 2019, 12 participants were chosen by lottery to participate in the program and represent multiple gear types utilized by the Rhode Island commercial fleet: three otter trawl harvesters, one lobster pot harvester, three gillnet harvesters, one rod and reel harvester, three multi-gear harvesters, and one fish pot harvester. Three participants per gear type were sought in year one, but limited applications for lobster pot, fish pot, and rod and reel participants were received. Participants were increased in 2020 to a total of thirty. Three new participants for each gear type were sought in 2020, but not all types met this goal; participants were selected by lottery when more than three applications were received within a gear type. Participants in this pilot aggregate program represented both state-only and federally permitted vessels. New participants brought the totals by gear type to:

- 6 otter trawl
- 6 gillnet
- 2 lobster pot
- 5 fish pot
- 5 rod and reel
- 6 multi-gear (participants whose fishing history was not comprised of over 80% of a single gear type)

Actively fishing pilot aggregate program participants represented between 2.1% and 6.5% of fishers harvesting summer flounder by number of licenses, and between 2.3% and 6.4% of all RI fishers landing black sea bass across the three years of the pilot program. All 30 program participants were contacted via email to set up an interview. Based on the gear types of individuals that responded, an additional 14 participants were called soliciting for interviews to address other gear types that did not have as much interview coverage. At least three participants from each gear grouping needed to be interviewed for that gear type to be discussed in reporting, per data confidentiality requirements (i.e., ACCSP Rule of Three). Ultimately, a total of 14 program participants were interviewed, representing 47% of the program participants, as well as one dealer, for a total of 15 interviews conducted. Interviewees were offered embroidered baseball caps to thank them for their willingness to provide information about their experience in the pilot aggregate program.

While 14 respondents is a small number of individuals, this represents a saturated sample of the pilot participants and is an acceptable sample size in qualitative data collection. Guest et al. (2006) suggest that data saturation (when additional respondents do not provide new insights) occurs around 12 participants in homogeneous groups. Moreover, Crouch and McKenzie (2006) note that smaller samples can allow researchers to build and maintain trust with participants, and allow for optimal, open exchange of information. This is particularly important when respondents are being asked questions that they may consider sensitive such as those related to fishers' behaviors and their attitudes toward fisheries management. Given the use of purposive sampling of pilot aggregate program participants, it is reasonable to assume that this study reached saturation at 12 or more interviews, as a 40% positive interview response rate should achieve an acceptable sample size to determine overall program efficiency for all gear types combined.

Since the COVID-19 pandemic was still ongoing at the time of interviewing, the interviews were conducted either in-person or over the phone, depending on interviewee preference. Interviews ranged from ten to sixty-six minutes (mean ± SD = 35.13 minutes ± 16.8). All interviews were recorded and transcribed for reporting accuracy, after providing consent to the interview and being recorded.

Qualitative data analysis

Interview recordings were transcribed using Temi transcription services (www.temi.com), and manual correction. Transcriptions were then coded in NVivo software (QSR International 2022) for qualitative analysis. Coding allows for indexing qualitative data to make sense of information in the context of specific research questions (Elliott, 2018). Closed-ended questions were analyzed using summary statistics, while open-ended questions were descriptively coded by theme and then analyzed (see Saldaña, 2015). Themes included, but were not limited to, attitudes towards the program, conservation, costs and profits, discards, factors external to fishing, flexibility, safety, quota or season length, and welfare. A description of themes is presented below using direct language from the participants where appropriate.

Fisheries dependent data analysis

To supplement the qualitative data from the interviews, dealer reports from the Standard Atlantic Fisheries Information System (SAFIS), were also examined along with state logbooks and vessel trip reports from the Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse for all fishing activity resulting in Rhode Island fluke and black sea bass landings between 2016 and 2021 (three years prior and three years during the program). These data were analyzed in R statistical software (R Core Team, 2022). Analysis of the fishery-dependent data allowed for direct comparison to participant perceptions of changes in number of trips, pounds landed, and dealer price of catch and to test for potential strategic bias. A variety of analyses were conducted including data visualization (line plots and boxplots), Kolmogorov-Smirnov tests, and difference-in-differences regression models; all analytical approaches were applied to summer flounder and black sea bass separately.

The basic difference-in-differences model estimated by ordinary least squares over the fishers' price per pound of individual landings (dependent variable Y) of one species is expressed as:

$$Y_{it} = \beta_0 + \beta_1 Treated_i + \beta_2 Post_t + \lambda Treated_i \cdot Post_t + X_{it} + \epsilon_{it} \quad (1)$$

where i indexes fisher, t indexes period, *Post* is a dummy variable equal to 1 if the observation is from the period after the program began (0 if the observation is from before the program) and *Treated* is a dummy variable equal to 1 if the fisher is in the program (and 0 if they are not in the program). X includes control variables (dummy variables for market, day of week, month in year, and year). The parameter of interest λ gives the average causal effect on price of catch per pound for program participants after the program began, as compared to non-program participants.

Results

Interviewee characteristics

The interviewees represented participants from five different gear types: fish pot (3), rod and reel (4), gillnet (3), otter trawl (3), and use of multi-gear types (1). Based on the Rule of Three, interview data fish pot, rod and reel, gillnet, and otter trawl were eligible to be discussed in isolation, while multi-gear cannot. Interviewees had between 12 and 50+ years of work experience in the fishing industry. The number of aggregate participants landing black sea bass and summer flounder in each year differed (Table 1); not all eligible participants landed black sea bass in 2020 and 2021. Joining the program allowed participants to land both species in aggregate limits, though some participants targeted only one of the two species.

TABLE 1 Number of aggregate and non-aggregate participants fishing in each of the three program years.

Species	Year	Aggregate	Non-Aggregate	% Aggregate
Black Sea Bass	2019	12	515	2.3%
Black Sea Bass	2020	29	452	6.4%
Black Sea Bass	2021	25	448	5.6%
Summer Flounder	2019	10	473	2.1%
Summer Flounder	2020	25	384	6.5%
Summer Flounder	2021	21	404	5.2%

The number of total aggregate program participants in 2019 was 12 and was increased to 30 in 2020 and 2021.

Environmental benefits

Discards

One of the key topic areas discussed by participants related to the program was the impact on discarded fish. Of the 15 individuals interviewed, ten stated that they thought the program reduced regulatory discards (Table 2). One of these ten stated, "I think [the program] cuts down tremendously on bycatch," while another offered, "…[fishers] will change their behavior and modify some of the destructive discarding practices voluntarily because you're giving them a means of making more money."

Two of the remaining five respondents suggested that the program may have reduced discards, one of which noted that there was no change to their discard numbers, but for other gear types it is likely to reduce them. One additional interviewee stated that they had the same number of dead fish but got to keep fish that would have been discards previously because they fished the same number of days as before. Only one individual thought that there was no change to discards due to the program. A key point expressed by multiple individuals was that the program's effect on discards may be different by gear type. For example, it was noted that controlling discards with gillnets can be challenging, but this program does allow for more fish to be kept that traditionally may have been discarded. However, another perspective was that if you hit your target catch more efficiently each week, you may fish less for aggregate species, resulting in fewer discards.

TABLE 2 Percent of interviewees that discussed various program benefits.

Program benefit	Interviewees that noted benefit
Improved safety	86.7%
Reduced fuel consumption and costs	86.7%
Reduced discards	66.7%
Increased flexibility to target other species	53.3%
Reduced wear and tear on vessel and gear	40.0%
Reduced bait costs	33.3%
Resulted in environmental benefits	26.7%
Allowed for more family time	20.0%
Allowed for making up of lost days	13.3%
Improved mental health	13.3%
Enabled coordination with dealers	13.3%

Broader conservation measures

While not asked about directly during interviews, two respondents noted additional environmental benefits of the aggregate program. One highlighted the reduction in gear interaction with the bottom, resulting in less damage to benthic habitats. They stressed that this occurred due to a reduction in trips or fishing time (discussed in more detail below). Further, another individual described that less fishing equated to less fuel consumption and therefore a reduction in carbon emissions. They described that incentivizing more economical fishing could lead to a reduction in greenhouse gas emissions. This respondent closed their thoughts on the aggregate landings program's environmental effects with, "It's a win for the environment and for mankind."

Safety

Most respondents (13 of 15) indicated that the program improved safety. Rationales included the ability to pick fishing days based on weather rather than necessity to catch a daily limit (noted by ten individuals), less time on the water overall (fewer days or shorter days), taking time when needed to make vessel repairs correctly due to reduced pressure to catch a daily limit, and a general ability to avoid risks without losing money. One of these 13 respondents offered, "That's one of the issues, safety. If you break down or something or you have a family emergency, or any reason that you can't fish that day, you feel like you've lost that money for the day. If you're in the aggregate program, you feel like you have at least a chance to make it up."

However, the two remaining individuals said the program had no effect on their safety, primarily because they either fish inshore or are already avoiding bad weather days.

Well-being

Two program participants emphasized how the program had directly improved their quality of life, using the terms "quality of

life" or "well-being" explicitly. Both individuals noted a reduction in stress associated with program participation, and two others described the program as helping to manage stress, improve mental health, and avoid burnout. One also described how the program made them actually want to go fishing again, instead of feeling obligated to go in order to get their maximum allowable catch each day.

Others discussed well-being more generally, like how the program improved overall flexibility in their daily lives. In most cases, a reduction in stress was attributed to less pressure to fish daily, but one interviewee highlighted that the more flexible possession limit was also a driver. One noted, "It's a big opportunity to navigate lifestyle and weather, and [provides] the ability to go engage in other business activities after getting the aggregate limit." Three of these respondents discussed being able to spend more time with family, without sacrificing earnings, as a result of the program.

Business efficiency

Trips

Just over half of the program participants interviewed (8 of 15) explained that they took fewer trips while in the program. Additionally, two others noted that while they still took the same number of trips, fewer were spent specifically targeting fluke and black sea bass. Of those that indicated they had taken fewer trips during their time in the pilot aggregate program, six offered detailed explanations of how reductions occurred and provided information demonstrating reductions in the number of trips ranging between 17 and 86%. One of these six also noted that their catch of black sea bass increased while in the program, along with a reduction in the number of trips taken, resulting in a 200% increase in profits during the program relative to prior.

While some participants said they did not reduce the number of trips during the program, they did express other benefits of the program. For instance, days were shorter and less gear may have been set in the water and more fish that would have become discards on trips prior to being in the program were kept. Others noted that they might reduce trips if fish are not around in large numbers, as individual day trips for a 50-pound limit of black sea bass may not be enough to justify a trip, or if there were aggregate landings allowances for more species.

Quantitative analysis of vessel trip reports in conjunction with landings for all aggregate participants suggested there were reductions in the number of trips by fishers participating in the pilot aggregate program across multiple gear types. Results presented at a public workshop in January 2022 indicate that most fish pot captains had fewer trips in 2020 and 2021 than the 2014-2018 median. Most gillnet and rod and reel fishers had fewer trips than the 2014-2018 median in all three aggregate years (2019, 2020, and 2021). Lobster pot fishers overall had fewer trips during the aggregate time period but had an equal number of captains harvesting above and below the median in 2020. Trawlers had a similar pattern, where most captains had fewer trips than the median in 2019 and 2022, but an equal number of captains harvesting above and below the median in 2020. Most multi-gear captains had fewer trips than the median in 2019 and 2022, but a larger number of captains with more trips than the median in 2020. Overall, there is a reduction in the number of trips during the pilot aggregate program for aggregate captains relative to their 2014-2018 activity.

It is worth noting that 2020 was an anomalous year for all fishing activity due to the COVID-19 pandemic. While overall pounds landed in Rhode Island of black sea bass and summer flounder increased from 2019 to 2020 (39% and 2%, respectively), the value associated with those landings decreased between the two years (12% and 16%, respectively) (RIDEM, 2022a; RIDEM, 2022b). Therefore, the low price of ex-vessel landings during the pandemic may have affected harvester behavior.

Fuel

A reduction in fuel usage was noted by 13 individuals. For most gear types, this resulted from a reduction in the number of trips, but for some gillnetters, their days on the water were shorter because they were able to set fewer nets while still hitting their weekly target catch. One person noted no change in fuel usage, while another was unsure because they targeted other species more as a result of the program, so parsing out fuel usage to target fluke and black sea bass alone was not possible.

Bait

For gear types that use bait (i.e., fish pots and rod and reel), five participants stated that they thought the pilot aggregate program resulted in savings on bait costs. Two others suggested there was no effect on bait expenses, while another two discussed challenges in determining whether changes in bait costs were associated with the pilot aggregate program. Bait prices were noted to be increasing during the program period, and two discussed how they switched from using clam bellies as bait to squid gurry to save money. However, this had nothing to do with the pilot aggregate program.

Labor

Participants generally thought that labor costs did not change due to the pilot aggregate programs. Only one individual suggested a reduction in labor costs, while seven others stated that they did not observe any changes in paying for crew associated with the program. The majority of interviewees noted that they worked alone or with family members, so there was no change to crew expenses during the program versus prior years.

Wear and tear

Six interviewees indicated that the program likely resulted in a reduction in wear and tear on either the vessel and/or fishing gear. Of these six, three stated that these reductions were limited in scope and hard to parse out. The other three noted specific situations including replacing gear less frequently because it spent less time in the water, gear not needing to be modified as much to target different species, or a reduction in vessel maintenance time and costs. An additional two individuals believed that the program had no effect on costs or time associated with vessel or gear maintenance.

Changes in catch

For some gillnetters, the program allowed them to reach their weekly possession limits (equaling more than they would catch fishing on daily limits) because they could catch a large enough amount to make fishing worthwhile. For fish potters, one noted that their catch of black sea bass increased even while the number of trips decreased because they were able to keep more fish on a single trip. Two individuals also suggested that catch (and profits) was higher because the pilot aggregate program prevented them from having "lost" fishing days. Being able to land in aggregate allowed them to make up for "lost" days, where historically, if they had not fished, that access to the daily possession limit was eliminated.

Landings data were analyzed to evaluate the difference in catch of black sea bass and fluke of participants in the pilot aggregate program relative to those harvesting under daily possession limits for both a baseline of three years prior to the program and three years during the program. Independent of whether the program was active or not, program participants landed more black sea bass than their non-program counterparts (Figure 1). However, with the commencement of the program, participants increased their landings even more relative to their pre-program baseline than non-program harvesters. Distributions of average weekly catch differed statistically between the two across the three years of the pilot program (Kolmogorov–Smirnov test p-value< 0.001). Aggregate participant members landing summer flounder also differed each year (Table 1); in all three years, not all eligible participants landed summer flounder. Similar to black sea bass landings, prior to the start of the program, program participants landed more summer flounder than non-program participants. After the initiation of the program, program participants further increased their landings beyond both their baseline and that of the non-program participants (Figure 2). Average weekly catch distributions also differed between aggregate and non-aggregate harvesters during years in the program (Kolmogorov–Smirnov test p-value< 0.001).

Ex-vessel price of catch

When asked about whether they thought the aggregate landings program impacted the price of their catch, most interviewees (11 of 15) noted that they did not observe any change in the price per pound of either species. However, other factors negatively affected ex-vessel price during the program, including the COVID-19 pandemic (3 respondents), interstate landing limits (1 respondent), and increases in Rhode Island state quota (2 respondents). Two additional program participants suggested that the program did have a positive effect on price of black sea bass because they were able to coordinate with seafood dealers about when would be the best time to land catch. Nevertheless, five respondents did note concerns that if the entire fleet could land in aggregate amounts, the price could be negatively affected if large volumes of either species are landed at the same time.

The difference-in-differences model for summer flounder found no causal effect of the aggregate program on average price per pound of ex-vessel landings; the program effect (interaction factor between post and treated dummy variables) was small (0.024), and not statistically significant (p-value = 0.101; Table 3). Prices per pound followed the same trend for both program participants and non-participants prior to and during the program (Figure 3).

In contrast, the difference-in-differences model for black sea bass did find evidence of an effect on price due to the program, holding all else equal (interaction factor = 0.058, p-value< 0.001; Table 4). Trend analysis suggested that prices also followed the same trend for all harvesters prior to the program, but had a slight, variable increase during the program for aggregate landings program participants (Figure 4).

Discussion

Just as individual fishing quota programs (rights-based management) may encourage fishers to take on less risk while still maximizing their utility (Pfeiffer and Gratz, 2016; Errend et al., 2018), the summer/fall aggregate landing program implemented in Rhode Island for summer flounder and black sea bass appeared to similarly increase the flexibility of when fishing occurred within the week, without reducing access to the state's quota. Increased operational flexibility was associated with decreased variable costs, profit maximization, and increased opportunity costs to participate in

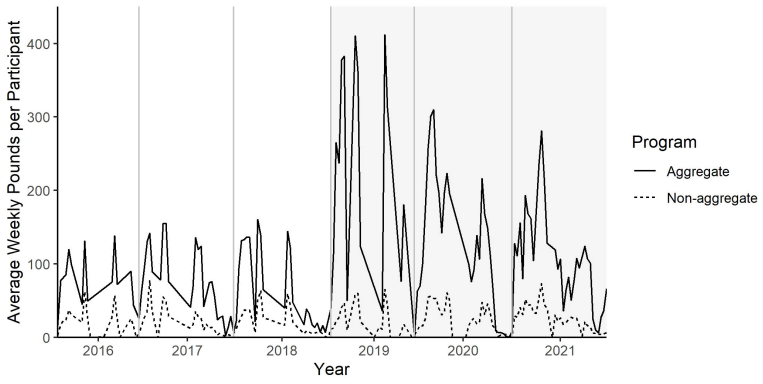

FIGURE 1
Average weekly pounds of black sea bass landings from 2016-2021 separated by aggregate versus non-aggregate participants. Pilot program years are shaded gray. The aggregate landings period was only in effect from May – December each year. Only weeks during the aggregate period are included in this plot. Lateral lags in the data result from season sub-period closures due to reaching the sub-period quota allocation. There were 5 closures in 2016, 3 closures in 2017, 3 closures in 2018, 4 closures in 2019, 1 closure in 2020, and 1 closure in 2021.

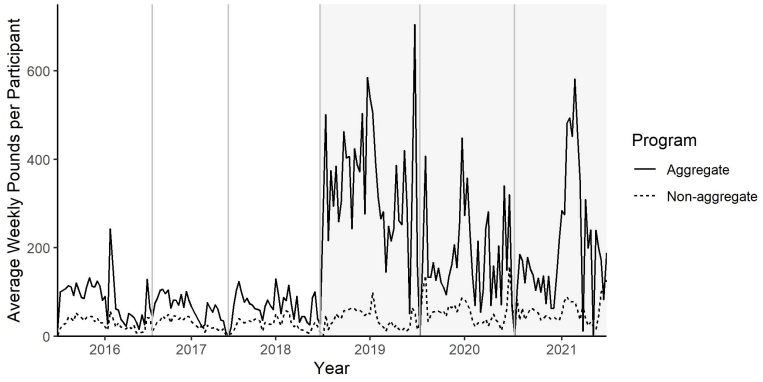

FIGURE 2
Average weekly pounds of summer flounder landings from 2016-2021 separated by aggregate versus non-aggregate participants. Pilot program years are shaded gray. The aggregate landings period was only in effect from May – December each year. Only weeks during the aggregate period are included in this plot. Lateral lags in the data result from season sub-period closures due to reaching the sub-period quota allocation. There were 2 closures in 2017, but no closures in all other years.

TABLE 3 Difference in differences regression model of the price per pound of summer flounder (N= 140,774). 2021 was omitted due to collinearity with the time variable.

Independent Variables		Dependent Variable: Price per pound		
		β	Standard Error	*p*
Post	Constant (Before Program)			
	During Program	-0.475070	0.008183	<0.001
Treated	Constant (Not in Program)			
	In Program	-0.087273	0.010185	<0.001
Market	Constant (Jumbo)			
	Large	-0.339878	0.005787	<0.001
	Medium or Select	-1.335907	0.005937	<0.001
	Mixed or Unsized	-0.021793	0.596874	0.9709
	Small	-2.285827	0.225649	<0.001
	Unclassified	-1.564235	0.046049	<0.001
Day of Week	Constant (Sunday)			
	Monday	0.011890	0.009119	0.1923
	Tuesday	0.010414	0.009061	0.2504
	Wednesday	0.002312	0.009030	0.7979
	Thursday	-0.014217	0.009074	0.1172
	Friday	-0.016601	0.011103	0.1349
	Saturday	0.024476	0.011633	0.0354
Month in Year	Constant (May)			
	June	0.034650	0.007421	<0.001
	July	-0.637007	0.007472	<0.001
	August	-0.301104	0.007985	<0.001
	September	-0.820004	0.009557	<0.001
	October	-1.407113	0.010414	<0.001

(Continued)

TABLE 3 Continued

Independent Variables		Dependent Variable: Price per pound		
		β	Standard Error	p
	November	-1.390789	0.012607	<0.001
	December	-1.251948	0.015558	<0.001
Year	Constant (2016)			
	2017	0.206197	0.007679	<0.001
	2018	0.404907	0.007484	<0.001
	2019	-0.113636	0.008026	<0.001
	2020	-0.853434	0.008621	<0.001
Post-Treated Difference		0.024448	0.014900	0.1009
Intercept		5.904576	0.010654	<0.001
R^2		0.5535		
Adjusted R^2		0.5534		

other fisheries, similar to individual allocation management (Errend et al., 2018). Through the aggregate landings program, participants' profits were maximized by taking fewer trips or spending shorter days on the water to catch the same amount of fish (or more), reduced fuel and bait (where applicable) costs, reduced wear and tear on vessels or fishing gear (through reduced time on the water), and the elimination of "lost days" (where the possession limit is lost). The program also led to increased average weekly harvest for program participants of both fluke and black sea bass, relative to the larger fishery. For black sea bass, program participation was also associated with an increase in price of catch, likely due to harvesters increased ability to coordinate with dealers on timing of landings.

Harvesters aim to maximize their profit subject to regulatory, biological and temporal constraints (Smith, 1969; Clark, 1980), which can result in a race-to-fish under daily possession limits, where harvesters land amounts each day until the season is closed in spite of low prices. An aggregate landings approach may not eliminate the race-to-fish, as is theoretically possible through an IFQ regime. By spreading out catch over the year and avoiding the race-to-fish, the sector pilot program in Rhode Island likely also reduced regulatory discards. However, the Rhode Island fishing industry historically has not supported the sector approach due to philosophical concerns over allocating a public resource to private individuals (Macinko and Bromley, 2002; Bromley, 2015), as well as concerns over consolidation like that seen in the New England groundfish fishery (Brewer et al., 2017). Since fluke and black sea bass are managed under a maximum sustainable yield approach through the ASMFC and MAFMC, the RIDEM DMF proposed allowing landing in aggregate for target species as an alternative method to reduce the number of trips taken by harvesters to reduce the number of regulatory discards. Based on the two pilot programs and ongoing management, sectors, aggregate landings, and daily possession limits all present different risks and benefits to management metrics like overall fleet capacity, discards, and enforcement.

Additional research beyond this effort conducted by the RIDEM DMF (e.g., Balouskus et al., 2023) also indicated that the pilot aggregate

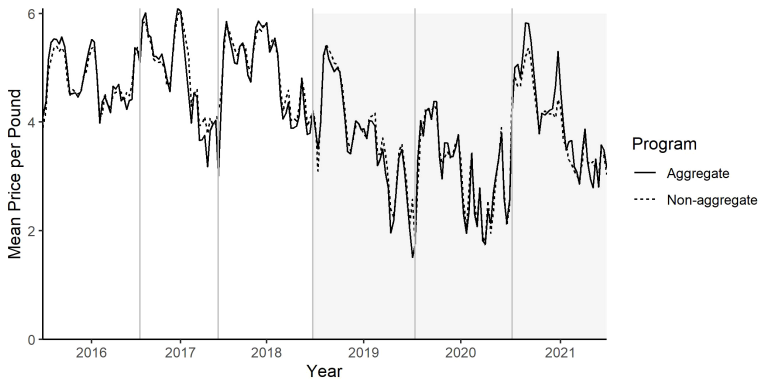

FIGURE 3
Weekly mean price per pound of summer flounder from 2016 - 2021 for participants that did and did not join the program. Pilot program years are shaded gray.

TABLE 4 Difference in differences regression model of the price per pound of black sea bass (N= 118,685). 2021 was omitted due to collinearity with the time variable.

Independent Variables		Dependent Variable: Price per pound		
		β	Standard Error	p
Post	Constant (Before Program)			
	During Program	-0.128191	0.008460	<0.001
Treated	Constant (Not in Program)			
	In Program	0.038224	0.010505	<0.001
Market	Constant (Extra Small)			
	Jumbo	-1.259265	0.762865	0.098801
	Large	-2.348027	0.762867	<0.001
	Medium or Select	-3.268269	0.762871	<0.001
	Small	-3.690839	0.762887	<0.001
	Unclassified	-2.563643	0.763395	<0.001
Day of Week	Constant (Sunday)			
	Monday	0.040629	0.008269	<0.001
	Tuesday	0.030291	0.008231	<0.001
	Wednesday	0.035323	0.008296	<0.001
	Thursday	0.057530	0.008339	<0.001
	Friday	0.000266	0.009616	<0.001
	Saturday	-0.032845	0.008851	0.977931
Month in Year	Constant (May)			
	June	-0.397745	0.007857	<0.001
	July	-0.610660	0.006935	<0.001
	August	-0.193601	0.016993	<0.001
	September	0.072681	0.007765	<0.001
	October	-0.318103	0.009829	<0.001
	November	-0.489870	0.009508	<0.001
	December	-0.465675	0.018570	<0.001
Year	Constant (2016)			
	2017	-0.274634	0.008646	<0.001
	2018	0.362063	0.008574	<0.001
	2019	0.331673	0.007696	<0.001
	2020	-0.923037	0.007135	<0.001
Post-Treated Difference		0.058399	0.014412	<0.001
Intercept		6.050962	0.762891	<0.001
R^2		0.6580		
Adjusted R^2		0.6579		

program did not affect quota availability or the number of days the fishery had to be closed, relative to prior fishing years. Simulation analyses were conducted looking at quota utilization if the program were expanded to the whole fishery and suggested that the aggregate program could result in additional closed days (Balouskus et al., 2023). However, it is essential to note that simulations were generated by replacing historic reported catch from the entire Rhode Island fleet with random catches from the pilot fleet during the program, and this

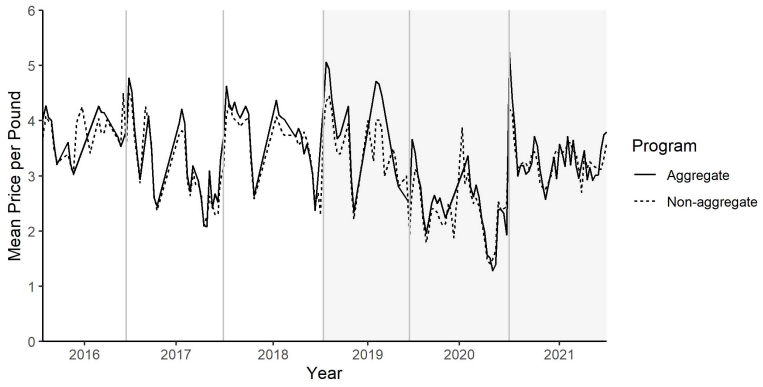

FIGURE 4
Weekly mean price per pound of black sea bass from 2016 - 2021 for participants that did and did not join the program. Pilot program years are shaded gray.

study found that catch of pilot participants for both species was already higher than the larger fleet's prior to the pilot. Consequently, the overall catch of program participants may not be representative of other fishers' potential activity under a broader aggregate program and the simulations may overestimate quota utilization. Moreover, due to limited quota availability and resulting low possession limits, the fishery is already subject to frequent sub-period closures.

While the primary objective of the aggregate landings program was to reduce regulatory discards and make businesses more efficient, it resulted in a variety of improvements to fishers' well-being. Program participants overwhelmingly noted reductions in discards, but improved safety and increased profits and flexibility in fishing approach were also described among the top program benefits. The ability to pick fishing days based on weather, less time on the water overall, and taking time to make vessel repairs, all without the loss of catch in the form of daily possession limits, improved safety by allowing fishers to avoid risks without losing money. As discussed earlier, making a decision about whether to fish given weather conditions is a common one, which puts safety at odds with the marginal value of a day of fishing (Jin and Thunberg, 2005; Pfeiffer and Gratz, 2016). Severe weather remains a contributing factor to fatal vessel accidents (Lincoln and Lucas, 2010), yet management measures may restrict fishers' decisions, escalating their physical risks (Pfeiffer and Gratz, 2016).

Consistent with Pollnac et al. (2015), who suggested that management changes could influence job characteristics like safety, the aggregate landings program enhanced job satisfaction for some participants. General well-being of harvesters was noted to improve through reductions in stress and increased flexibility in daily life, sometimes resulting in improved mental health, as found by King et al. (2021) as well. Increased time with family and more flexibility to meet business goals are examples of enhanced quality of life, which suggests that well-being, as defined by Breslow et al. (2016), is being augmented. Further, participants also experienced a renewed passion for fishing because stress was reduced, and they were more able to enjoy their time on the water. Fishing is not only an economic activity (Anderson, 1980; Smith, 1981; Bunce et al., 2000; Pollnac et al., 2006) and creation of a more flexible management measure enabled harvesters to enjoy the non-economic benefits of interacting with marine resources.

Though standard fishery dependent data reporting in the form of trip (state logbooks or federal vessel trip reports) and dealer reports (landings) can provide information on changes in the timing and frequency of fishing and the amount and value of catch, these data sources are unable to provide explanatory information on the drivers of such changes or on the socioeconomic factors; only direct industry input was able to offer supplementary evidence to capture these variables. Brinson and Thunberg (2016) note that many studies evaluating program performance of catch share programs have compared end results to those expected by economic theory instead of to the goals of such programs. Discussions with aggregate landings program participants allowed this study's focus to be tailored directly to program objectives to conduct program evaluation. Our program assessment serves as a valuable case study of the effectiveness of aggregate landings programs in improving fishers' profitability and well-being, as well as the importance of collecting direct fishery input to evaluate fisheries management programs.

Based on both qualitative and quantitative analysis of the program, there were direct benefits to program participants both economically and socially. However, some questions about the program remain. For example, future research should seek to quantify the change in discards associated with an aggregate landings program. This could include fisheries observers onboard commercial vessels to collect information on the number of black sea bass and summer flounder discarded, as well as information on size, sex, and maturity of discarded fish. Further, analysis on the variability in catch between aggregate and non-aggregate participants across program years is necessary to better understand potential drivers. This should include incorporation of year class effects for both black sea bass and fluke to determine whether differences may be attributed to the program or external influences and additional modeling incorporating market factors (e.g., COVID-19) should be conducted. Uncertainty whether the discussed program benefits would still occur if the entire fishing fleet were to land in aggregate remains a persistent question as well. Thus, further analysis including more detailed characterization of program participants versus the larger fishing fleet targeting fluke and black sea bass may be needed.

Since the aggregate landings program was implemented in Rhode Island, other states have requested information from the RIDEM

DMF about how the program performed in terms of quota management and impacts to harvesters and the State of Massachusetts has proposed to implement a summer flounder aggregate program for trawlers as of February 2023 (McKiernan, 2023). As previously noted, changes to management measures can cause restructuring of a person's job in the fishing industry, which may drive changes in psychological, economic, and social aspects of that person's well-being (Pollnac and Poggie Jr, 1988). In light of all the current challenges facing commercial harvesters (i.e., climate change, offshore development, endangered species interactions, inflation), management measures should be designed with harvesters' well-being in mind. Further, regulatory agencies often switch from one management approach to another if one fails to meet management goals (Scheld et al., 2012). The pilot aggregate was a rare effort to implement a pilot program prior to implementation of a new management approach. As such, the pilot program has provided valuable information about how fishers' may behave under an aggregate landings approach, which may offer benefits to harvesters and management and may be useful in other management areas (e.g., other states' waters, federal waters, or other countries).

Data availability statement

The datasets presented in this article are not readily available because all data collected as part of this study are subject to strict confidentiality rules. All responses must be kept confidential and are subject to the Rule of Three, as is required of all fisheries-dependent data (e.g., landings information reported in SAFIS). Requests to access the datasets should be directed to julia.livermore@dem.ri.gov.

Ethics statement

The studies involving humans were approved by University of Rhode Island Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written or verbal informed consent to participate in this study.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1223192/full#supplementary-material

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