Alaska's emergent fisheries processes

Keywords: Alaska, fisheries, climate change, species distribution shift, species switching

Abstract

Under climate change, shifts in distributions of commercialized marine species challenge livelihoods and management in some fisheries and create opportunities in others. Whether existing management processes can enable fishers to access emergent fisheries – efforts by fishers to commercialize species – is unclear. Thus far, the literature has largely focused on reactive management processes that lead to overharvest and conflicts over fisheries allocations under species distributional shifts. We examine the progress and outcomes of 144 emergent fisheries in the state waters of Alaska, illustrating the historical diversity of management mechanisms, regions, species, and gears in the state's unique system of permitting and data collection for emergent fisheries. We further examine 28 emergent fisheries' roles in fishing portfolios through a métier analysis, finding that most are small extensions to existing portfolio strategies instead of novel opportunities for specialization. Together, these findings underscore challenges in adapting current processes to future shifts in marine species distributions, reflecting the need for large scale reconsiderations of scale, tradeoffs and a more holistic approach.

Introduction

Shifts in spatial distributions of species under climate change create challenges for resource-dependent communities, scientists, and resource managers (Pecl et al., 2017). In marine ecosystems, intensifying changes in temperatures and currents complicate predictions of species distribution and abundance for fisheries management (Cooley et al., 2022). While climate change tends to drive species poleward, local and regional conditions influence distributional shifts

(Pinsky et al., 2013), for example in the ecosystems of the North Pacific (Cheung et al., 2015). Shifts in species distributions across jurisdictions spark conflict between fishing fleets over management (Vogel et al., 2023), while fishery managers face challenges to sustainable management as historical stock definitions clash with rapid change (Pinsky et al., 2018). Where shifts in species distributions occur within jurisdictions, fishers benefit from capital to fish harder and further in diverse fisheries (Kiyama and Yamazaki, 2022; Powell et al., 2022; Young et al., 2019), as well as access to novel or emergent fisheries – those that were not historically commercialized (Rogers et al., 2019). Climate change driven changes to fisheries will necessitate more nimble management processes, including the potential for exploring novel fishing opportunities. Experiences doing so in Alaska State fisheries examined in this paper provide critical insight on the need for a more robust, planned fisheries development process.

While management to support fishers' adaptation often lags behind distributional shifts (Pinsky and Fogarty, 2012), case studies of management for emergent fisheries suggest paths forward. In Japan's Maizuru Bay, access to alternative species buffered fishers' revenues against declines in their historical portfolios (Kiyama and Yamazaki, 2022). In Western Australia, a process for developing fisheries includes regular assessment and stakeholder participation (Fisheries Western Australia, 1999). In the United States, the state of California legislated an experimental permit program for the market squid fishery at the northern end of the species' shifting distribution, enabling fishers to access alternative areas and gather data for management (Powell et al., 2022). Where market squid have shifted north into Oregon's state waters, fisheries managers have begun implementing regulations on harvest timing, gear, and data collection (Powell et al., 2022). Off the eastern coast of the United States, a northward shift in the distribution of summer flounder has motivated a shift in fishing effort and federal rulemaking to

reallocate summer flounder quota and ease restrictions on locations of landings (Dubik et al., 2019). A shift of blueline tilefish off the states of North Carolina and Virginia precipitated several years of unregulated harvest until the implementation of emergency regulations by federal fisheries managers (Pinsky et al., 2018). Together, these examples indicate the potential for proactive management to support fishers' adaptation and fisheries conservation, as well as the hazard of maladaptation through unequal access and overharvest under shifting species distributions.

The Gulf of Alaska is experiencing tremendous ecological change with shifting stock distributions and fisheries availability, the emergence of new species, and increasing abundance of species previously considered below their optimal thermal limit in the Gulf, including tuna, sunfish, and market squid (Alaska Department of Fish and Game, 2023a; Free et al., 2023). A climate vulnerability assessment of species in the California Current predicted changing geographic distributions for many commercialized species due to warming waters (McClure et al., 2023). Such northward range shifts coupled with predator release or reductions in competition may present new fishing opportunities for fishers in the Gulf. With revenues declining in many fisheries, novel fishing opportunities may be increasingly important. This study explores processes for emergent fisheries managed by the state of Alaska, the performance of those processes, insights for similar processes elsewhere, and opportunities to improve those processes under climate change.

Alaska fisheries management is bifurcated into Federal and State management, with Federal jurisdiction beginning three nautical miles from the coastline and extending 200 nautical miles. The State manages fisheries within the three nautical miles of the coastline and other fisheries, including salmon, under agreements with Federal managers. Alaska State fisheries

management provides for regulating new fishing opportunities for fishers. Emergent fisheries in Alaska under State jurisdiction undergo an iterative process with two pathways. Fishers can receive an exploratory permit for emergent fisheries known as a commissioner's permit (CP) from area management biologists in the Alaska Department of Fish and Game (ADF&G). Fishers can also advance proposals for emergent fisheries through the State fisheries management body, the Board of Fisheries (BOF). The BOF considers proposals for changes to regulations specific to region and species groups, e.g., Kodiak finfish, in meetings on a three-year cycle. Calls for proposals include all stakeholders: individuals, tribes, local governments, regional aquaculture associations, fishing industry groups, and nonprofit organizations. However, previous research has identified barriers to participation in the proposal process and unequal outcomes of proposals across stakeholder groups (Gordon et al., 2022; Krupa et al., 2020, 2018). Other research has shown that the proposal process involves complex conflicts over allocation between stakeholder groups (Harrison, 2021; Szymkowiak and Steinkruger, 2023).

Despite global evidence of shifting fisheries resources in response to climate-driven changes, fisheries management processes remain largely reactive. Reactive management can result in excessive constraints or permissions, exacerbating allocation battles, lost income, or overfishing (Pinsky et al. 2018; Dubik et al. 2019). Through examining the emergent fisheries process in Alaska, this study provides critical insight on how fisheries management may respond to emerging fisheries, crux points in management processes, and opportunities to facilitate responsive management. Lessons from Alaska on efficiencies, successes, and failures apply to other contexts where fishing opportunities could emerge with climate change. These processes have existed in Alaska's fisheries for decades, providing opportunities for fishers to explore fisheries and for scientists to understand insights for new fisheries elsewhere.

We examine Alaska's emergent fisheries processes to understand opportunities across regions, gears, and species. We also compare these opportunities to existing fisheries and analyze impediments to future emergent fisheries. We focus on State fisheries, where fishers have participated for decades in processes to explore new fisheries, to establish a sufficient time series for analysis and develop a complete description of existing processes. We focus on commercial fisheries in the Gulf of Alaska, excluding sport, subsistence, and personal use fisheries, as well as fisheries on the Bering Sea, to reflect divisions in management processes.

Data and Methods

Identifying new fisheries processes and data

Expert semi-structured interviews with ADF&G area management biologists informed our understanding of emergent fisheries in State waters. Our interviewees manage fisheries across the Gulf of Alaska, from Southeast Alaska to the Western Gulf, including all groundfish and shellfish fisheries. While most new fisheries prosecute groundfish and shellfish, area management biologists also issue permits for pelagics (e.g. squid) and aquatic plants. The intent of these interviews was to develop a detailed understanding of processes for new fisheries. Our interviewees provided lists of commissioner's permits (CPs) issued within their regions and identified which had transitioned to permanent management plans. Based on the list of CPs provided, interviewees were asked to describe their experiences with issuing CPs including processes, triggers, exclusions, limitations, and other nuances. Because the CP process is not otherwise described anywhere that the researchers could locate, the interviewees were invaluable to the researchers' understanding of the process. This included follow up emails to understand details about issuing CPs (their timeframe; their specificity in terms of individuals, gears, and species; their intersection with BOF processes; and the process of their transition to formal

fisheries). Interview notes informed a detailed description and flowchart of these processes, which our interviewees reviewed.

Our CP data reflect the tenure of interviewed area management biologists, resulting in different data extents across regions. CPs are not tracked in historical databases except in the Southeast and Yakutat region; 2022 is the final year of all CP time series. The first years of CP time series are 1982 for Southeast and Yakutat, 2004 for Alaska Peninsula and Aleutian Islands, 2006 for Cook Inlet, 2012 for Kodiak, and 2013 for Prince William Sound.

A CP is specific to an area, species, and gear, and is issued to an individual, although multiple individuals can be issued CPs for the same combination of area, species, and gear. CPs can be contingent on bycatch, seasonality, and harvest quantity. CPs include a mandatory logbook for tracking effort and harvest. CPs are annual or seasonal in duration, and renewal is subject to the fishers meeting the stipulations of the permit, as well as any changes in the overall considerations for the permit (i.e., regulations, feasibility, etc.). CP data provided by area management biologists included these variables of interest. The region variable in our analysis reflects ADF&G conventions, although some CPs cover much smaller areas within these regions. If multiple gears or species are included under a CP, we counted each gear and species as a distinct emergent fisheries attempt. In some cases, we aggregated similar CP fisheries. For instance, we aggregated seaweed species targeted with the same gear in the same region.

The ultimate outcomes of CP fisheries can be classified as: halted, due to, for example, lack of a market or lack of sufficient harvest; ongoing, as fishers explore a fishery; and transitioned, when a fishery transitions to formal management. Our CP data demarcate these outcomes for CP fisheries that area biologists identified as having transitioned to management plans and for CP fisheries with permits issued in 2022 (ongoing) or not (halted).

Available Board of Fisheries meeting materials include proposals, outcomes, and any associated written reports or oral presentations (Alaska Department of Fish and Game, 2023b). Each BOF meeting's materials include, for each proposal, a descriptive title and the BOF vote on the proposal. This information enabled identification of potential "new" fishery proposals, which were evaluated on the full language of each proposal for area, species, and gear in the research software MAXQDA. BOF meeting information is available from 2003 to 2022. We reduced meeting information to proposals involving Gulf of Alaska fisheries.

Proposals to the BOF generally involve fishery seasons, areas, species, gears, and allocations between stakeholder groups. We identified "new fishery" proposals through an iterative coding process. We first identified proposals that would provide novel fishing opportunities, then coded those proposals by opportunity type (new area, resource or species, gear, or reallocation of harvest). Each author reviewed all proposals to ensure reliable identification of fisheries and types of opportunities.

There are often multiple, similar proposals under consideration in a single BOF meeting. In such instances, the BOF will only vote on one proposal and assign similar proposals to a "no action" vote. In these cases, we only coded the first of multiple proposals. However, proposals recurring over time were included in our analysis once for each year to capture outcomes of different BOF votes. Regions for proposals reflect regions applied in BOF procedures and in CP management. Some proposals straddle multiple regions; these were counted once for each of those areas. Proposals designating multiple gears were, like CP fisheries, counted once for each gear. Proposals withdrawn by submitters were omitted from the analysis to avoid conflating the intent of proposals withdrawn for procedural or practical reasons, which are not clarified in any of

the publicly available documentation, with that of proposals that advanced through BOF processes.

The ultimate outcomes of BOF proposals are classified in our analysis as: carried, representing proposals that were approved; tabled, representing proposals that were delayed to different processes or later meetings; and failed, representing proposals that were rejected. The "carried" outcome reflects the forthcoming implementation of the proposal by ADF&G, and is equivalent to the "transitioned to management" outcome of CP fisheries. Our BOF data demarcates these outcomes on the vote for each proposal. To avoid double-counting, we omitted one instance of a BOF "carried" vote pertaining to a CP.

For the first four years in our dataset, 2003-2006, meeting notes summarize the BOF's discourse on the proposal and the vote. These paragraphs were coded in-vivo to identify the major reasons for BOF votes. For proposals with multiple reasons or justifications for vote outcomes, each justification is coded for each proposal. Since justifications are unavailable for the full dataset, they are not analyzed in-depth. Instead, justifications are used to understand how the BOF process may be improved to provide emergent fisheries opportunities into the future.

Given that the interactions of CP and BOF processes drive fishing opportunities, the data from these processes was combined for this analysis. Because CP data are limited by the tenure of local area management biologists and BOF data reflect the meeting cycle of the Board, neither dataset lends itself to time series analysis. In addition, comparisons between regions are limited by differentiated efforts across the regions to gather CP information and differing tenures of area management biologists. Instead, we use the combined data to understand the use of these processes to explore novel fishing opportunities within regions.

Examining regional and species dimensions of emergent fisheries

To facilitate analysis, we standardized variables across BOF proposals and CP fisheries. First, we aggregated species into species groups reflecting standard scientific and management aggregations (Table 1) (McClure et al., 2023; North Pacific Fishery Management Council, 2020). We also simplified gears, in most cases standardizing similar strings; otherwise, we subsume dredge into trawl, habitat pot into pot, dipnet gear into "Other," variants of dive and hand gear into those gears, longline into hook and line, and dinglebar into troll. Where proposals and fisheries include multiple regions, we split regions or combine regions into "Statewide." The resulting CP and BOF data illustrate distributions of emergent fisheries across regions, species, gears, and time.

Table 1. Species group aggregations employed in analysis. Coral is included under the mollusk group because it is designated as a miscellaneous shellfish in ADF&G CPs.

Species group	Species included in species groups
Coastal pelagic	Squid, armhook squid, market squid, smelt, herring, sardine
Crab	Dungeness crab, Grooved Tanner crab, Deepwater Tanner crab, King crab, Golden King crab
Elasmobranch	Spiny dogfish, skates, sharks
Groundfish	Atka mackerel, Pacific cod, pollock, rockfish, sablefish, groundfish, flatfish, flounder and sole, Pacific hagfish
Mollusk	Octopus, scallop, sea cucumber, shrimp, sea urchin, gumboots, clams, horse clams, coral, Geoducks, gooseneck barnacles, sea snails, little neck clams, star fish
Salmonid	Salmon, dolly varden
Aquatic plants	Seaweed, kelp, algae

We explore these distributions through visualizations implemented in R and RStudio with packages tidyverse (Wickham et al., 2019), janitor (Firke, 2023), ggpubr (Kassambara, 2023), patchwork (Pedersen, 2023), and packages referenced throughout this section. We first illustrate the extent of regions and counts of emergent fisheries by region with packages sf (Pebesma, 2018) and rnaturalearth (Massicotte and South, 2023) and spatial data provided by ADF&G (Alaska Department of Fish and Game, 2023c). We next represent distributions of emergent fisheries over regions, species groups, and gears in barplots, highlighting differences across regions in specialization into species groups and gears. We also track outcomes of emergent fisheries over species groups, gears, and management processes through Sankey diagrams created with package ggsankey (Joberg, 2023). Sankey diagrams underscore the hurdles facing emergent fisheries, representing failures, successes, and ongoing experiments over species groups and gears.

Examining the "success" of emergent fisheries

Examining process outcomes above only illuminates failures and successes of fisheries through policy and management. In fact, only the "transitioned" outcome points to success. The other types of successes, carried and ongoing, represent the initialization or continuation of experimental fisheries. Yet none of these outcomes represent the extent to which these fisheries provide opportunities, nor to whom or how much.

To examine these dimensions, we used a métier analysis to define distinct fisheries using landings data (Alaska Fisheries Information Network and Pacific States Marine Fisheries Commission, 2022). A métier analysis identifies clusters of species that are jointly targeted, and is particularly useful when vessels target many species individually or groups of species simultaneously (Deporte et al., 2012). The clusters identified by the métier analysis represent all

fisheries available to fishers. To conduct the métier analysis, we defined fishing trips on unique combinations of vessel, landing date, port of landing, gear, state fishery permit code, and management subarea. Trips were partitioned to disjoint sets on state fishery permit codes and management subareas. Trips in each partition were then clustered on proportions of trip revenue generated by each species using a Partition Around Medioids (PAM) algorithm. Because of the large number of trips for some partitions, we used the Clustering Large Applications (CLARA) variant of PAM in the 'cluster' package in R (Maechler et al., 2022). We first evaluated clusters using mean silhouette width, which measures the distinctness and cohesion of the clusters. We assessed the stability of the cluster using 100 bootstrap draws and tested the similarity of the clustering results compared to the initial clustering. If less than 70% of the composition of each cluster was in agreement across the bootstrap draws, the number of clusters was reduced by one and the bootstrap re-run until stability reached 70% (Parsa et al., 2020).

We evaluate new fisheries using the métier analysis in several ways. First, we identify the extent to which new fisheries represent distinct métiers. Each landing that comprises the métiers is tested to see whether it belongs to an emergent fishery. The geographic location, gear type, species, and years for each landing is compared against the definition of each emergent fishery that became active under either of the two pathways we outlined in the introductory section, and assigned to the appropriate emerging fishery, if applicable. If no match is found, it is assumed the landing is not part of an emergent fishery. If an emerging fishery represents a new fishing opportunity rather than a marginal extension of an existing fishery, trips and revenue in the new fishery should be associated with a unique cluster.

Second, we compare revenue in new fisheries to revenue in existing fisheries. We make this comparison in terms of overall and relative economic value for participant vessels. We

represent overall economic value as the mean total annual ex-vessel revenue in the fishery across all years when the fishery was active. Relative economic value is measured as the mean proportion of ex-vessel revenue the fishery contributes to each participating vessel's annual fishing portfolio. For these calculations, we include only those vessels with at least $10,000 of inflation-adjusted annual revenue in a given year to avoid including vessels that are not primarily involved in commercial fishing, and only those fisheries with at least three participating vessels in accordance with confidentiality rules.

Results

Alaska State emergent fisheries process description

The determination of which emergent fisheries process to pursue is based on a number of factors, including existing regulations, species, area, previous efforts at developing that fishery, and the Board meeting cycle. Alaska State regulations mandate CPs for some species (skates; rays; lingcod; octopi; squid; hair crab; sea urchins; sea cucumbers; sea snails; herring spawn, bait, and food fisheries), and prohibit CPs in other instances, for example for established fisheries, including king, Tanner, and Dungeness crab. There is also interplay between the two processes, with the BOF sometimes authorizing the issuance of CPs and the transition of a CP fishery into a formal fishery or vice versa.

Some successful fisheries have operated under CPs for years because there is no guidance triggering the transition to a formalized fishery. This transition necessitates Board approval, which occurs in response to a proposal (from ADF&G or stakeholders). Formalizing a fishery allows for a more open, public process in debating fisheries regulations, although it requires proposals to pass through lags in the BOF process. To receive approval from the BOF, the fishery

must also meet criteria including enforceability, sustainability, and authority (of the Board to regulate the fishery).

The alternative to the CP process is a proposal to the BOF. This process is used when a fishery is ineligible for a CP, when ADF&G is resistant to issuing a CP (or applicants perceive resistance), or when applicants hope to bypass the CP process. The Board then considers the proposals under the same criteria as a proposal to transition a CP (enforceability, sustainability, and authority), and ADF&G comments on biological considerations of the fishery. The Board may approve a formal fishery or the issuance of a CP for a fishery; the latter still requires review and approval by ADF&G. Identical proposals have been submitted to the Board from year to year.

Emergent fisheries across regions and species

Figure 1 shows emergent fisheries attempts across regions of the Gulf of Alaska, with regions demarcated in Panel A and numbers of emergent fisheries attempts by region in Panel B. Emergent fisheries attempts occur in all regions, with some proposals to the BOF having a Statewide designation. The greater number of emergent fisheries attempts in Southeast and Yakutat is associated with that region's relatively greater proportion of CP fisheries, which could result from the region's relatively longer time series, greater spatial extent, and greater density of fishing communities. The prevalence of CP fisheries in Southeast and Yakutat also reflects area management biologists' systematic efforts to gather comprehensive information about CP fisheries, and is not necessarily associated with differences in the propensity of biologists to issue CPs, which cannot be ascertained from available data. 144 emergent fisheries attempts have been identified across the processes and regions; this total is consistent through subsequent analyses.

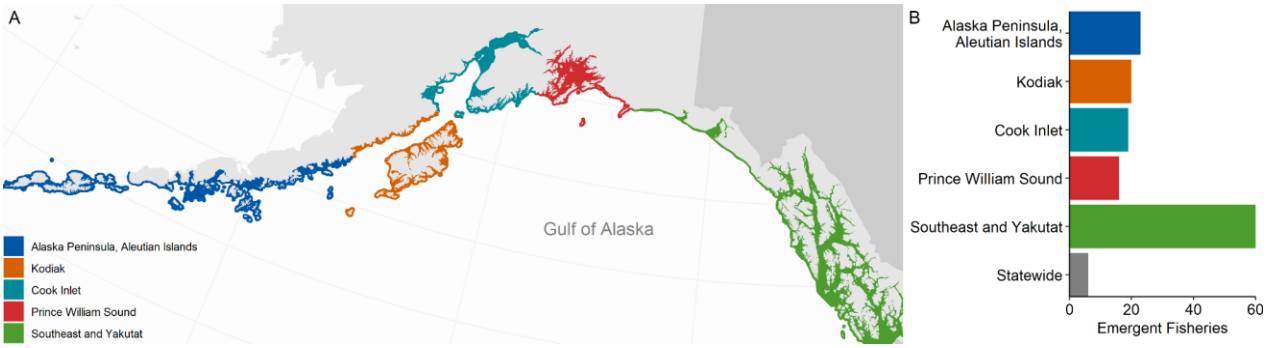


Figure 1. Emergent fisheries attempts across fisheries management regions. Panel A demarcates regions; Panel B counts emergent fisheries attempts by region.

Figure 2 demonstrates the distribution of species (A) and gears (B) for emergent fisheries attempts by fisheries management region. The "Aggregate" column in Figure 2 reflects emergent fisheries attempts summed across regions, plus "Statewide" BOF proposals. Regional barplots in Figure 2 demonstrate the diversity of emergent fisheries attempts in terms of species and gears. Although there is no completely dominant species or group, groundfish are prominent across regions and in aggregate. Mollusks are less prominent, reflecting emergent fisheries attempts in Southeast and Yakutat as well as Kodiak. The breakdown of gears in panel B relates to species in panel A; trawl and pot gear are prominent gears used to target groundfish and mollusks, while jig, hook-and-line, and seine gear target these species to a lesser extent. In regional barplots, strong relationships between species and gears are more pronounced, reflecting gears present in those regions and the species that are available to those gears. For example, Cook Inlet is dominated by salmon fisheries employing gillnet and seine gear. Fishers in the region have attempted to extend salmon fisheries to new combinations of areas and species, as well as exploring fisheries for groundfish, elasmobranchs, and mollusks with gillnet, seine, and other gear.

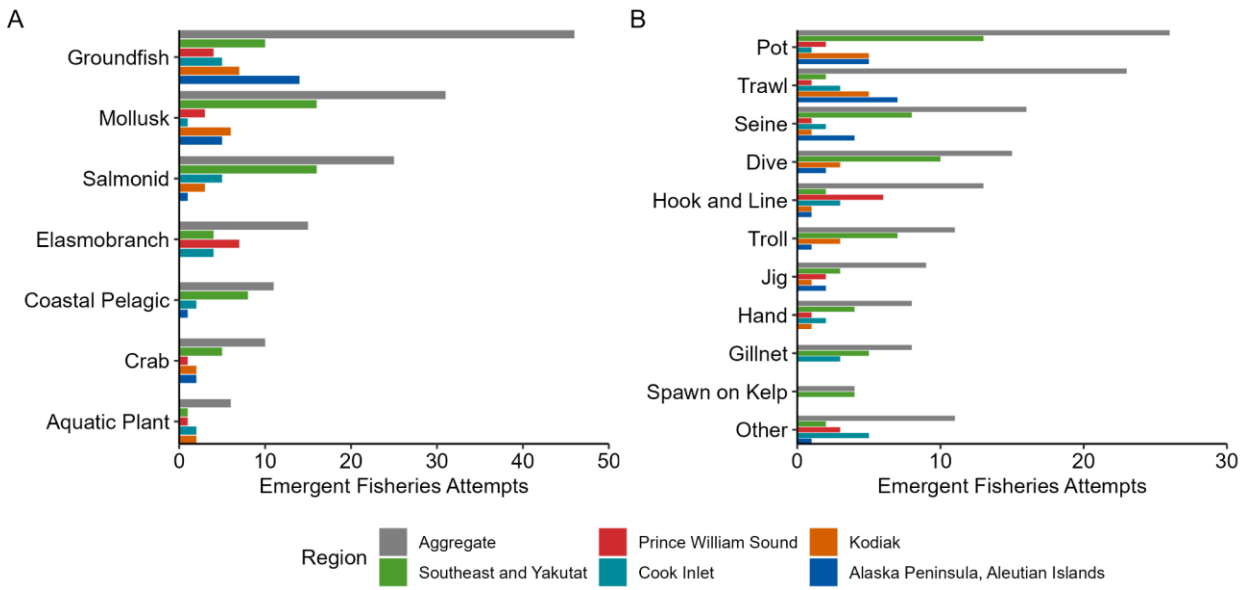


Figure 2. Counts of emergent fisheries attempts by species (A) and gears (B) across regions. All counts and percentages for species and gears are detailed in Tables A1-2.

Figure 3 represents the outcomes of both emergent fisheries processes. “Carried,” “Tabled,” and “Failed” are BOF process outcomes, while “Transitioned,” “Ongoing,” and “Halted” are CP fishery outcomes. Emergent fisheries attempts are shown by outcomes for species groups (A) and gear groups (B). Half of all attempts do not succeed, with 34 fisheries (24%) in the BOF process resulting in a “failed” outcome and 39 CP fisheries (27%) eventually discontinued (“halted”). Another 21 (15%) of fisheries in BOF processes stalled out with a “tabled” vote. Other fisheries were relatively successful in emergent fisheries processes as ongoing CP fisheries (“ongoing,” 9%) and as efforts through the BOF to provide opportunities for novel fisheries (“carried,” 23%). However, the clearest indicator of success through these processes are those CP fisheries that transitioned to a formal fishery, amounting to 4 (3%) fisheries represented in Figure 3.

The Sankey diagram in Figure 3 demonstrates mixed outcomes for all species groups within BOF and CP processes. The most successful within BOF processes are salmonid and crab fisheries, with 4 (40%) of crab fisheries and 13 (52%) of salmonid fisheries resulting in “carried” outcomes. Opportunities created by hatchery production could be a driver of success forBOF proposals for salmonid fisheries. Coastal pelagic and aquatic plant fisheries are evenly distributed across outcomes for both processes. Other species groups have high rates of overall failure. Elasmobranchs largely result in failed and tabled outcomes within the BOF. Mollusks are also relatively unsuccessful, largely resulting in halted outcomes. Groundfish also seem to have largely unsuccessful outcomes with 34 (74%) proposals and fisheries resulting in tabled, failed, or halted outcomes. Whereas many species groups represent novel species and resources (sea cucumbers, snails, kelp), emergent fisheries attempts for groundfish species are largely for new gears targeting existing fisheries or for reallocations between Federal and State fisheries.

Outcomes for gears and species groups in Figure 3 Panel B align, although because gears can target multiple resources, there are often multiple outcomes within gears. For example, pots can target groundfish, mollusks, or crab, aligning outcomes for this gear with outcomes for these resources. Similarly, jig gear can target groundfish and mollusks; therefore outcomes for this gear align with outcomes for these species groups. Attempts at mollusk fisheries with dive gear were overwhelmingly halted. In contrast, carried outcomes for seine, gillnet, and troll gear reflect outcomes for salmon fishery attempts. Attempts with hand picking gear targeted aquatic plants resulting in relative success with that gear type. Trawl and dredge gear is used in groundfish and some mollusk fishery attempts, resulting in tabled, failed, and halted outcomes. Hook and line gear attempts largely target elasmobranchs, also resulting in tabled, failed, and halted outcomes.

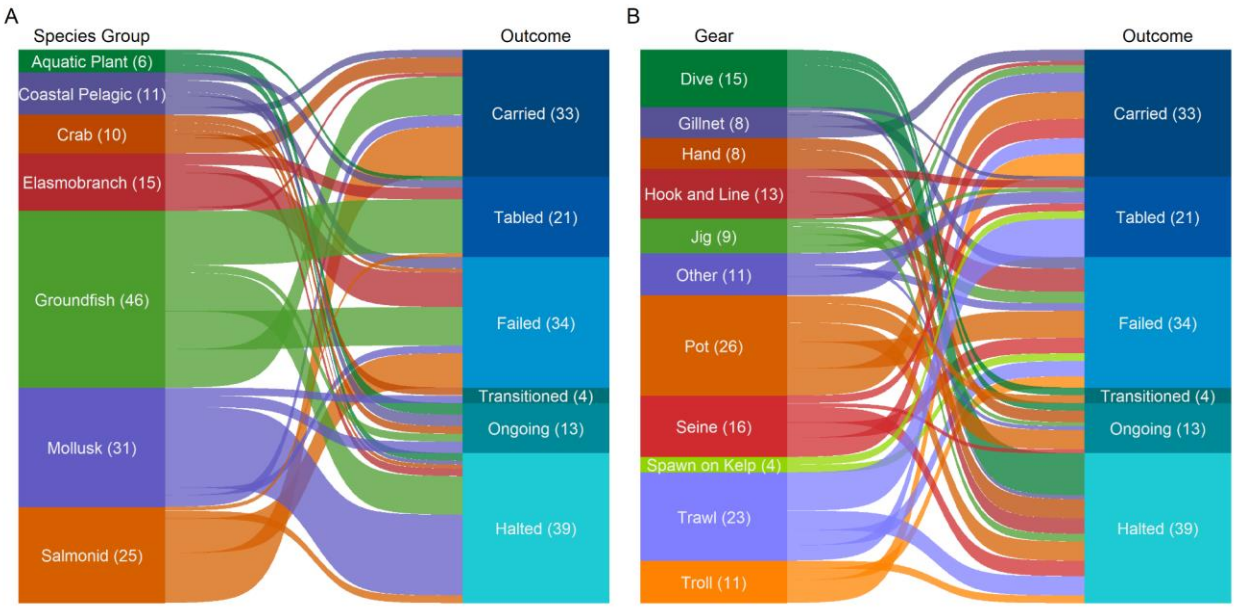


Figure 3. Outcomes of emergent fisheries attempts by species group (A) and gear (B). Counts and percentages for species groups, gears, and corresponding outcomes are detailed in Tables A3-4.

Justifications for BOF votes for the first four years of our dataset illuminate BOF choices on emergent fisheries proposals. Table 2 counts BOF votes and justifications in terms of numbers of emergent fisheries proposals. Emergent fisheries proposals tend to be carried if they provide an economic opportunity. Emergent fisheries proposals tend to fail due to conservation concerns or ongoing consideration of related proposals. Justifications for failed votes that cite fully allocated resources overlap with other ongoing processes. In one instance, a lack of processing capacity is cited in a failed vote. The ongoing process justification also appears in tabled votes, with the BOF deferring to ongoing processes.

Table 2. Votes and justifications on emergent fisheries proposals to the BOF.

Vote	Justification	Number of proposals
Carried	Economic opportunity	7
Failed	Conservation concern	5

	Fully allocated resource	3
	Lack of processing capacity	1
	Ongoing committee or process	5
Tabled	Ongoing committee or process	11
	Fully allocated resource	1

Emergent fisheries as part of fishing portfolios

Of successful fisheries attempts, only 28 (56%) are identifiable in fisheries landings data, reflecting the frequent failure of these efforts to realize new fishing opportunities. Of emergent fisheries with identifiable landings data, we evaluated whether landings for each emergent fishery were clustered as a distinct fishery by the métier analysis. The results of this analysis are presented in Figure 4.

We find that four emergent fisheries are identified as wholly distinct fisheries. For each of these four fisheries, landings associated with the emergent fishery comprise all or nearly all of the revenue from a unique métier, which suggests that the emergent fishery is distinct from existing fisheries. Two additional emergent fisheries each comprised more than 50% of the revenue of a unique métier. These six fisheries are the only emergent fisheries that make up majorities of métiers and comprise just 12% of the total number of emergent fisheries that succeeded through CPs or BOF proposals. While each of the six emerging fishing opportunities are remarkable in our dataset for comprising the majority of a distinct fishery as defined by our métier analysis, there is not sufficient data to draw generalizable inferences as to fishery characteristics - in terms of management process, region, species or gear - that allow for an emerging fishery to attain relative commercial success.

The remaining 22 emergent fisheries with non-zero landings revenue comprise at most 13% of their métiers' revenues. 17 emergent fisheries make up less than 1% of their métiers' revenue. This suggests that most emergent fisheries that succeed through CPs or BOF proposals are marginal fishing opportunities, fished only as extensions of existing fisheries. In the case of a BOF proposal allowing landings of shark bycatch in the Kodiak longline fishery, for example, the vast majority of revenue was in Pacific cod and sablefish, while shark landings accounted for just 0.01% of the métier's revenue. In these cases where the emerging fishery makes up such a minor part of the métier, it is likely that the emerging fishery rules are newly allowing bycatch that was already occurring in the fishery to be landed and sold.

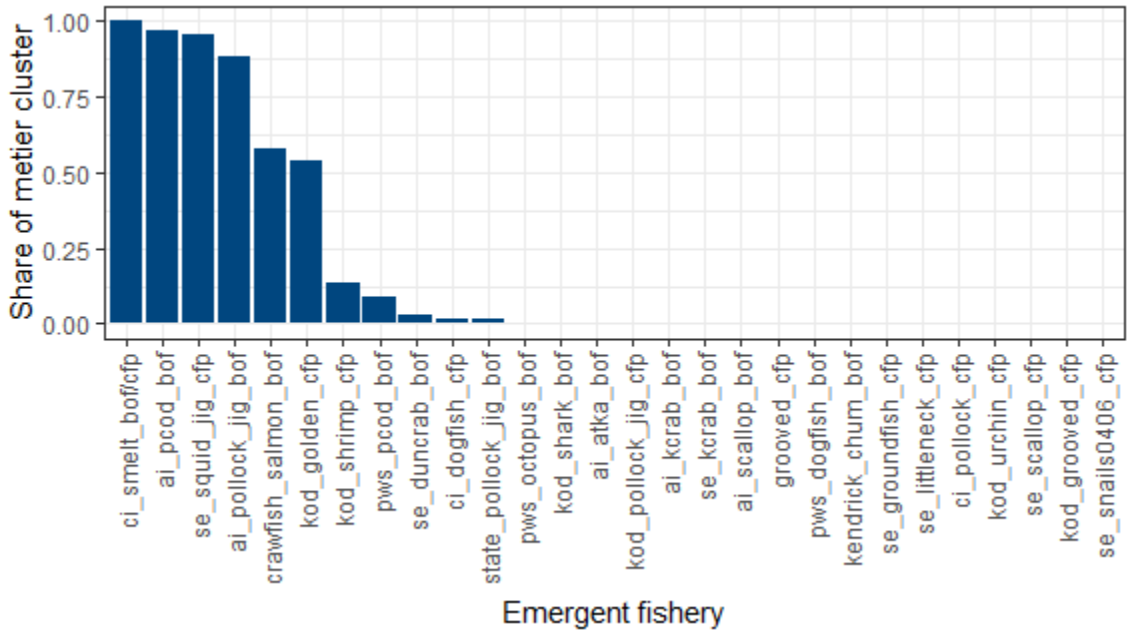


Figure 4. Emergent fisheries' share of revenue within their métiers. Fishery naming convention is [area_species_gear_permit type].

Figure 5 compares the total and relative economic value of emergent fisheries and existing fisheries. For this figure and successive figures in this section, each emergent fishery is

considered its own fishery and is compared to fisheries identified by the métier analysis. Due to confidentiality rules, 13 of the 28 emergent fisheries with landings data are not present in Figures 5 and 6 as they are fished by fewer than three vessels, though patterns summarized here would not be altered by these fisheries. Increasing along the x-axis of Figure 5 represents a larger overall economic role for a fishery. The Bristol Bay driftnet salmon fishery and Bering Sea snow crab fishery are examples of older, non-emergent fisheries identified in the métier analysis that are among the highest in economic value and are included for the purposes of comparison. Several emergent fisheries are among the fisheries with relatively high economic value. These include several new fisheries based on BOF proposals, including Aleutian Islands Pacific cod, Southeast Dungeness crab, and Cook Inlet smelt, though the latter was initially permitted under a CP. However, as a group, emergent fisheries have lower economic value than existing fisheries, which is demonstrated further by the percentile rank of the fisheries in terms of mean annual revenue, shown in Figure 6a. Most emergent fisheries fall in the lowest quartile of fisheries by this metric. In total, identifiable emergent fisheries make up less than 0.5% of the total ex-vessel revenue of Alaska fisheries for the years 2012-2021.

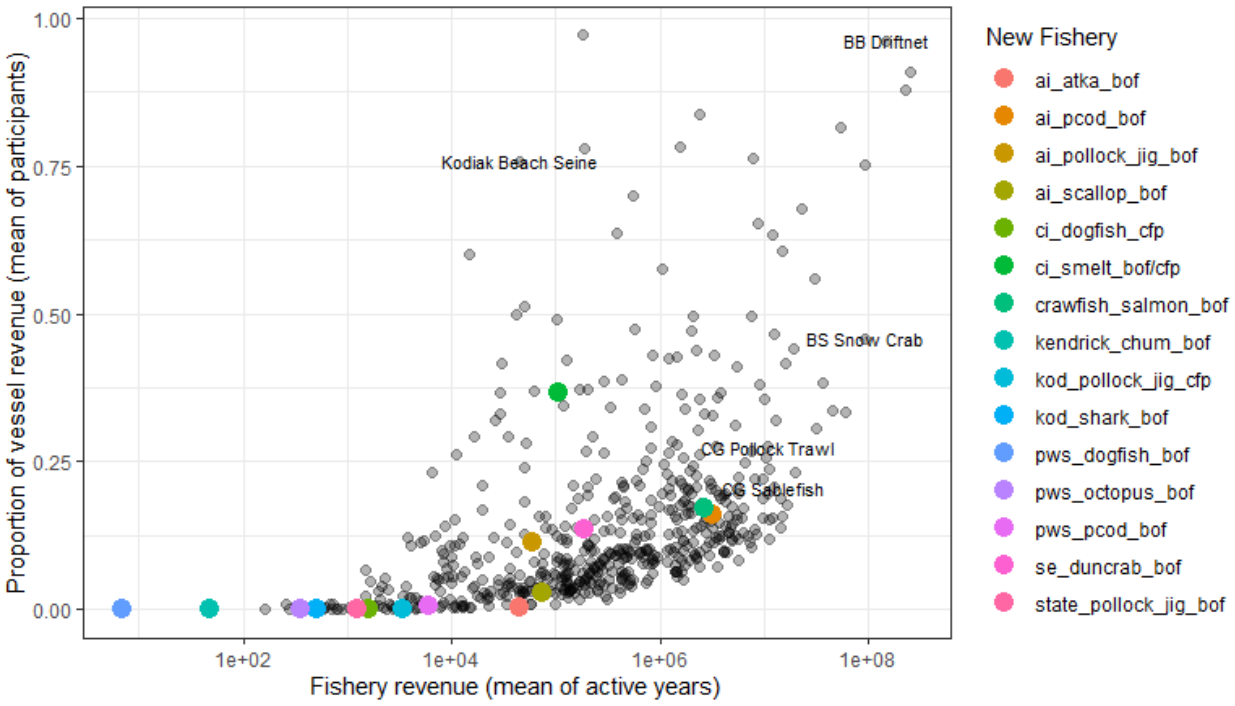
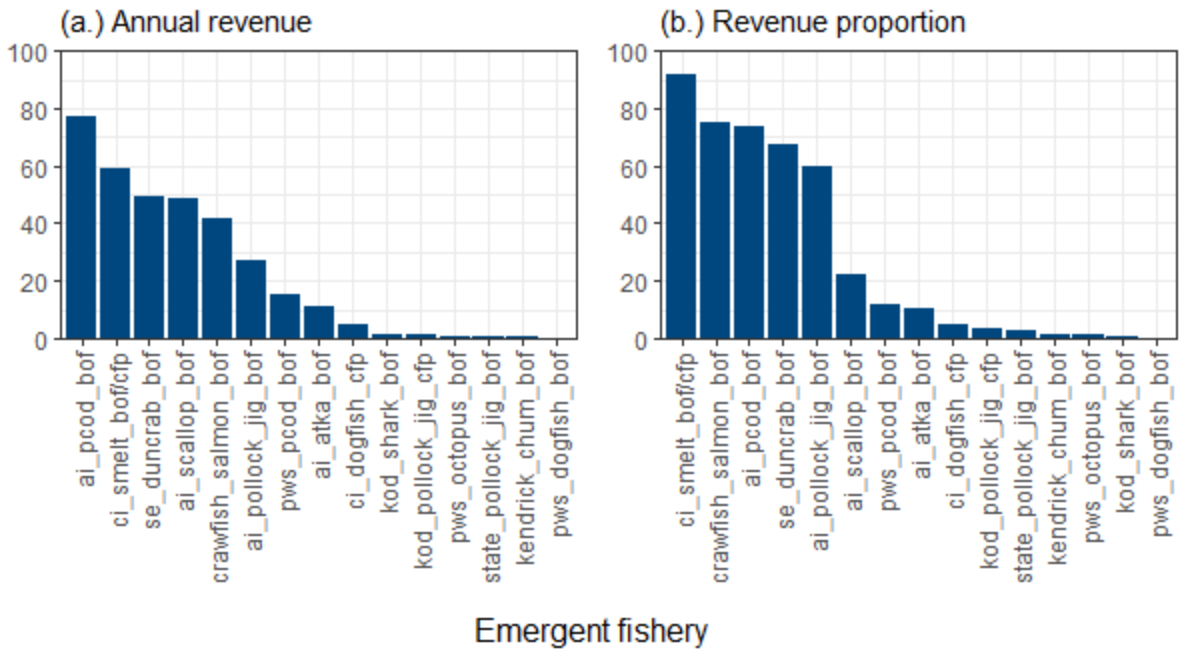


Figure 5. Fisheries by mean annual revenue (x-axis) and mean proportion of revenue among participating vessels (y-axis). Limited to vessels with at least $10,000 in annual revenue and fisheries with at least three participating vessels. Fisheries shown in larger, solid points with color are identifiable emergent fisheries; others are not. Fisheries identified with labels are not emergent, but illustrate extremes of the distribution (Bristol Bay driftnet, Kodiak beach seine, Bering Sea snow crab) or fisheries comparable to the most successful emergent fisheries (Central Gulf pollock trawl, Central Gulf sablefish).



406

407 **Figure 6.** Panel a. Fisheries by percentile of annual revenue compared to all other fisheries. Panel
408 b. Fisheries by percentile of mean proportion of revenue among participating vessels compared to
409 all other fisheries. Limited to vessels with at least $10,000 in annual revenue and fisheries with at
410 least three participating vessels.

411 A similar pattern is evident when focusing on relative value rather than absolute value.
412 Emergent fisheries score higher on this measure as they make up a larger proportion of vessel
413 revenue. Figure 5 shows that total and relative economic value are highly correlated. Kodiak
414 beach seiners represent an established fishery of modest overall value and large relative value,
415 suggesting a niche fishery with high value to relatively few fishers who do not fish other fisheries.
416 Among emerging fisheries, the Cook Inlet smelt fishery again stands out as important to fishery
417 participants, as does the Crawfish Inlet terminal harvest area salmon fishery, Aleutian Islands
418 Pacific cod and jig pollock, and Southeast Dungeness crab. As with total economic value,
419 emergent fisheries in general have low relative value, as illustrated by Figure 6b, which again
420 shows most emergent fisheries fall in the lowest quartile.

Discussion

In Alaska, fishers have explored diverse opportunities in State waters across regions, species, and gears through exploratory permits and management processes. Across these many trials, only a little over a third of the attempts have resulted in successful process outcomes. Yet success in processes does not equate to commercial success, which may be particularly true in BOF processes where there may not be trial periods for emergent fisheries. The disconnect between process and fishery outcomes is evident in harvest data: less than a fifth of emergent fisheries attempts are associated with harvests. Those harvests are largely nominal in terms of total and relative value. In essence, Alaska State fisheries exploratory processes have enabled experiments in fisheries that can provide additional, marginal revenues. Nevertheless, these fisheries can provide meaningful opportunities to employ crew through off-season periods and smooth revenues, and potential climate-driven range shifts stand to increase the importance of that role for emergent fisheries.

Emergent fisheries in Alaska are arguably attempts at new fisheries in a fully exploited fisheries system. This is demonstrated in concerns over conservation resource allocations in justifications for BOF votes to fail proposals. To some extent, fisheries attempted through these processes manifest "fishing down the food web" – a combination of declining finfish harvests (especially salmon) and higher prices for invertebrates (Pauly et al., 1998; Perry et al., 1999). Furthermore, attempts at novel fisheries in groundfish are largely redistributive in nature, while trials in the elasmobranch species group represent attempts to create value in otherwise largely economically marginal species in the region. However, the role of climate change in northward range shifts and potential predator release could shift this paradigm for important commercial species, e.g. market squid (Free et al. 2023). The extension of existing processes for fisheries

444 exploration to new, large-scale fishing opportunities will necessitate taking stock of those
445 processes' performance and opportunities for improvements.
446 The processes exhibit regulatory inefficiencies in terms of inefficient mechanisms to
447 achieve regulatory objectives (new fishing opportunities) and excessive dependence on rules
448 (Spence and Gopalakrishnan, 2000). Both CP and BOF processes necessitate that fishers know
449 combinations of area, species, and gears for their fisheries, which constrains exploration.
450 Fisheries may function under CPs for decades without a trigger to transition to regular
451 management. Proposals to the BOF for emergent fisheries are constrained to the Board's three-
452 year meeting cycle, resulting in lagged responses to ecosystem conditions and delays in
453 opportunities for harvest and data collection. This lag is exacerbated by the BOF deferring to
454 ongoing processes or jurisdictional issues in tabled or failed votes on proposals, which are also on
455 a multi-annual meeting cycle. Proposals for the same emergent fisheries are brought before the
456 BOF and fail in multiple years, triggering public debate and BOF review for fisheries with no
457 realistic path forward.
458 Nevertheless, these shortcomings in emergent fisheries processes have positive tradeoffs.
459 The combination of BOF and CP processes can balance both. CP processes allow ADF&G to
460 work with fishers to explore new fishing opportunities and iterate on areas, species, and gears,
461 avoiding the lagged BOF meeting cycle and providing for flexibility. BOF proposals allow the
462 BOF to mediate between fishers and ADF&G biologists. Furthermore, the BOF can allow
463 fisheries that are otherwise prohibited through regulations, unlike CPs. The transition from CPs to
464 a formal fishery is also important, as it allows a public process to address issues and inform
465 regulatory revisions. Cooperation between biologists and fishers along with the logbook
466 component of CPs, allows this process to explicitly consider sustainability outcomes. In part, this

addresses concerns that fisheries may be overexploited in their early years (Perry et al., 1999). However, ADF&G area biologists manage large geographic areas with diverse ecosystems and fisheries, which could result in imprecise estimates of sustainability outcomes. Conservative estimates could result in lost opportunities for fishers (Smith, 1993). Although the BOF process does not include a similar trial period to assess sustainability, ADF&G biologists provide written and verbal reports in response to proposals to the BOF.

The extension of existing emergent fisheries processes in Alaska to new opportunities resulting from climate change will necessitate new considerations of scale, tradeoffs, and a more holistic approach. In the face of ecosystem changes, fully availing fisheries stakeholders of emergent opportunities could require the State to move from the current, piecemeal approach to new fisheries development and the development of a targeted emergent fisheries policy, regulatory body, and dedicated staff. Indeed, there has been some recognition of this in the past. In the early 2000s, the BOF reviewed proposals to establish a developing fisheries policy and a dedicated body for emergent fisheries development (Alaska Board of Fisheries, 2005, 2003). The former was introduced by ADF&G and withdrawn for more stakeholder input; the latter was proposed by an individual and opposed because the BOF did not want to transfer its management responsibilities. In the 2021-2022 session of the Alaska State Legislature, a bill was put forward for the development of regional fishery development associations, in order to identify and promote new commercial fisheries (*An Act relating to regional fishery development associations; and relating to developing fishery management assessments*, 2023). A dedicated body for emergent fisheries could address scalability and knowledge transfer, both of which are critical under climate-driven changes to fisheries. A more formalized process for emergent fisheries

development could ensure equitable and objective assessments of requests for CPs as well as a uniform approach to transitioning CP fisheries to regular management.

New fisheries development in Alaska will have to balance sustainability with opportunity, considerations that are already evident in BOF decisions. In 2018, the BOF rejected a new market squid fishery in Southeast Alaska that was proposed by fishers in the region after a substantial increase in the resource following the marine heatwave of 2014-2016. The BOF cited conservation concerns over king salmon bycatch in its rejection decision. Changes in resources under climate change will make considerations of tradeoffs between climate winners and losers more prominent into the future, as declines in historical fisheries complicate choices about new fisheries (Cheung et al. 2010, Lam et al. 2016). This may necessitate consideration of compensation for fishers left at the trailing edge of a stock that they previously harvested or reconsideration of management boundaries that constrain where those fishers can harvest (Dubik et al. 2019). The development of large-scale emergent fisheries may also necessitate reconstituting programs that were in place during the first development of American fisheries capacity. Investment in transitioning fishing, processing, and infrastructure capacity to novel species with climate change (as well as industries like mariculture) may be considered akin to American investments in domestic fishing capacity in the 1970s and 80s (National Research Council, 2014). At that time, both Federal and State governments targeted fisheries development programs to provide funding, oversight, and administration of new fisheries (Alaska Department of Fish and Game, 1981). Although at least one grant program addresses this gap (National Marine Fisheries Service, 2023), none provide the comprehensive structure for development and monitoring that was afforded by historical Federal and State programs.

Although our study provides critical insights into emergent fisheries processes, several caveats are noteworthy. Our dataset is largely constrained to the tenure of current State biologists in Alaska and to fisheries approved for CPs. This implies that we lack historical CP information for most regions and information about CP fisheries that were rejected, although interviews with State biologists indicate they generally issue CPs unless they are illegal or repeated failures. Some species that are already, or are expected to, migrate north into waters off Alaska – albacore tuna, Pacific hake, and sardines – will necessitate coordination between Federal and State managers, as well as potential renegotiations of bilateral agreements (Palacios-Abrantes et al., 2020). Although this study focused on the State process for emergent fisheries we acknowledge that there is a critical link between State and Federal fisheries to explore in follow-on work.

Conclusion

Range shifts and large-scale ecosystem changes brought about by climate change will redistribute historical commercial fish species and, in some cases, provide novel fishing opportunities. Managing for a balance of opportunity and sustainability will be critical for fishers, communities, and ecosystems. This study details the emergent fisheries process in Alaska, examining its role in exploring novel fisheries across regions, species, and gears. Despite a myriad of trials across diverse potential opportunities, novel fisheries developed through this process have had marginal outcomes, reflecting a fully exploited system. The piecemeal nature of the current approach may not scale to large-scale ecosystem changes under climate change, which may necessitate a dedicated management body and policy for emergent fisheries development. However, a targeted process for emergent fisheries development is a meaningful alternative to reactive processes elsewhere and provides valuable insights into tailoring these processes for novel fisheries.

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