Harvest portfolio diversification and emergent conservation challenges in an Alaskan recreational fishery

Anne H. Beaudreau[1], Maggie N. Chan[1], Philip A. Loring[2]

[1] University of Alaska Fairbanks, College of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road, Juneau, AK 99801, USA

[2] University of Saskatchewan, School of Environment and Sustainability, 117 Science Place Saskatoon, SK S7N 5C8, Canada

Corresponding author: Anne H. Beaudreau, University of Alaska Fairbanks, College of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road, Juneau, AK 99801; Email: abeaudreau@alaska.edu; Phone: 1-907-796-5454

Abstract

Diversification of harvest portfolios can benefit resource users by providing increased flexibility to respond to regulatory, economic, and environmental pressures. These adaptations, while important for maintaining harvesting opportunities, can lead to conservation challenges by shifting effort to other species or habitats. Using semi-structured interviews with charter fishing captains (N = 52) and logbook data, we examined shifts in the diversity of target species portfolios in a major recreational fishery in Alaska over three decades. To understand the role of regulation in affecting what species charter captains choose to target, we contrasted harvest portfolios in communities from two regions with differing histories of regulation. Portfolio structure was dynamic, with the majority of respondents reporting changes in the number of harvested species, relative preference for different species, or both since the 1990s. Diversification emerged primarily as a result of increased retention of historically less-preferred species, such as rockfishes, sablefish, and Pacific cod. Patterns of rockfish retention in charter logbook data mirrored patterns in targeting reported by respondents. Southeast Alaska captains largely attributed portfolio diversification and shifts in species preferences to greater restrictions on harvest of a primary target species (Pacific halibut), while Southcentral Alaska captains identified shifting customer interests and declines in some target species as driving changes. Our findings suggest that avoiding unintended conservation impacts of single-species regulations requires broader recognition of the multispecies nature of recreational fishing in management. Understanding fisher behaviors, values, and motivations is essential, so that managers may better anticipate the responses of fishers to new regulations.

Keywords

charter fishing; diversification; harvest portfolio; Pacific halibut; recreational fisheries; rockfishes

Introduction

In fisheries and hunting systems, diversification of target species and harvesting activities can mitigate risk to individuals and increase adaptive capacity of resource-dependent communities (Folke, Colding, & Berkes 2003; Hanazaki et al. 2013; Kasperski & Holland 2013; Anderson et al. 2017). Maintaining a diverse portfolio of harvested species, for example, gives harvesters the flexibility to switch among target species based on changes in their abundance or availability (Brashares et al. 2004). Portfolio shifts may also arise when more restrictive regulations are imposed on a primary target species. Subsistence communities in Interior Alaska shifted towards greater use of waterfowl and moose to compensate for the loss of Chinook salmon resulting from fishing closures (Loring & Gerlach 2010; Loring et al. 2011). Likewise, the near-closure of a Canadian groundfish fishery in the 1990s led to diversification of the commercial harvest portfolio through increased targeting of crustaceans (Hilborn et al. 2001).

Although important for maintaining harvesting opportunities in the face of change, resource substitution or addition can increase exploitation rates on other species (Gentner 2004; Loring 2016) and result in effort shifts that compromise conservation goals (Sutton & Ditton 2005). For instance, harvesters in West Africa intensified use of terrestrial mammals during years of low fish abundance, resulting in wildlife declines (Brashares et al. 2004). In fisheries, ecological sustainability of resource substitution can depend on aspects of fishing behavior, including the ability for fishers to harvest selectively (Katsukawa & Matsuda 2003). Therefore, understanding the effects of regulations on harvesting behavior and patterns of resource use is important for evaluating potential ecosystem effects of management and conservation strategies (Metcalf, Moyle, & Gaughan 2010).

52 Predicting shifts in resource use arising from regulations is particularly challenging in
53 recreational fisheries because of the diversity of fisher behavior and motivations (Salas &
54 Gaertner 2004; Sutton & Ditton 2005). Yet, recreational fisheries can have widespread impacts
55 on species and habitats (Coleman et al. 2004; Cooke & Cowx 2004; Arlinghaus & Cooke 2009)
56 and angler behavior can have important effects on conservation outcomes (Salas & Gaertner
57 2004; Cooke et al. 2013). Here, we examined the role of regulations as a potential driver of
58 resource substitution or addition in the Gulf of Alaska recreational charter fishery. Saltwater
59 charter anglers pursue multiple species in Alaska, but Pacific halibut (*Hippoglossus stenolepis*) is
60 a primary target (Lew, Lee, & Larson 2010). Declining spawning stock biomass and size-at-age
61 of halibut, coinciding with enormous growth of recreational landings (IPHC 2014), led to a suite
62 of new halibut charter regulations beginning in the mid-2000s. To understand the role of
63 regulation in affecting what species charter captains choose to target, we contrasted harvest
64 portfolios in communities from two regions with differing histories of regulation.
65 We used a mixed methods approach to address three primary objectives. Using semi-
66 structured interviews with charter operators in Southeast and Southcentral Alaska, we first
67 evaluated shifts in the portfolio of species targeted on halibut charter fishing trips over the past
68 three decades (Objective 1) and identified possible social, ecological, regulatory, and economic
69 drivers of those shifts (Objective 2). We then summarized charter logbook data to determine
70 whether interviewees' experiences matched broader, fleet-wide patterns in harvest (Objective 3).
71 We hypothesized that increasing restrictions in allowable halibut harvest since the early 2000s
72 may have led to greater retention of historically less-preferred species. We also expected that
73 portfolio structure would differ between operators in Southeast and Southcentral Alaska, who
74 have access to different species (Chan, Beaudreau, & Loring 2017) and are subject to different

75 management measures for halibut and other species. This study presents a novel application of
76 the portfolio concept to recreational fisheries and shows that portfolio diversification can emerge
77 from fishers' responses to restrictions on a preferred species. Accounting for fisher behavior and
78 explicitly recognizing potential trade-offs among species are important for adopting a portfolio
79 approach to managing recreational fisheries that promotes sustainability of livelihoods and
80 ecosystems.
81
82 **Materials and methods**
83 *Study communities and charter fishery characteristics*
84 Our research was conducted primarily in the communities of Sitka and Homer, which are
85 among the most popular sport fishing destinations in Alaska for both resident and non-resident
86 anglers (Lew, Lee, & Larson 2010). They are also the major halibut charter ports in Southeast
87 and Southcentral Alaska, where ~80% of the state's sport-caught halibut are harvested annually
88 (Dykstra 2017). Since the mid-2000s, major changes have taken place in charter halibut
89 management in these areas, including establishment of sector-wide harvest limits and changes in
90 the numbers and sizes of halibut that can be retained. The timing and types of regulatory changes
91 have differed between Southeast and Southcentral regions, which fall into separate International
92 Pacific Halibut Commission management areas (Appendix A). Briefly, the Southeast region has
93 been subject to historically more restrictive charter halibut regulations compared to the
94 Southcentral region.
95 Charter businesses in Alaska vary in their size, trip offerings (type and duration), and
96 clientele (Chan, Beaudreau, & Loring 2017). Businesses range from single owner-operator
97 vessels to fishing lodges with multiple boats and vessel capacity varies from six passengers to

more than twenty. Some charter businesses offer a mix of fishing, hunting, and/or wildlife viewing activities. In Southcentral Alaska, charter businesses offer single species (halibut only) and/or multispecies trips, while in Southeast Alaska, businesses primarily operate multispecies trips (Powers & Sigurdsson 2014). In addition, businesses offer trips ranging from a half-day to multiple days in duration. The customer base in both regions is predominantly comprised of anglers from outside Alaska; in 2014, 97% and 74% of the angler-days reported were fished by non-resident anglers in Southeast and Southcentral Alaska, respectively (Powers & Sigurdsson 2014).

Overview of mixed methods approach

We used triangulation (Jick 1979) to address our objectives and hypotheses. In this view, quantitative and qualitative approaches are complementary, informing and extending the findings of each other to provide a more complete understanding of the same phenomenon (Jick 1979, Rossman & Wilson 1985). Changes in harvest portfolios were documented using semi-structured interviews with charter captains and analyzed using a combination of univariate statistics, network visualization, and network analysis. Drivers of those changes were assessed using qualitative analysis of charter captains' responses to open-ended interview questions, which allowed us to contextualize and interpret the quantitative depictions of harvest portfolio shifts ("elaboration" sensu Rossman & Wilson 1985). Charter logbook data provided a means of corroborating temporal shifts in harvest portfolios identified from semi-structured interviews with charter captains. Together, these methods and data sources provide a richer, more holistic view of the nature and causes of harvest portfolio shifts than any one approach alone.

121 *Interviews with charter captains*

122 We conducted in-person interviews with charter captains operating their businesses in Sitka
123 (Southeast) and Homer, Seward, and Ninilchik (Southcentral) in May and June of 2014 and
124 2015. Since 2011, charter vessels targeting halibut have been required to hold a Charter Halibut
125 Permit (CHP; 50 C.F.R. §300.67) and the annual list is publicly available (NOAA 2017). To
126 recruit interview respondents, we contacted CHP holders through angler association newsletters
127 and by mail (i.e., letters sent to CHP holders with business addresses in the above communities
128 in 2014-2015). Additional respondents were identified through snowball sampling, in which each
129 interviewee refers other potential participants (Bernard 2006). Our intention was not to conduct a
130 representative survey of charter operators, but rather to identify individuals with long-term
131 experience as a captain (≥5 years) who could provide insight into changes in charter fishing
132 practices. To confirm the adequacy of our sample size for characterizing the diversity of the
133 harvest portfolios, we calculated a species rarefaction curve (Gotelli & Colwell 2001) separately
134 for each region (Appendix B).

135 During interviews, respondents were first asked to list all species they have targeted on
136 charter trips (i.e., those harvested and retained by customers). Next, we asked them to "rank each
137 species according to customer preference on a charter fishing trip," assuming that all species
138 were available (i.e., legally harvestable and present on the fishing grounds). We tested and
139 discussed the wording of this question through several pilot interviews with experienced charter
140 captains to identify a way to elicit the relative importance of harvested species that would be
141 interpreted similarly across interviewees. "Customer preference" was most easily understood and
142 interpreted by charter captains as reflecting a combination of what types of fishing (species and
143 locations) they were willing to offer their customers and what their customers desired to target

144 on charter fishing trips. A ranking of 1 indicated that a species was most preferred (i.e., most
145 targeted). Respondents were permitted to give the same rank to multiple species. We asked
146 respondents to provide separate rankings for when they started operating charter trips ("past")
147 and for recent years, including the current season ("present"). If a change in ranking was
148 identified, we asked when it occurred and what the reasons were for the change. Each respondent
149 could provide more than one reason for shifts in portfolios.
150
151 *Interview data analysis*
152 We defined harvest portfolios in terms of their diversity (number of species), composition
153 (identity of species in the portfolio), and structure (relative species preferences). To address
154 Objective 1, temporal changes in harvested species portfolios were assessed at two scales: 1)
155 individual portfolios: relative changes over the lifetime experience of individual charter captains;
156 and 2) aggregate portfolios: changes by decade across all respondents. Calculations were
157 performed separately for each region. To examine relative changes, we assessed portfolio
158 diversity, composition, and structure for each individual's past and present periods, as defined
159 above. While these periods may represent different years for each respondent, the comparison
160 between past and present provides insight into behavioral shifts over the course of an
161 individual's career (Neis et al. 1999). To examine portfolio shifts across decades, we compared
162 the mean number of harvested species per respondent between the 1990s and 2010s using paired
163 t-tests (i.e., comparisons only included respondents who had fished during both decades). For
164 every decade, we calculated the mean ranking and percentage of respondents targeting each
165 species. Due to the small number of respondents who fished in the 1980s, analysis was restricted
166 to the 1990s and later.

167 Aggregate harvest portfolios (across all respondents) were visualized as network maps using
168 the 'igraph' package in R (Csardi & Nepusz 2006). Network maps are useful tools for
169 visualization because they represent quantitative information about portfolio diversity,
170 composition, and structure within a single figure (Cinner & Bodin 2010). Conceptually, each
171 harvested species is represented as a node (i.e., point or vertex) and a link (i.e., edge) is drawn
172 between every pair of species. Links are directional, pointing from the more preferred to the less
173 preferred species, and weighted by the number of respondents who targeted that pair of species.
174 Because respondents may have ranked species differently, some species have bidirectional links
175 in the aggregate portfolio. The size of each node in the network map is proportional to the
176 number of respondents who targeted that species. Likewise, the width of each link is proportional
177 to the number of respondents who targeted each pair of species. Because networks are intended
178 to represent the overall portfolio of the respondent group, we eliminated network links and nodes
179 derived from fewer than two individuals. This reduced the influence of rare or erroneous species
180 on the network structure. Input data for generating networks are provided in Appendix C.
181 We used standard network statistics to quantify structural characteristics of the networks,
182 particularly the relative positioning of nodes and relationships among them (Cinner & Bodin
183 2010). Specifically, we calculated in-degree and out-degree centrality, the number of incoming
184 or outgoing links to a given node in a directed network, respectively (Wasserman & Faust 1994).
185 Species with relatively higher out-degree centrality scores are those that tend to be more
186 preferred. To aid in interpretation, we rescaled centrality scores between 0 and 1 by dividing
187 each in-degree and out-degree centrality score by the maximum possible number of ingoing or
188 outgoing links per node, respectively. Out-degree centrality, combined with node size (the

189 proportion of respondents targeting each species), provides a measure of the relative importance
190 of each species to the aggregate portfolio.
191 To address Objective 2, we analyzed interviewees' stated reasons for shifts in portfolios
192 using inductive coding for themes (Creswell & Poth 2017). Interview notes were double checked
193 against interview recordings and read several times to identify themes and subthemes. Full
194 transcriptions were not made, except for quotes that exemplify some of the reasons for portfolio
195 shifts reported by charter captains in each region. For example, one respondent who did not keep
196 black rockfish when he began charter fishing but does currently, explained it this way: "When
197 we could keep bigger halibut and two halibut a day, [the customers'] boxes would be filled with
198 halibut and salmon and they didn't want those other things in there." This response was coded
199 "more restrictive regulations for halibut" and "more customer interest in other species" with the
200 subtheme "more interest in rockfish."
201
202 *Charter logbook data analysis*
203 We used charter logbook data from 1998 to 2015 to evaluate whether portfolio shifts reported
204 by respondents were reflected in regional charter landings (Objective 3). Alaska recreational
205 harvest data are collected using a variety of methods for charter (guided) and non-charter
206 (unguided) anglers. A Statewide Harvest Survey (SWHS) is administered by the Alaska
207 Department of Fish and Game (ADFG) annually, in which a random sample of households with
208 at least one licensed angler receives a mail survey regarding their catch and effort (number of
209 trips) for the year (Dykstra 2017). Fish size information is collected by ADFG through a
210 dockside creel sampling program (Dykstra 2017). Logbooks have been required for saltwater
211 charter vessels statewide since 1998 (Powers & Sigurdsson 2014). Charter operators are required

212 to record the statistical area fished, names and license numbers of clients, salmon fishing hours,
213 bottomfish fishing hours, and number of retained and released fish of certain species
214 (http://www.adfg.alaska.gov/index.cfm?adfg=prolicenses.logbook). Logbook records are
215 confidential, pursuant to Alaska Statute 16.05.815, and may not be publicly obtained.
216 Recreational harvest is not recorded comprehensively for all species in the SWHS, creel
217 sampling, or charter logbooks. Charter logbook records are available for Pacific halibut, Chinook
218 salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), pink
219 salmon (*O. gorbuscha*), chum salmon (*O. keta*), lingcod (*Ophiodon elongatus*), pelagic
220 rockfishes [combined species, including black rockfish (*Sebastes melanops*), yellowtail rockfish
221 (*S. flavidus*), and dusky rockfish (*S. ciliatus*)], non-pelagic rockfishes [combined species,
222 including yelloweye rockfish (*S. ruberrimus*), copper rockfish (*S. caurinus*), silvergray rockfish
223 (*S. brevispinis*), tiger rockfish (*S. nigrocinctus*), China rockfish (*S. nebulosus*), and quillback
224 rockfish (*S. maliger*)], sablefish (*Anoplopoma fimbria*), and salmon shark (*Lamna ditropis*).
225 Yelloweye rockfish were recorded separately from other non-pelagic rockfishes starting in 2006.
226 Sablefish were not recorded until 2010. Halibut were not recorded from 2002-2005. Some
227 salmon species were combined into a single category in some years.
228 To examine fleet-wide shifts in the composition of species harvested on charter trips, annual
229 logbook data were summarized in terms of the proportion of all charter trips that retained a given
230 species or species group, from 1998 to 2015. A charter trip is defined as the time from when the
231 charter vessel leaves the dock to the time it returns. We chose to evaluate patterns in retained
232 species in terms of their presence or absence on trips because abundance and biomass-based
233 metrics, such as total catch and catch-per-unit-effort, are confounded with changes in bag and
234 size limits as well as the duration of individual trips. Proportional frequencies of occurrence by

235 species or species group were calculated separately for each year and region (Homer area: ADFG
236 SWHS area P, Sitka area: ADFG SWHS area D; Romberg 2016). The proportion of trips was
237 summarized for the following species or species groups: Pacific halibut, salmon, lingcod, pelagic
238 rockfishes, non-pelagic rockfishes, yelloweye rockfish (2006-2015 only), and sablefish (2010-
239 2015 only). Logbook summaries were provided by the Alaska Department of Fish and Game
240 (Scott Meyer, Fishery Biologist, ADFG, 3298 Douglas Place, Homer, AK 99603-7942; date of
241 communication: 9/1/17).
242
243 **Results**
244 We interviewed 52 charter captains in Southeast (N=26) and Southcentral (N=26) Alaska,
245 comprising ~15% of the 2014 CHP holders in Sitka, Homer, Seward, and Ninilchik. These
246 sample sizes align with guidelines for thematic analysis (i.e., 20-30; Creswell & Poth 2017) and
247 were adequate to characterize the total diversity of harvest portfolios in both regions (Appendix
248 B). On average (±SD), participants had an estimated 17 (±9) years of experience as charter
249 captains, with a mean starting year of 1998 (Table 1). The majority of interviewees were charter
250 business owners operating single or multiple vessels (owner/operator) in both regions (Table 1).
251 A higher percentage of interviewees in Southeast Alaska were hired captains compared to those
252 in Southcentral Alaska (Table 1). Most captains operated fishing-only trips (full day or partial
253 day, includes halibut-only and multispecies trips), with a minority offering combination
254 fishing/hunting or fishing/wildlife viewing trips (Table 1). Charter captains operated boats
255 ranging from 20 to 50 feet, with a median size of 30 feet, carrying an average (±SD) of 6 (±3.4)
256 passengers per trip. The predominant gear type used on charter trips is rod and reel (i.e., hook

257 and line), with some use of pots to target crab and shrimp. Salmon are targeted by trolling or
258 mooching, while halibut and other bottomfish are targeted by jigging or soaking baited hooks.
259
260 *Temporal changes in individual portfolios*
261 The majority of Southeast captains (69%) and nearly half of Southcentral captains (46%)
262 reported a change in species preference and/or number of harvested species over their lifetime
263 charter experience (Table 1). Of the 25 respondents reporting a change in the number of
264 harvested species, only one (in Southcentral) reduced the number of species from when s/he
265 began charter fishing to the present; all others expanded their species portfolios (Table 1).
266 Southeast captains who diversified (N=10) added an average of 2.1 new species and Southcentral
267 captains (N=14) added 3.8 species between past and present periods. For respondents who
268 specified the year(s) in which they shifted species targeting behavior, the most common
269 transition year for Southeast captains was 2011 (56%). There was a wide distribution of
270 transition years reported by Southcentral captains, with no single year reported by more than 3
271 respondents.
272 Over all decades, the top five species targeted by Southeast and Southcentral captains were
273 identical but differed slightly in rank order; for both regions, halibut and Chinook salmon were
274 the top two species (Fig. 1). The rank order of species was fairly stable over time, except that for
275 Southeast captains, the mean rankings of historically more preferred species declined over time
276 as new species were added (Fig. 1). Southeast captains reported an increase in the average (±SD)
277 number of target species, from 5.6 (±2.3) per respondent in the 1990s to 7.5 (±2.4) in the 2010s
278 (t=-3.161, df=9, P=0.012). The average (±SD) number of species targeted by Southcentral

279 captains was relatively stable over the same period, with no significant change from the 1990s
280 (6.3 ±3.2 per respondent) to the 2010s (7.2 ±2.9 per respondent; t=-0.088, df=18, P=0.931).
281
282 *Temporal changes in aggregate portfolios*
283 The network plots show an overall diversification of target species portfolios from the 1990s
284 to the 2010s, particularly among Southeast captains, as indicated by increasing species diversity
285 and number of linkages between species over time (Fig. 2). In both regions, the percentage of
286 respondents targeting particular species varied over time. Most notable were increases in the
287 percentage of respondents targeting black rockfish (from 40% in the 1990s to 85% in the 2010s),
288 sablefish (20% to 65%), and Pacific cod (*Gadus microcephalus*; 20% to 42%) in Southeast; and
289 walleye pollock (*G. chalcogrammus*; 5% to 19%) and Pacific cod (63% to 81%) in Southcentral
290 (Fig. 2). Measures of in-degree centrality (the number of incoming links to a given node) and
291 out-degree centrality (the number of outgoing links from a given node) were inversely correlated
292 (Appendix D), so we summarize only out-degree centrality measures here (indication of high
293 preference). Halibut, Chinook salmon, and coho salmon consistently showed the highest out-
294 degree centrality measures across decades and regions, indicating that they tended to be more
295 preferred than other species in the aggregate portfolio (Fig. 3). Measures of out-degree centrality
296 were also consistently high for lingcod, yelloweye rockfish, and black rockfish in the
297 Southcentral portfolio across decades (Fig. 3b).
298 Changes in out-degree centrality measures across decades result from both the addition of
299 new species to the aggregate portfolio and shifts in ranking by individual charter captains. Out-
300 degree centrality measures increased from the 1990s to the 2010s for the vast majority of species,
301 resulting from diversification of the aggregate portfolios over time. The largest increases in

302 measures of out-degree centrality were for sablefish and black rockfish in the Southeast portfolio
303 (Fig. 3a) and for sockeye, cod, and chum salmon in the Southcentral portfolio (Fig. 3b). Overall,
304 the out-degree centrality measures showed larger shifts from the 1990s to the 2010s for the
305 Southeast portfolio, suggesting that the Southcentral portfolio was more stable over time. Some
306 caveats are warranted in interpretation of the centrality measures. Degree centrality is influenced
307 by errors in specifying the network (e.g., missing nodes or links). However, basic network
308 measures like centrality are affected similarly by different types of error in the data used to
309 construct the network and may be relatively robust to misspecifications (Borgatti, Carley, &
310 Krackhardt 2006). Because we used data from the same set of respondents to assess changes over
311 time, qualitative (i.e., visual) comparisons among networks also provide useful inference about
312 relative changes in portfolio structure across decades.
313
314 *Drivers of portfolio shifts*
315 Reported reasons for portfolio shifts fell into four primary themes: changes in customer
316 preferences, regulatory changes, ecological shifts, and changes in fishing practices (Table 2). The
317 dominant drivers of portfolio changes, cited by more than 20% of Southeast captains who had
318 reported a change in target species or ranking (N=18), were more restrictive regulations for
319 halibut (N=16) and more restrictive regulations for other species (N=5). Of the specific
320 regulations mentioned (Table 2), the 2011 rule that established a maximum size limit of 37
321 inches on charter halibut was most frequently reported to have affected species targeting
322 behavior (N=8). The dominant drivers of portfolio changes in Southcentral were more customer
323 interest in other species (N=7 out of 12 reporting a change), particularly Pacific cod; changes in
324 species abundance (N=5), such as declines in lingcod and yelloweye rockfish; changes in trip

type, such as a shift from a single-species to multispecies trip or a change in trip duration (N=4); and changes in fishing area or depth (N=4).

Patterns in charter logbook data

A total of 165,467 charter trips were taken in the Sitka area (SWHS area D) and 223,764 in the Homer area (SWHS area P) from 1998 to 2015 (Table 3). The number of annual trips ranged from 7,235 to 12,140 in the Sitka area and 8,739 to 15,637 in the Homer area (Table 3). In the Sitka area (Fig. 4a), the proportion of trips retaining salmon was relatively stable, ranging from 80-93% of trips per year. The proportion of trips retaining halibut increased from 54 to 73% between 1998 and 2015. Lingcod varied from 10 to 26% over the same period. Pelagic and non-pelagic rockfishes showed a marked increase between 1998 and 2015, from 18 to 55% of trips and 21 to 56% of trips, respectively. In the Homer area (Fig. 4b), halibut were retained on 91-97% of trips during the period from 1998 to 2015, while salmon varied without trend from 11 to 24% of trips from 1998 to 2012, followed by a monotonic increase to 35% of trips in 2015. Lingcod were retained on 1-6% of trips from 1998 to 2015. Pelagic rockfishes and non-pelagic rockfishes increased from 2 to 12% and 1 to 6%, respectively, over the same period.

Triangulation of results

While the mean rankings across individual charter captains (Fig. 1) and the out-degree centrality measures for the aggregate portfolio (Fig. 3) present different types of information, they tell a similar story. Halibut and Chinook salmon are primary target species, but coho salmon, lingcod, yelloweye rockfish, and black rockfish are also important to the harvest portfolio in both regions. These six species have been core components of the charter portfolio

348 over nearly three decades. Overall, the Southeast portfolio has diversified, while the diversity of
349 the Southcentral portfolio has remained relatively stable since the 1990s. The percentage of
350 respondents targeting black rockfish and sablefish in Southeast and Pacific cod in Southcentral
351 has increased, along with the relative importance of these species to the aggregate portfolios. The
352 increase in targeting of rockfish was corroborated by charter logbook data, which showed a large
353 increase in the proportion of charter trips retaining rockfishes across the entire fleet. Qualitative
354 analysis of the interviews provided a deeper understanding of the mechanisms underlying these
355 shifts. Southeast captains largely attributed portfolio changes to greater restrictions on harvest of
356 halibut, while Southcentral captains identified shifting customer interests and declines in some
357 target species as key drivers.
358
359 **Discussion**
360 Charter businesses rely on a diverse portfolio of activities, target species, and fishing
361 locations to ensure viability when faced with regulatory, economic, and environmental pressures.
362 The diversity of the Southcentral species portfolio was relatively stable over time, while the
363 Southeast portfolio expanded from the 1990s to the 2000s. These patterns likely reflect the
364 differing role of regulations as a driver of diversification in each region. Charter captains
365 diversified in other ways too, such as marketing a combination of hunting and fishing activities,
366 similar to the mixed fish and wildlife portfolios that are common in subsistence communities
367 (Loring & Gerlach 2010) and small-scale fisheries (Brashares et al. 2004). These forms of
368 strategic substitution may confer greater resilience to businesses that are confronted with a host
369 of simultaneous pressures (Gentner & Sutton 2008). Substitution behavior by recreational
370 anglers, such as shifting to new resources or locations in response to changing policies or

371 environmental conditions, is common (Gentner 2004; Gentner & Sutton 2008), suggesting that
372 the potential for diversification exists broadly in recreational fisheries.
373 The diversification of charter portfolios was largely driven by shifts towards increased
374 retention of long-lived species that are susceptible to overfishing. Harvest data suggest that the
375 growing interest in rockfish and sablefish reported by respondents reflects a broader fleet-wide
376 trend. From 2000 to 2015, total recreational harvest of rockfish (by guided and unguided anglers)
377 in the Sitka area increased by more than 450% (ADFG 2017a). While rockfishes have always
378 been a component of the harvest portfolio for many charter captains, most interviewees in
379 Southeast Alaska attributed this increased retention of rockfishes and other species to greater
380 restrictions on halibut. As one charter captain observed,
381 "I grew up here and my stepmom would say, if you want to eat, go catch fish. Well, rockfish
382 was the easiest so I targeted it. So I have a love for rockfish. But there were so many people
383 out here…that never targeted the rockfish. Now with the [halibut] restrictions as high as they
384 are, I see that overall over the fleet, that rockfish are getting a higher preference."
385 This shift has led to concerns about the sustainability of rockfish harvest. In 2017, a portion of
386 Southeast Alaska waters were closed by emergency order to retention of demersal rockfishes and
387 a deep water release mechanism was required on all boats (ADFG 2017b). This emerging
388 rockfish conservation issue draws parallels to rockfish declines along the U.S. west coast,
389 particularly in Washington state where a recreational rockfish fishery emerged in the 1970s in
390 response to reduced opportunities for salmon (Williams, Levin, & Palsson 2010). Decades later,
391 three species of rockfish in Puget Sound were listed for protection under the Endangered Species
392 Act due to severe declines (Williams, Levin, & Palsson 2010). As in Washington, most
393 recreationally harvested rockfishes in Alaska are not assessed or monitored on a species-specific

394 basis, further limiting the ability of managers to anticipate and respond to shifts in effort.
395 Improved monitoring of a wider diversity of recreational species could help elucidate effort
396 shifts towards species or habitats that were of less importance to anglers historically.
397 The socioeconomic benefits of diversification do not have to come at an ecological cost if the
398 multispecies nature of recreational fishing is more explicitly recognized in policy analyses and
399 decision-making. From a management perspective, understanding how fishing behavior is likely
400 to change under different sets of regulations is important for anticipating indirect effects of
401 single-species regulations on other components of the ecosystem (Hunt, Sutton, & Arlinghaus
402 2013; Lew & Larson 2015). In our study, the 2011 regulation that established a 37-inch
403 maximum size limit on halibut in Southeast Alaska was mentioned by interviewees more than
404 any other single regulation as having an impact on species targeting behavior. Our research also
405 shows that different regulations can lead to a diversity of response behaviors by charter captains.
406 Just 6% of the Sitka respondents who reported shifts in their portfolios attributed the change to
407 the 2009 bag limit reduction from 2 to 1 fish per angler-day; however, 58% of interviewees
408 reported that this same regulation increased the distance they travel on an average charter trip
409 (Chan, Beaudreau, & Loring 2018). Importantly, regulation changes do not drive fishing
410 behavior in isolation; our results also indicate that charter captains are responding to a complex
411 suite of simultaneous socioeconomic and ecological pressures that affect fishing strategies. To
412 illustrate, one captain explained why targeting of Pacific cod had increased as follows:
413 "Halibut are getting smaller. So [the customers] think, 'Oh I'm going to catch a couple cod
414 fish, that'll work. We are out here on this two-hundred dollar charter, might as well throw
415 them in the box and take them home.'"

In this case, cod serves as a supplemental "white fish" to replace lost poundage of halibut. Thus, the proximate reason for increased targeting of cod was customer desire, while the ultimate reason was reduced body size of halibut, which has been well documented in recent years (IPHC 2014).

Our results demonstrate that approaches to recreational fisheries management and conservation must not only focus on effort and harvest controls, but are broadened to capture the sociocultural values that inform angler motivations and strategies (Fedler & Ditton 1994; Sutton & Ditton 2005; Arlinghaus & Cooke 2009; Fenichel, Abbott, & Huang 2012). Individual decision-making and responses to risk may lead to collective outcomes that are unanticipated, potentially undermining management goals (Busch, Brown, & Mayer 2003; Minnegal & Dwyer 2008). In the case of Alaska charter fisheries, strategic responses of charter operators to regulations set for halibut have resulted in effort shifts to new locations (Chan, Beaudreau, & Loring 2017) and species. The challenge of accounting for individual behavior is amplified in management of charter fisheries because of the interplay between captains and customers in determining the parameters of a fishing trip. Effectively managing recreational fisheries in Alaska relies on a richer understanding of how both charter businesses and their customers anticipate and respond to regulation change. Over half of the Southcentral respondents attributed changes in species portfolios to changing customer interests; however, charter owners and operators play a significant role in setting customers' expectations by marketing specific opportunities. This is exemplified by a quote from a charter captain in the Homer area, who stated:

"We started fishing more for those [lingcod and yelloweye] in 1997, 1998. And it wasn't because the resource was going down or anything. It was mainly trying to provide something

different for your customers to do… And then of course when you are hanging fish up, people see that so more [customers] are inquiring about it. Then more people want to do it so more operators are offering to do that."

As guides, charter operators have a unique opportunity to promote conservation values to a diverse population of recreational anglers. Conservation and fisher objectives could be aligned by promoting catch-and-release fishing or certifying charter businesses as 'environmental stewards,' giving them access to a new customer market, in exchange for self-imposing limits on their catch (Granek et al. 2008). In addition, recreational fishery views could be better incorporated into the existing management system through increased representation of recreational fishers on federal fishery management councils (Chan, Beaudreau, & Loring 2018).

Management has an important role to play in affording charter operators the flexibility to adapt to an ever-changing landscape of socioecological pressures. Yet, government agencies often promote specialization (Hilborn et al. 2001; Kasperski & Holland 2013) through rigid, command-and-control based management (Holling & Meffe 1996). Perhaps the greatest challenge to implementing a portfolio framework in fishery management is building compatible institutions that are, themselves, flexible and adaptive (Edwards, Link, & Rountree 2004; Hilborn et al. 2001; Salas & Gaertner 2004). Recognizing the limits of formal institutions, some of our interviewees discussed personal conservation actions they had taken, like imposing more conservative bag limits on their customers and voluntary avoidance of locally depleted species. In Canada, recreational fishers worked with managers to address declines in rockfish abundance, resulting in harvest rate reductions (Granek et al. 2008). Public education and informal approaches to governance that are developed in collaboration with stakeholders (Cooke et al.

2013, Sawchuk et al. 2015) may serve an important role in fostering conservation behavior among anglers.

Acknowledgements

Funding was provided by a NOAA Saltonstall-Kennedy Grant (NA14NMF4270059) and a National Science Foundation IGERT (DGE-0801720). We thank Scott Meyer and Richard Yamada for their assistance with the project and the many charter captains who contributed their time and knowledge. Thanks to Phil Levin and two anonymous reviewers for reviewing a draft of the manuscript. This study was approved by the University of Alaska Fairbanks Institutional Review Board (#583323). The authors have no competing interests to declare.

Data accessibility

To preserve respondent confidentiality, as required by the University of Alaska Fairbanks Institutional Review Board (#583323), raw data from interviews may not be provided publicly. Aggregated data for generating networks are provided in Appendix C. Charter logbook records are also confidential, pursuant to Alaska Statute 16.05.815. Aggregated data that are sufficient to maintain confidentiality requirements may be requested from the Alaska Department of Fish and Game, Division of Sport Fish, RTS (Logbook Program), 333 Raspberry Rd., Anchorage, AK, 99518-1599.

References

Alaska Department of Fish and Game (ADFG). (2017a). Alaska Sport Fishing Survey database, http://www.adfg.alaska.gov/sf/sportfishingsurvey/. Accessed 2/17/17.

484 Alaska Department of Fish and Game (ADFG). (2017b). Sport Fishing Emergency Order, 1-RF-
485 R-09-17 (Mar. 20, 2017), superseding 5 AAC § 47.020(8)(B) and 5 AAC § 47.030(m).
486 Anderson, S.C., Ward, E.J., Shelton, A.O., Adkison, M.A., Beaudreau, A.H., Brenner, R.E.,
487 Haynie, A.C., Shriver, J.C., Watson, J.T., & Williams, B.C. (2017). Benefits and risks of
488 diversification for individual fishers. Proc. Natl. Acad. Sci., doi: 10.1073/pnas.1702506114
489 Arlinghaus, R. & Cooke, S.J. (2009). Recreational fisheries: Socioeconomic importance,
490 conservation issues and management challenges. In: Recreational hunting, conservation and
491 rural livelihoods: science and practice (eds. Dickson, B., Hutton, J., Adams, W.M.).
492 Blackwell Publishing, Oxford, pp. 39–58.
493 Bernard, H.R. (2006). Research methods in anthropology: qualitative and quantitative
494 approaches. Fourth. AltaMira Press, Lanham, MD.
495 Borgatti, S.P., Carley, K.M. & Krackhardt, D. (2006). On the robustness of centrality measures
496 under conditions of imperfect data. Social Networks, 28, 124–136.
497 Brashares, J.S., Arcese, P., Sam, M.K., Coppolillo, P.B., Sinclair, A.R.E. & Balmford, A. (2004).
498 Bushmeat hunting, wildlife declines, and fish supply in West Africa. Science, 306 (5699),
499 1180–1183.
500 Busch, W.D.N., Brown, B.L., & Mayer, G.F. (eds). (2003). Strategic guidance for
501 implementing an ecosystem-based approach to fisheries management. United States
502 Department of Commerce, National Oceanic and Atmospheric Administration, NMFS, Silver
503 Spring, MD 62p.
504 Chan, M.N., Beaudreau, A.H. & Loring, P.A. (2017). Evaluating patterns and drivers of spatial
505 change in the recreational guided fishing sector in Alaska. PLoS One, 12, 1–19.
506 Chan, M.N., Beaudreau, A.H., & Loring, P.A. (2018). Evaluating the recreational fishery

507 management toolbox: Charter captains' perceptions of harvest controls, limited access, and
508 quota leasing in the guided halibut fishing sector in Alaska. Marine Policy, 91, 129–135.
509 Cinner, J.E. & Bodin, O. (2010). Livelihood diversification in tropical coastal communities: A
510 network-based approach to analyzing 'livelihood landscapes.' PLoS One, 5(8), 1–14.
511 Coleman, F.C., Figueira, W.F., Ueland, J.S. & Crowder, L.B. (2004). The impact of United
512 States recreational fisheries on marine fish populations. Science, 305 (5692), 1958–1960.
513 Cooke, S.J. & Cowx, I.G. (2004). The role of recreational fishing in global fish crises.
514 Bioscience, 54, 857–859.
515 Cooke, S.J., Suski, C.D., Arlinghaus, R. & Danylchuk, A.J. (2013). Voluntary institutions and
516 behaviours as alternatives to formal regulations in recreational fisheries management. Fish
517 Fish., 14, 439–457.
518 Creswell, J.W., & Poth, C.N. (2017). Qualitative Inquiry and Research Design: Choosing Among
519 Five Approaches. SAGE Publications.
520 Csardi, G., & Nepusz, T. (2006). The igraph software package for complex network research,
521 InterJournal, Complex Systems 1695. http://igraph.org
522 Dykstra, C. (2017). 2016 Pacific halibut sport fishery review. Int. Pac. Halibut Comm. Report of
523 Assessment and Research Activities 2016. IPHC–2016– RARA–26–R: 50-62.
524 Edwards, S.F., Link, J.S. & Rountree, B.P. (2004). Portfolio management of wild fish stocks.
525 Ecol. Econ., 49, 317–329.
526 Fedler, A.J. & Ditton, R.B. (1994). Understanding angler motivations in fisheries management.
527 Fisheries, 19, 6–13.
528 Fenichel, E.P., Abbott, J.K. & Huang, B. (2012). Modelling angler behaviour as a part of the
529 management system: Synthesizing a multi-disciplinary literature. Fish Fish., 14, 137–157.

530 Folke, C., Colding, J., & Berkes, F. (2003). Synthesis: building resilience and adaptive capacity
531 in social-ecological systems. In: Navigating Social-Ecological Systems (eds. Berkes, F.,
532 Colding, J., Folke, C.). Cambridge University Press, Cambridge, pp. 352–387.
533 Gentner, B. (2004). Examining target species substitution in the face of changing recreational
534 fishing policies. In: Proc. Twelfth Bienn. Conf. Int. Inst. Fish. Econ. Trade. pp. 1–12.
535 Gentner, B. & Sutton, S. (2008). Substitution in Recreational Fishing. Glob. Challenges Recreat.
536 Fish., 150–169.
537 Gotelli, N.J. & Colwell, R.K. (2001). Quantifying biodiversity: procedures and pitfalls in
538 the measurement and comparison of species richness. Ecology Letters, 4, 379–391.
539 Granek, E.F., Madin, E.M.P., Brown, M.A., Figueira, W., Cameron, D.S., Hogan, Z.,
540 Kristianson, G., De Villiers, P., Williams, J.E., Post, J., Zahn, S., & Arlinhaus, R. (2008).
541 Engaging recreational fishers in management and conservation: Global case studies.
542 Conservation Biology, 22(5), 1125–1134.
543 Hanazaki, N., Berkes, F., Seixas, C.S. & Peroni, N. (2013). Livelihood diversity, food security
544 and resilience among the Caiçara of coastal Brazil. Hum. Ecol., 41, 153–164.
545 Hilborn, R., Maguire, J.-J., Parma, A.M. & Rosenberg, A. (2001). The Precautionary
546 Approach and risk management: can they increase the probability of successes in fishery
547 management? Can. J. Fish. Aquat. Sci., 58, 99–107.
548 Holling, C.S. & Meffe, G.K. (1996). Command and control and the pathology of natural
549 resource management. Conserv. Biol., 10, 328–337.
550 Hunt, L.M., Sutton, S.G., & Arlinghaus, R. (2013). Illustrating the critical role of human
551 dimensions research for understanding and managing recreational fisheries within a social-
552 ecological system framework. Fisheries Management and Ecology, doi: 10.1111/j.1365-

553 2400.2012.00870.x
554 International Pacific Halibut Commission (IPHC). (2014). The Pacific Halibut: Biology, Fishery,
555 and Management. Keith, S., Kong, T., Sadorus, L., Stewart, I., and Williams, G., eds.
556 Technical Report No. 59. IPHC, 2320 West Commodore Way, Suite 300, Seattle, WA, USA,
557 98199-1287. Available: http://www.iphc.int/
558 Jick, T.D. (1979). Mixing qualitative and quantitative methods: Triangulation in action.
559 Administrative Science Quarterly, 24(4), 602–611.
560 Kasperski, S. & Holland, D.S. (2013). Income diversification and risk for fishermen. Proc. Natl.
561 Acad. Sci., 110, 2076–2081.
562 Katsukawa, T. & Matsuda, H. (2003). Simulated effects of target switching on yield and
563 sustainability of fish stocks. Fisheries Research, 60, 515–525.
564 Lew, D.K., Lee, J., & Larson, D.M. (2010). Saltwater sportfishing in Alaska: A summary and
565 description of the Alaska saltwater sportfishing economic survey, 2007. U.S. Dep. Commer.,
566 NOAA Tech. Memo. NMFS-AFSC-214, 229 p.
567 Lew, D.K. & Larson, D.M. (2015). Stated preferences for size and bag limits of Alaska charter
568 boat anglers. Marine Policy, 61, 66–76.
569 Loring, P.A. & Gerlach, C. (2010). Food security and conservation of Yukon River Salmon: Are
570 we asking too much of the Yukon river? Sustainability, 2, 2965–2987.
571 Loring, P.A., Gerlach, S.C., Atkinson, D.E. & Murray, M.S. (2011). Ways to help and ways to
572 hinder: Governance for effective adaptation to an uncertain climate. Arctic, 64, 73–88.
573 Loring, P.A. (2016). Toward a theory of coexistence in shared social-ecological systems: The
574 case of Cook Inlet salmon fisheries. Human Ecology, 44(2), 153–165.
575 Metcalf, S.J., Moyle, K. & Gaughan, D.J. (2010). Qualitative analysis of recreational fisher

response and the ecosystem impacts of management strategies in a data-limited situation. Fish. Res., 106, 289–297.

Minnegal, M. & Dwyer, P. (2008). Managing risk, resisting management: Stability and diversity in a southern Australian fishing fleet. Hum. Organ., 67, 97–108.

Neis, B., Felt, L., Schneider, D.C., Haedrich, R., Hutchings, J. & Fischer, J. (1999). Northern cod stock assessment: what can be learned from interviewing resource users? Can. J. Fish. Aquat. Sci., 56, 1949–1963.

NOAA. (2017). Charter Halibut Permits List. https://alaskafisheries.noaa.gov/permits-licenses?field_fishery_pm_value=Charter+Halibut. Accessed: April 2014 & April 2015.

Powers, B. & Sigurdsson, D. (2014). Participation, effort, and harvest in the sport fish business/guide licensing and logbook programs, 2014. ADF&G Fishery Data Series No. 16-02, Anchorage.

Romberg, W.J. (2016). Alaska statewide sport fish harvest survey, 2015. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan ROP.SF.4A.2015.05, Anchorage. Available: http://www.adfg.alaska.gov/FedAidPDFs/ROP.SF.4A.2015.05.pdf

Rossman, G.B. & Wilson, B.L. (1985). Numbers and words: Combining quantitative and qualitative methods in a single large-scale evaluation study. Evaluation Review, 9(5), 627–643.

Salas, S. & Gaertner, D. (2004). The behavioural dynamics of fishers: management implications. Fish Fish., 5, 153–167.

Sawchuk, J.H., Beaudreau, A.H., Tonnes, D., & Fluharty, D. (2015). Using stakeholder engagement to inform endangered species management and improve conservation. Marine Policy, 54, 98–107.

599 Sutton, S.G. & Ditton, R.B. (2005). The substitutability of one type of fishing for another.
600 North Am. J. Fish. Manag., 25, 536–546.
601 Wasserman, S. & Faust, K. (1994). Social network analysis: Methods and applications.
602 Cambridge, UK: Cambridge University Press. 576 p.
603 Williams, G.D., Levin, P.S. & Palsson, W.A. (2010). Rockfish in Puget Sound: An ecological
604 history of exploitation. Mar. Policy, 34, 1010–1020.
605

606 **Table 1.** Characteristics of interview respondents and number of respondents reporting a change
607 in harvested species. *percentages do not add up to 100% because some respondents identified
608 multiple trip types

	Southeast	Southcentral
Number of respondents	26	26
Mean (SD) age	41 (11)	54 (13)
Mean (SD) years of experience	13 (7)	21 (9)
Position		
Charter owner/operator	58%	85%
Hired captain	42%	15%
Type of trip offered*		
Fishing only, full day trip	100%	88%
Fishing only, partial day trip	0%	35%
Combination fishing/hunting or fishing/wildlife viewing	19%	27%
Change in harvested species		
Number of respondents reporting a change in species rankings or harvested species diversity	18	12
Number reporting an increase in harvested species diversity	14	10
Number reporting a decrease in harvested species diversity	0	1
Number reporting no change in harvested species diversity	12	15

609
610

611 **Table 2.** Respondents' reasons for changes in the number of harvested species and/or species
612 preferences, derived from an inductive analysis of themes. Primary themes are shown in bold
613 with secondary and tertiary (indented) themes beneath.

	Southeast		Southcentral	
Reasons for change	**N**	**%**	**N**	**%**
Change in customer preferences	**4**	**22%**	**8**	**67%**
Needed more options for customers	2	11%	1	8%
More customer interest in other species	3	17%	7	58%
More interest in rockfish	3	17%	2	17%
More interest in sablefish	3	17%	0	0%
More interest in Chinook salmon	0	0%	2	17%
More interest in Pacific cod	0	0%	3	25%
Regulatory changes	**18**	**100%**	**1**	**8%**
More restrictive regulations (halibut)	16	89%	1	8%
Limited entry (CHLAP 2011)	1	6%	0	0%
2 fish, 1 under 32 inches (2007)	2	11%	NA	NA
1-fish bag limit (2009)	1	6%	NA	NA
1 fish, max. size 37 inches (2011)	8	44%	NA	NA
Reverse slot limit (2012)	1	6%	NA	NA
2 fish, 1 with max. size 29 inches (2014)	NA	NA	1	8%
More restrictive regulations (other species)	5	28%	0	0%
More liberal regulations (other species)	1	6%	0	0%
Ecological shifts	**0**	**0%**	**5**	**42%**

Changes in species abundance	0	0%	5	42%
Decline in lingcod	0	0%	2	17%
Decline in yelloweye rockfish	0	0%	1	8%
Change in fishing practices	**3**	**17%**	**7**	**58%**
Increase in vessel power or fish-finding technology	1	6%	1	8%
Change in fishing area and/or depth	2	11%	4	33%
Fishing deeper because of halibut regulation changes	2	11%	0	0%
Change in trip type	0	0%	4	33%

614

615

Table 3. Annual number of charter trips and proportions of trips in which a given species or species group was retained, calculated from charter logbook data for the years 1998-2015. Numbers and proportions are shown separately for the Sitka area [Alaska Statewide Household Survey (SWHS) area D] and the Homer area (SWHS area P). 'NR' stands for not reported.

Year	Total trips	Salmon (all spp.)	Pacific halibut	Lingcod	Pelagic rockfishes	Non-pelagic rockfishes	Yelloweye rockfish	Sablefish
Sitka area (SWHS area D)								
1998	7235	0.84	0.54	0.25	0.18	0.21	NR	NR
1999	7585	0.88	0.56	0.26	0.14	0.30	NR	NR
2000	9123	0.83	0.63	0.15	0.17	0.39	NR	NR
2001	9421	0.91	0.60	0.17	0.12	0.35	NR	NR
2002	9441	0.88	NR	0.10	0.14	0.31	NR	NR
2003	9825	0.90	NR	0.13	0.17	0.28	NR	NR
2004	10735	0.92	NR	0.13	0.20	0.34	NR	NR
2005	11284	0.92	NR	0.17	0.21	0.36	NR	NR
2006	12140	0.90	0.60	0.17	0.26	0.38	0.33	NR
2007	12017	0.90	0.63	0.14	0.31	0.42	0.35	NR
2008	11397	0.80	0.59	0.12	0.40	0.44	0.34	NR
2009	7722	0.88	0.63	0.10	0.37	0.43	0.36	NR
2010	7840	0.88	0.60	0.10	0.43	0.52	0.40	0.01
2011	7828	0.93	0.62	0.15	0.52	0.47	0.27	0.02
2012	7647	0.89	0.68	0.21	0.54	0.55	0.31	0.04
2013	7306	0.92	0.72	0.20	0.53	0.51	0.30	0.06

2014	8264	0.92	0.74	0.16	0.55	0.51	0.27	0.04
2015	8657	0.92	0.73	0.13	0.55	0.56	0.32	0.03

Year	Total trips	Salmon (all spp.)	Pacific halibut	Lingcod	Pelagic rockfishes	Non-pelagic rockfishes	Yelloweye rockfish	Sablefish
Homer area (SWHS area P)								
1998	12035	0.20	0.91	0.01	0.02	0.01	NR	NR
1999	12231	0.19	0.91	0.01	0.02	0.01	NR	NR
2000	15637	0.15	0.93	0.01	0.02	0.02	NR	NR
2001	14927	0.19	0.94	0.02	0.02	0.02	NR	NR
2002	13051	0.23	NR	0.02	0.05	0.03	NR	NR
2003	12544	0.20	NR	0.02	0.08	0.03	NR	NR
2004	14374	0.22	NR	0.03	0.06	0.03	NR	NR
2005	14799	0.24	NR	0.03	0.06	0.03	NR	NR
2006	14668	0.22	0.95	0.03	0.04	0.02	0.02	NR
2007	15036	0.17	0.95	0.05	0.05	0.03	0.02	NR
2008	13332	0.13	0.96	0.05	0.04	0.03	0.03	NR
2009	10951	0.15	0.97	0.06	0.07	0.04	0.03	NR
2010	11261	0.14	0.97	0.06	0.07	0.06	0.04	0.00
2011	10845	0.18	0.97	0.06	0.08	0.06	0.05	0.00
2012	10242	0.11	0.97	0.05	0.08	0.06	0.04	0.00
2013	10326	0.16	0.96	0.05	0.08	0.06	0.04	0.00
2014	8739	0.23	0.97	0.05	0.10	0.06	0.05	0.00
2015	8766	0.35	0.92	0.03	0.12	0.06	0.04	0.00

620

Figure captions

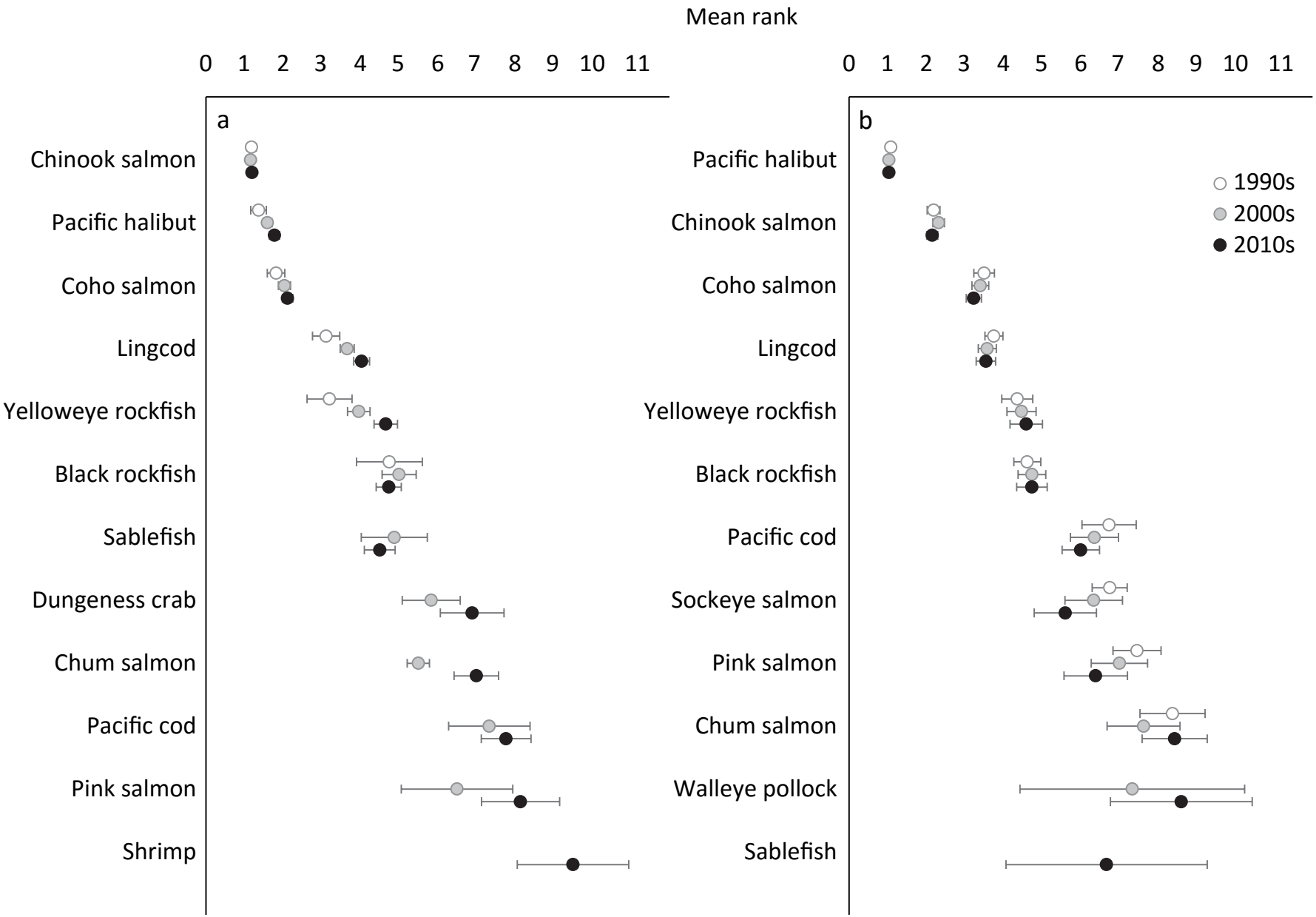
Figure 1 Average species ranking among interviewed charter captains in (a) Southeast and (b) Southcentral Alaska. A ranking of 1 indicates that a species was most preferred (i.e., most targeted). Error bars show ±1 SE. For each decade and region, only those species that were ranked by 3 or more respondents are shown.

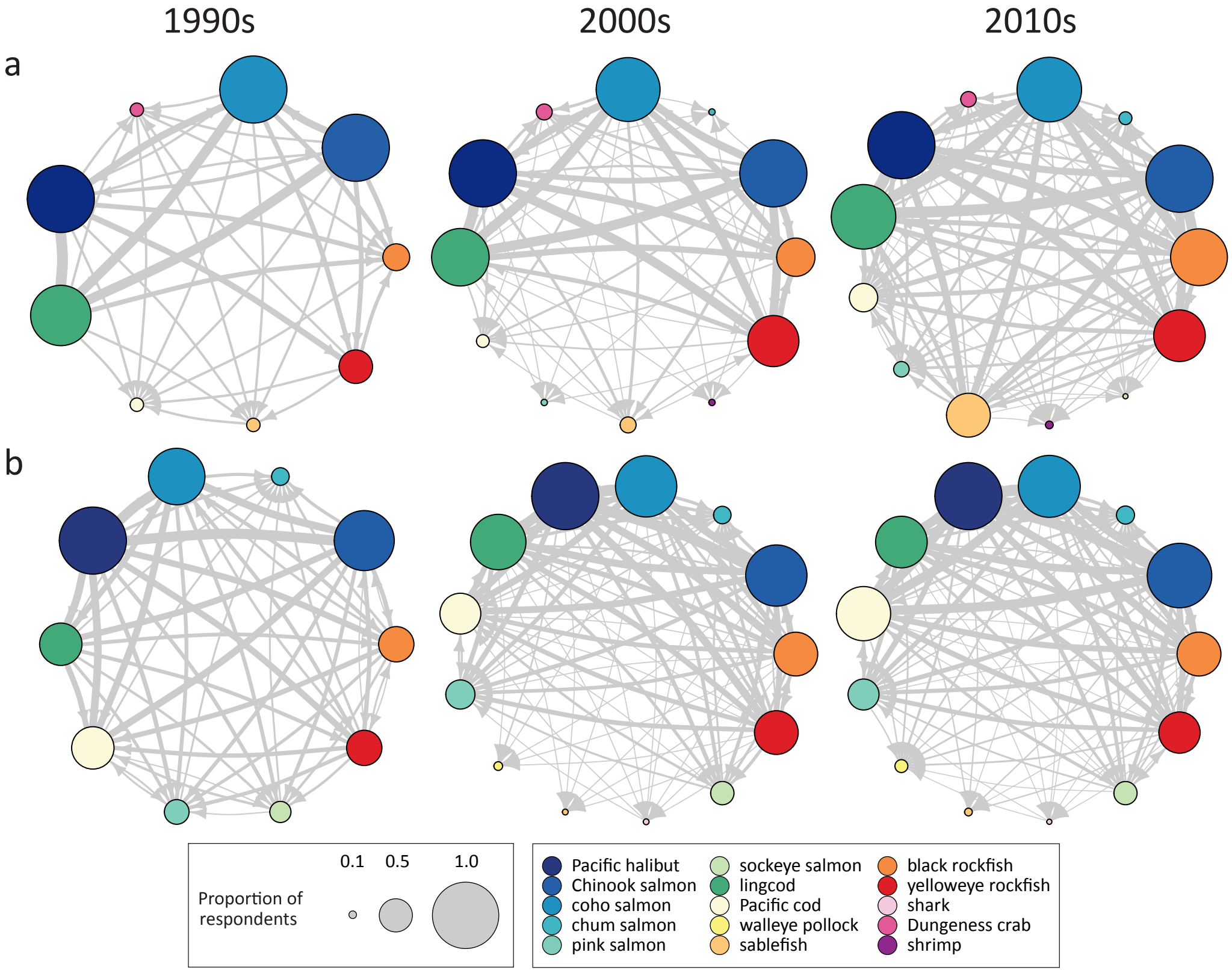
Figure 2 Network representations of harvested species portfolios among interviewed charter captains in (a) Southeast and (b) Southcentral Alaska for each decade from the 1990s to the 2010s. Colored circles represent species that are caught on charter trips and circle size is proportional to the number of respondents who harvested that species in a given region and period. Gray connecting arrows show relative rankings among pairs of species and their widths are proportional to the number of respondents who harvested each pair. An arrow originating from species A to species B indicates that species A was ranked as more preferred by all respondents who targeted that pair of species; bidirectional arrows indicate that the relative ranking between species varied among respondents. The number of arrows increases with the number of species combinations harvested by respondents (i.e., increasing portfolio diversity among respondents). Only pairs of species that were ranked relative to each other by at least two respondents in a given region and period were included in the visualization.

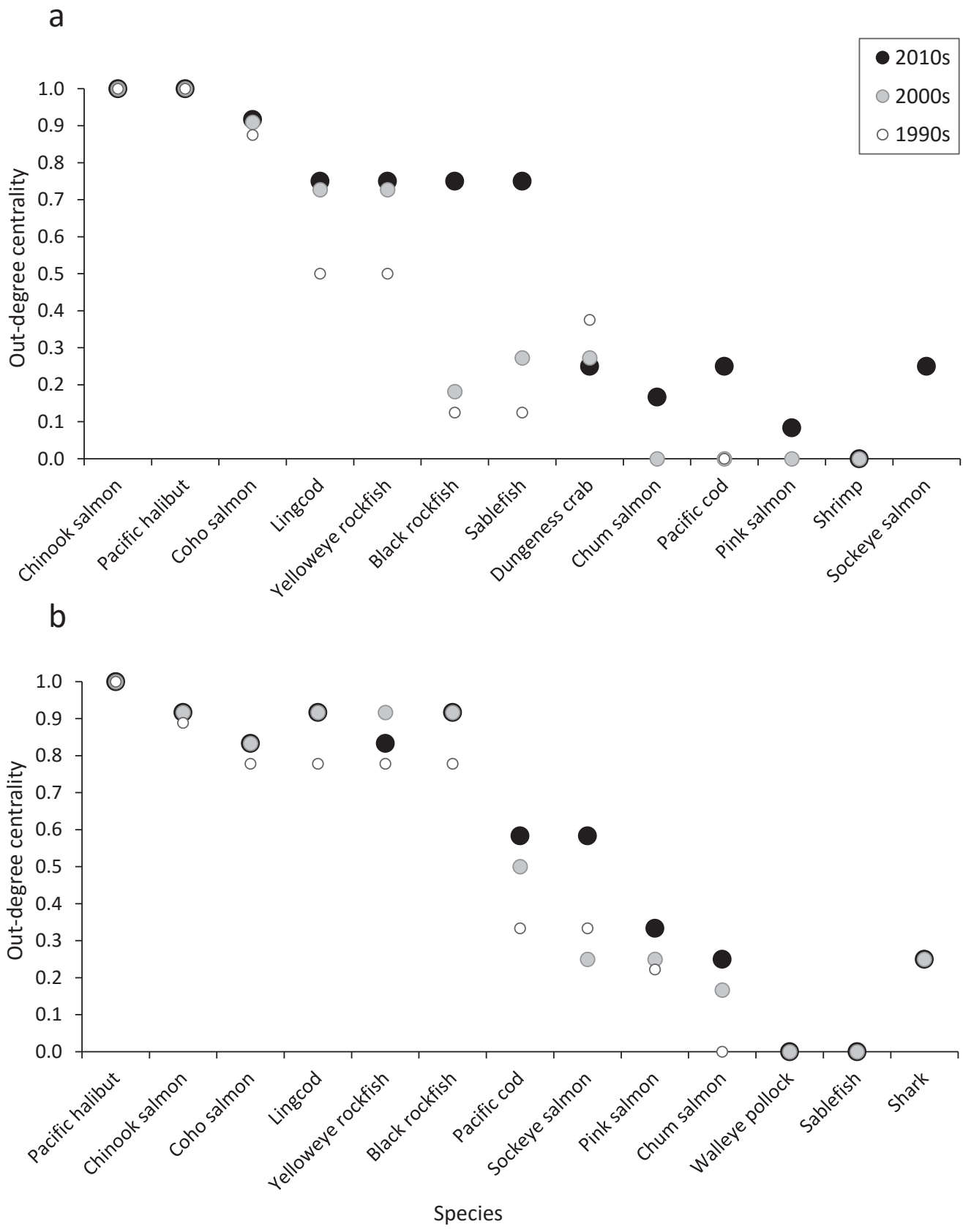
Figure 3 Out-degree centrality measures calculated from directed networks representing the aggregate harvest portfolios for charter captains in a) Southeast and b) Southcentral Alaska. Out-degree centrality is the number of outgoing links from each node (species) in the network.

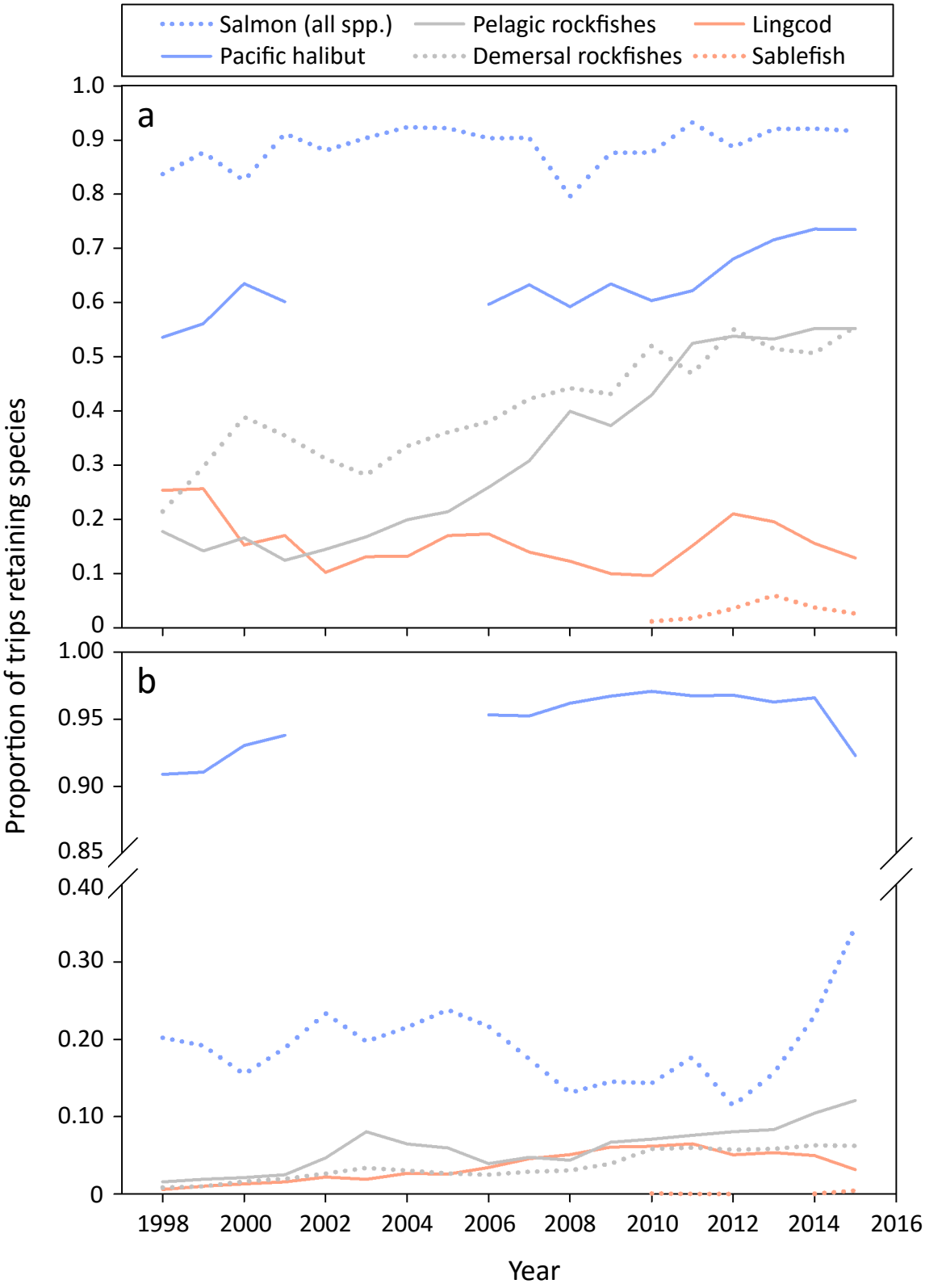
Figure 4 Proportion of charter trips in a) Sitka area (Southeast region), and b) Homer area (Southcentral region) in which particular species were retained by anglers. Trip-level data for the

643 years 1998 to 2015 were summarized from mandatory charter logbooks maintained by the
644 Alaska Department of Fish and Game.


Mean rank
0 1 2 3 4 5 6 7 8 9 10 11
a
Chinook salmon
Pacific halibut
Coho salmon
Lingcod
Yelloweye rockfish
Black rockfish
Sablefish
Dungeness crab
Chum salmon
Pacific cod
Pink salmon
Shrimp
0 1 2 3 4 5 6 7 8 9 10 11
b
Pacific halibut
Chinook salmon
Coho salmon
Lingcod
Yelloweye rockfish
Black rockfish
Pacific cod
Sockeye salmon
Pink salmon
Chum salmon
Walleye pollock
Sablefish
1990s
2000s
2010s


1990s
2000s
2010s
a
b
0.1
0.5
1.0
Proportion of respondents
Pacific halibut
Chinook salmon
coho salmon
chum salmon
pink salmon
sockeye salmon
lingcod
Pacific cod
walleye pollock
sablefish
black rockfish
yelloweye rockfish
shark
Dungeness crab
shrimp


a
2010s
2000s
1990s
Out-degree centrality
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Chinook salmon
Pacific halibut
Coho salmon
Lingcod
Yelloweye rockfish
Black rockfish
Sablefish
Dungeness crab
Chum salmon
Pacific cod
Pink salmon
Shrimp
Sockeye salmon
b
Out-degree centrality
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Pacific halibut
Chinook salmon
Coho salmon
Lingcod
Yelloweye rockfish
Black rockfish
Pacific cod
Sockeye salmon
Pink salmon
Chum salmon
Walleye pollock
Sablefish
Shark
Species


Salmon (all spp.)
Pelagic rockfishes
Lingcod
Pacific halibut
Demersal rockfishes
Sablefish
a
b
Proportion of trips retaining species
Year
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.00
0.95
0.90
0.85
0.40
0.30
0.20
0.10
0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016