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ABSTRACT: Most groundfish species managed by the North Pacific Fishery Management Council are closed to directed fishing for a portion of the fishing year for various reasons, the most common being the attainment of the total allowable catch (TAC) or the seasonal allowance of the TAC. Bycatch of non-targeted groundfish species for which directed fishing is closed may be retained in other fisheries up to a maximum retainable bycatch (MRB) level established by regulation as a percentage of the directed catch retained during a fishing trip. For some species, MRB percentages are generously set at levels that exceed "natural" bycatch rates to maximize the opportunity to retain these non-targeted species while reducing overall harvest rates. When the bycatch species is more economically valuable than the target species an incentive exists to "top off" by targeting the bycatch species until the MRB level is attained. We contrast 2 fisheries in which topping-off behavior was previously anecdotally reported. Because of differing species spatial distributions, some rockfish fisheries, *Sebastes* and *Sebastolobus*, in the Gulf of Alaska usually have an observed sablefish *Anoplopoma fimbria* bycatch rate below the prescribed MRB. These natural bycatch rates were estimated based on National Marine Fisheries Service survey and observer program fishery data. The estimated bycatch rates were reasonably precise with most coefficients of variation less than 50% for species of interest. By examining the observed catch from individual trawl hauls in a geographical information system, we were able to demonstrate topping-off behavior with more valuable sablefish in the rockfish fishery. The temporal and spatial targeting patterns of individual vessels were tracked, and distinctive hauls with sablefish as the dominant catch were identified. Similarly, shortraker *Sebastes borealis* and rougheye *S. aleutianus* rockfish are more valuable than Pacific ocean perch *S. alutus* in the Aleutian Islands, and there were anecdotal reports of topping-off with the shortraker–rougheye management complex of rockfish. However, our analysis did not reveal strong evidence of this practice.

INTRODUCTION

Fisheries resources are harvested under a framework of regulations. In addition to seasonal or area-specific guidelines, fishermen are regulated in the amounts and species of fish they are allowed to retain. Because much of the gear used in fishing is not species-specific, a species that cannot be retained due to management restrictions may still be subject to capture by fishing gear. In light of this fact, fishery managers must account for non-targeted catch, attempt to reduce encounters of sensitive or fully allocated species, and make retention allowances so that inadvertently encountered fish are not unnecessarily discarded.

Maximum retainable bycatch (MRB) is used by managers of Alaska's commercial groundfish fisheries to reduce the harvest rate of a species, which is closed to directed fishing, by limiting the amount of that species that may be retained in other directed fisheries. In the course of a fishing trip, the amount of a bycatch species allowed to be retained is equal to a percentage of the directed retained catch by weight. A fishing trip is defined as the period between commencement of fishing and delivery for processing or till the end of a weekly reporting period. For instance, sablefish *Anoplopoma fimbria* are currently allowed an MRB of up to 7% by weight of a trip's retained catch of rockfish, *Sebastes* and *Sebastolobus*, taken in an

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Table 1. Current Gulf of Alaska retainable percentages of bycatch species in rockfish fisheries.

	Target Species						
Bycatch Species (%)	Pacific Ocean Perch	Shortraker/ Rougheye Rockfish	Other Slope Rockfish	Northern Rockfish	Pelagic Shelf Rockfish	Demersal Shelf Rockfish	Shortspine Thornyhead
Walleye pollock	20	20	20	20	20	20	20
Pacific cod	20	20	20	20	20	20	20
Deep flatfish	20	20	20	20	20	20	20
Rex sole	20	20	20	20	20	20	20
Flathead sole	20	20	20	20	20	20	20
Shallow flatfish	20	20	20	20	20	20	20
Arrowtooth flounder	35	35	35	35	35	35	35
Sablefish	7	7	7	7	7	7	7
All rockfish	15	15	15	15	15	15	15
Demersal shelf rockfish	1	1	1	1	1		1
Atka mackerel	20	20	20	20	20	20	20
Other species	20	20	20	20	20	20	20

open rockfish fishery. Any sablefish caught in excess of this amount must be discarded. Such discards are in contrast to economic discards, which are related to factors such as markets and processing capacity (Pautzke 1996).

The MRB is one of many regulations or operational restrictions enacted by the North Pacific Fishery Management Council (NPFMC) to control bycatch. Seasons, gear restrictions, time and area closures, monitoring, and enforcement play important roles in controlling bycatch (Pautzke 1996; Witherell and Pautzke 1997). The intent is to set MRBs high enough to limit regulatory discards but low enough that they do not provide incentives for seeking out concentrations of restricted species thereby generating undesirably high harvest rates. In practice many MRBs have been widely set across broad categories, generally meeting the above goals without specifying individual fisheries or bycatch species. For instance, MRB rates for many bycatch species in the rockfish fisheries have been established at 20% (Table 1).

In this paper we define the bycatch rates usually seen in the pursuit of directed fishing as natural rates. Cases exist in which the established MRB levels are higher than the natural encounter rates for the bycatch species. In these cases, especially when the bycatch species are more economically valuable than the target species, an incentive exists to maximize the bycatch up to the MRB level. Maximizing the bycatch when the natural bycatch rates are low requires that hauls are made to "top off" the haul with, or specifically target, the bycatch species. Problems occur for fisheries managers when topping-off incentives inadvertently increase the harvest of a bycatch species above the total allowable catch (TAC) or disrupt the prescribed allocation among fisheries. When MRBs are too high, competition for the bycatch species occurs, and managers seek reductions in MRBs to reduce topping off without increasing discards.

Anecdotal reports of topping off sablefish in Gulf of Alaska rockfish fisheries and topping off shortraker *Sebastes borealis* and rougheye *S. aleutianus* rockfish in Pacific ocean perch *S. alutus* and Atka mackerel *Pleurogrammus monopterygius* fisheries in the Aleutian Islands provided the impetus for the analysis presented in this paper. Sablefish and shortraker and rougheye rockfish are economically valuable species, and the incentive to maximize their bycatch amounts is great. In 1996, for example, the average exvessel price for trawl-caught sablefish was $1.70 per pound, and the average exvessel price for rockfish (all species) was $0.15 per pound (Kinoshita et al. 1998). The rockfish price per pound is an average of the more valuable rockfish species such as the shortraker–rougheye rockfish complex and the less valuable but more plentiful species such as Pacific ocean perch. In 1996 shortraker–rougheye rockfish had a first wholesale value (exvessel price information was not available) of $1.10–$1.80 per pound. However, the amount of these species available as retainable bycatch in nondirected fisheries is limited. Sablefish are currently fully allocated and managed under an individual transferable quota system, and rockfish in the shortraker–rougheye management category have a relatively small TAC, which has been exceeded in recent years. Trawl fisheries in the Gulf of Alaska can retain sablefish only as bycatch, and shortraker and rougheye rockfish are retainable only as bycatch for all gear types in the Aleutian Islands.

The estimated natural bycatch rates of various species, including sablefish, were estimated in the Gulf of Alaska rockfish fisheries (Heifetz and Ackley 1997).

Bycatch of various rockfish species in the Aleutian Islands Pacific ocean perch and Atka mackerel fisheries was presented as part of a NPFMC proposed regulatory change to lower the MRB rate for shortraker–rougheye rockfish in Aleutian Islands fisheries in 1997.

This paper summarizes fisheries information primarily from the rockfish fisheries and provides: estimates of natural bycatch rates based on survey and fishery data, currently established MRB rates, examples of topping off of sablefish in the Gulf of Alaska which are apparent in the data, and examples of topping off of shortraker–rougheye rockfish in the Aleutian Islands not indicated by the data. The natural bycatch rates of individual hauls were examined for patterns in target categories, and topping-off behavior was indicated when hauls generally made in one target category shifted into another category. We emphasize bycatch of sablefish in the Gulf of Alaska because sablefish is a bycatch-only species during the entire year for all trawl fisheries, and we use sablefish as an example of topping-off behavior.

METHODS

Data

Two sources of data used to estimate natural bycatch rates were data from National Marine Fisheries Service (NMFS) triennial trawl surveys for 1990, 1993, and 1996, and fishery data from the NMFS Observer Program for 1994–1996. Although the rates generated from survey data do not necessarily represent normal fleet operations because of possible gear, geographic, and seasonal differences between the survey and the fishery, survey data can supply a fishery-independent estimate of bycatch rates that can be compared to rates determined from the fishery. Fishery data included vessel, haul, and catch information. In the Gulf of Alaska a total of 5,428 hauls were observed in 1994, 7,369 hauls in 1995, and 7,353 hauls in 1996. The observed tonnage in each year represented roughly 39%, 41%, and 53% of the total reported catch in 1994, 1995, and 1996, respectively. In the Aleutian Islands a total of 4,066 hauls were observed in 1995, and 4,931 were observed in 1996.

Assignment of Target Species

We based bycatch rates on the accumulation of the catch by species over all hauls within a target category. A problem in examining data from the fishery is that more than one species may be a target during a particular time period, and at times even species that are on bycatch-only status may be targeted in a particular haul if the bycatch allowance has not been met.

The first step in the estimation process was to determine the target species in each haul for both the survey and fishery data. Each haul was assigned the NPFMC management category with the highest catch weight. The categories were walleye pollock *Theragra chalcogramma*, Pacific cod *Gadus macrocephalus*, deepwater flatfish, rex sole *Glyptocephalus zachirus*, flathead sole *Hippoglossoides elassodon*, shallow-water flatfish, sablefish, Atka mackerel, and aggregated rockfish (all *Sebastes* and *Sebastolobus* rockfishes). Arrowtooth flounder *Atheresthes stomias* was not included as a category because it is rarely targeted by the commercial fishery, though arrowtooth flounder often dominates the catch of many survey hauls. Analysis of bycatch rates was limited to hauls in which aggregated rockfish was the dominant species group. In total, 187 tows from the 1990 triennial trawl survey, 204 tows from the 1993 survey, and 228 hauls from the 1996 survey were in the rockfish category. These aggregated rockfish hauls were further categorized based on the rockfish management group with the highest catch weight. The categories were Pacific ocean perch, shortraker–rougheye rockfish, other slope rockfish, demersal shelf rockfish, northern rockfish *Sebastes polyspinis*, pelagic shelf rockfish, and shortspine thornyheads *Sebastolobus alascanus*. These secondary targets represent the NPFMC management categories for rockfish. The pelagic shelf rockfish category was comprised almost entirely of dusky rockfish *Sebastes ciliatus*, and the 2 are considered to be synonymous. From the observer data, the demersal shelf rockfish category included only a few hauls and was not examined in detail in this analysis. The number of hauls (n_k) by rockfish category and year from NMFS survey and observer data are summarized in Tables 2 and 3.

In each rockfish category the bycatch rates of non-rockfish species and other rockfish species were examined as well as the bycatch rate of aggregated rockfish, which was defined as total rockfish minus the weight of the target rockfish species. For example, in the pelagic shelf rockfish category the bycatch rates of non-rockfish species, Pacific ocean perch, northern rockfish, shortspine thornyheads, shortraker–rougheye rockfish, demersal shelf rockfish, and other slope rockfish were examined as well as the bycatch rate of all rockfish combined minus the target species weight, in this case, pelagic shelf rockfish.

Table 2. Estimated natural bycatch rates in Gulf of Alaska rockfish fisheries based on survey data.

		Bycatch Rate (%)			Coefficient of Variation (%)		
Target Species	Bycatch Species	1990	1993	1996	1990	1993	1996
Northern rockfish	Pacific ocean perch	6.1	3.6	11.8	52.9	52.3	10.1
	Pelagic shelf rockfish	11.2	12.2	11.5	40.7	46.2	15.3
	Shortspine thornyhead	0.0	0.0	0.0		109.5	27.9
	Shortraker/rougheye	0.0	0.0	0.1	66.3	57.3	28.2
	Demersal shelf rockfish	0.1	0.2	0.3	69.7	62.5	27.7
	Other slope rockfish	9.3	2.8	4.6	79.2	45.2	8.4
	Rockfish minus target	27.0	18.7	28.3	23.7	40.9	5.0
	Sablefish	0.4	1.0	0.7	85.7	98.7	27.9
	Pacific cod	2.1	3.7	5.0	64.8	44.5	24.0
	Walleye pollock	0.2	0.8	1.9	94.0	77.9	26.0
	Rex sole	0.8	1.0	1.6	87.3	49.0	27.4
	Flathead sole	0.2	0.4	0.1	79.8	77.1	28.3
	Arrowtooth flounder	5.8	16.4	22.4	63.7	54.9	27.9
	Deepwater flatfish	0.1	0.3	0.9	76.1	56.3	27.5
	Shallow-water flatfish	1.4	0.8	1.9	57.8	49.5	25.5
	Number of Hauls	24	26	28			
Other slope rockfish	Pacific ocean perch	10.6	23.4	13.1	44.9	27.5	19.8
	Northern rockfish	0.4	8.3	0.0	67.7	83.8	26.5
	Pelagic shelf rockfish	7.6	18.8	7.3	62.8	51.7	18.5
	Shortspine thornyhead	1.5	3.6	0.8	52.6	36.1	27.6
	Shortraker/rougheye	0.5	0.5	0.7	64.0	62.4	25.4
	Demersal shelf rockfish	1.3	1.2	1.2	29.3	32.3	18.7
	Rockfish minus target	22.4	55.9	23.2	30.8	34.4	18.2
	Sablefish	3.2	4.0	1.2	58.9	32.0	25.9
	Pacific cod	3.4	3.6	1.5	37.8	27.6	28.7
	Walleye pollock	3.1	5.0	1.4	56.9	41.3	29.6
	Rex sole	0.7	2.8	1.4	39.0	41.9	29.8
	Flathead sole	0.5	0.4	0.0	103.1	93.8	24.4
	Arrowtooth flounder	16.5	34.8	13.2	44.3	51.5	29.2
	Deepwater flatfish	1.6	3.5	0.7	49.3	41.6	28.8
	Shallow-water flatfish	0.1	0.0	0.1	102.3	82.8	29.3
	Number of Hauls	30	28	28			
Pacific ocean perch	Northern rockfish	0.9	1.7	1.0	43.5	46.0	12.8
	Pelagic shelf rockfish	1.8	0.7	0.3	63.9	45.4	12.0
	Shortspine thornyhead	5.5	1.8	2.2	26.4	24.2	14.7
	Shortraker/rougheye	1.2	1.6	1.0	34.1	33.1	14.0
	Demersal shelf rockfish	0.2	0.1	0.1	35.6	33.2	15.3
	Other slope rockfish	4.5	4.7	2.8	28.5	35.3	13.1
	Rockfish minus target	14.1	10.7	7.3	11.2	21.0	12.5
	Sablefish	6.7	9.8	3.0	44.6	39.3	12.5
	Pacific cod	5.7	3.4	2.1	30.6	32.1	13.1
	Walleye pollock	10.0	3.9	2.2	31.5	28.2	13.4
	Rex sole	4.6	1.7	1.5	36.4	24.9	13.6
	Flathead sole	0.8	0.2	0.1	45.1	61.8	15.1
	Arrowtooth flounder	36.1	23.8	8.1	45.0	34.4	13.7
	Deepwater flatfish	4.7	2.5	1.4	28.6	28.6	14.8
	Shallow-water flatfish	0.2	0.1	0.1	71.0	47.2	14.3
	Number of Hauls	73	80	95			

– continued –

Table 2. (continued)

Target Species	Bycatch Species	Bycatch Rate (%) 1990	1993	1996	Coefficient of Variation (%) 1990	1993	1996
Pelagic shelf rockfish	Pacific ocean perch	12.7	7.9	46.0	35.1	88.7	21.2
	Northern rockfish	6.6	33.7	42.7	40.8	45.3	30.6
	Shortspine thornyhead	0.0	0.0	0.0	120.5	118.1	63.6
	Shortraker/rougheye	0.7	0.4	1.0	100.0	101.4	28.0
	Demersal shelf rockfish	1.1	0.2	0.2	71.4	115.5	45.2
	Other slope rockfish	37.3	1.7	4.2	29.8	40.6	26.6
	Rockfish minus target	58.3	43.9	94.1	36.3	49.9	4.2
	Sablefish	0.3	1.4	6.7	76.6	87.0	29.8
	Pacific cod	4.3	4.9	15.5	44.5	37.0	28.2
	Walleye pollock	0.9	0.1	0.4	89.1	41.9	63.9
	Rex sole	1.0	1.5	1.0	69.4	80.4	29.9
	Flathead sole	0.1	0.5	0.9	123.0	46.5	48.9
	Arrowtooth flounder	5.8	61.5	50.1	77.5	71.1	56.3
	Deepwater flatfish	0.3	2.0	1.4	81.9	67.3	45.2
	Shallow-water flatfish	0.0	2.1	0.1		0.0	60.8
	Number of Hauls	7	11	7			
Shortraker/rougheye rockfish	Pacific ocean perch	4.8	3.5	4.1	37.4	51.4	22.2
	Northern rockfish	0.0	0.1	0.0	71.8	48.5	
	Pelagic shelf rockfish	0.1	0.1	0.0	79.8	66.7	
	Shortspine thornyhead	17.4	12.0	20.8	13.6	26.9	16.6
	Demersal shelf rockfish	0.0	0.0	0.0	100.6		26.1
	Other slope rockfish	0.8	0.3	0.4	47.9	65.8	25.9
	Rockfish minus target	23.1	16.0	25.2	22.6	28.0	17.4
	Sablefish	18.8	15.3	18.7	26.9	31.8	22.3
	Pacific cod	0.2	1.8	0.1	62.2	51.8	23.8
	Walleye pollock	8.1	4.5	4.2	39.2	33.4	24.8
	Rex sole	1.8	6.2	5.2	31.7	29.7	27.5
	Flathead sole	1.2	3.6	1.3	81.5	45.2	27.6
	Arrowtooth flounder	37.1	65.8	31.2	40.7	29.8	26.7
	Deepwater flatfish	11.1	10.9	11.3	19.8	32.8	24.4
	Shallow-water flatfish	0.0	0.0	0.0	75.6	85.4	23.0
	Number of Hauls	39	39	33			
Shortspine thornyhead	Pacific ocean perch	24.9	13.3	20.3	25.3	33.3	16.4
	Northern rockfish	0.0	0.2	0.1		82.9	23.4
	Pelagic shelf rockfish	0.2	0.5	0.4	93.8	80.5	22.6
	Shortraker/rougheye	30.4	34.5	28.3	34.9	20.3	18.4
	Demersal shelf rockfish	0.6	0.0	0.0	75.8		
	Other slope rockfish	14.0	1.1	1.4	63.8	39.6	23.0
	Rockfish minus target	70.1	49.7	50.5	35.3	17.1	13.5
	Sablefish	29.0	59.2	45.5	30.3	19.1	14.1
	Pacific cod	3.0	1.0	1.4	70.2	87.7	22.6
	Walleye pollock	24.5	26.9	13.9	46.6	24.3	24.8
	Rex sole	13.9	23.5	20.6	26.6	29.6	21.1
	Flathead sole	8.4	10.6	1.8	87.9	74.3	25.3
	Arrowtooth flounder	113.9	84.4	48.3	50.2	14.4	21.6
	Deepwater flatfish	47.4	53.2	34.7	26.1	23.2	21.2
	Shallow-water flatfish	0.1	0.1	0.0	101.4	71.0	23.4
	Number of Hauls	14	20	37			

Table 3. Estimated bycatch rates in Gulf of Alaska rockfish fisheries based on observer data for the entire year.

		Bycatch Rate (%)			Coefficient of Variation (%)		
Target Species	Bycatch Species	1994	1995	1996	1994	1995	1996
Northern rockfish	Pacific ocean perch	2.2	3.2	4.6	29.7	18.2	24.4
	Pelagic shelf rockfish	16.3	19.3	34.4	5.5	7.2	7.5
	Shortspine thornyhead	0.0	0.2	0.0	66.6	41.6	59.9
	Shortraker/rougheye	0.1	0.1	0.2	34.2	47.6	57.3
	Demersal shelf rockfish	0.2	0.3	0.5	29.1	22.5	20.6
	Other slope rockfish	3.5	3.6	6.9	11.7	14.4	16.0
	Rockfish minus target	22.4	28.8	48.4	6.3	7.7	8.2
	Sablefish	0.3	0.4	0.4	35.0	35.7	50.1
	Pacific cod	2.0	2.1	3.7	15.9	15.2	22.8
	Walleye pollock	0.1	0.1	0.2	45.1	54.1	60.5
	Pacific halibut	0.6	1.4	2.6	21.9	24.7	15.0
	Rex sole	0.1	0.2	1.6	32.5	29.9	38.5
	Flathead sole	0.0	0.1	0.5	36.5	36.7	43.5
	Arrowtooth flounder	1.0	2.1	6.6	26.3	23.7	33.2
	Deepwater flatfish	0.1	0.1	0.2	36.5	34.1	43.6
	Shallow-water flatfish	0.1	0.1	0.2	28.3	20.6	28.2
	Number of Hauls	281	283	156			
Other slope rockfish	Pacific ocean perch	6.0	9.4	4.5	42.2	43.6	30.8
	Northern rockfish	13.7	17.0	22.7	53.3	28.1	24.7
	Pelagic shelf rockfish	51.4	39.8	50.3	19.7	21.2	18.5
	Shortspine thornyhead	0.5	0.1	0.7	51.4	61.5	65.5
	Shortraker/rougheye	0.2	0.1	0.2	97.7	84.2	53.1
	Demersal shelf rockfish	20.1	1.4	2.8	44.1	39.7	60.5
	Rockfish minus target	130.6	75.6	106.2	13.6	17.6	15.7
	Sablefish	1.6	0.5	1.2	45.9	62.8	107.8
	Pacific cod	1.5	2.8	1.9	38.2	50.3	41.1
	Walleye pollock	0.5	0.3	0.4	87.7	97.1	50.5
	Pacific halibut	2.6	1.0	4.5	38.8	60.3	45.9
	Rex sole	0.2	0.4	0.7	46.6	78.0	55.6
	Flathead sole	0.0	0.2	0.0	104.7	73.5	
	Arrowtooth flounder	2.3	4.7	6.0	48.4	72.0	78.7
	Deepwater flatfish	0.3	0.2	0.2	52.7	104.3	90.6
	Shallow-water flatfish	0.0	0.0	0.0	88.5	108.8	
	Number of Hauls	41	19	16			
Pacific ocean perch	Northern rockfish	10.0	1.5	1.6	53.4	24.8	17.5
	Pelagic shelf rockfish	6.9	2.8	1.4	29.4	26.0	15.4
	Shortspine thornyhead	2.2	2.0	1.1	25.1	13.2	14.1
	Shortraker/rougheye	4.2	5.3	2.1	24.9	12.8	21.4
	Demersal shelf rockfish	0.1	0.1	0.0	30.9	30.4	29.0
	Other slope rockfish	6.0	1.5	0.7	27.7	33.3	19.4
	Rockfish minus target	36.2	15.3	9.5	21.7	11.8	9.9
	Sablefish	11.5	5.0	3.8	20.1	16.2	15.2
	Pacific cod	3.8	1.6	1.9	24.1	14.9	13.0
	Walleye pollock	1.8	2.2	1.6	25.0	14.4	17.2
	Pacific halibut	4.5	3.0	1.5	22.0	21.1	14.1
	Rex sole	4.1	1.7	2.0	25.2	23.0	15.8
	Flathead sole	0.8	0.2	0.2	34.3	25.5	28.5
	Arrowtooth flounder	25.6	11.4	10.8	17.8	11.5	13.9
	Deepwater flatfish	3.0	0.5	0.6	25.7	16.1	15.5
	Shallow-water flatfish	0.1	0.0	0.1	57.4	52.0	41.8
	Number of Hauls	104	213	330			

– continued –

Table 3. (continued)

Target Species	Bycatch Species	Bycatch Rate (%) 1994	1995	1996	Coefficient of Variation (%) 1994	1995	1996
Pelagic shelf rockfish	Pacific ocean perch	4.6	11.1	7.4	18.2	16.5	27.5
	Northern rockfish	23.1	30.7	49.1	16.5	13.9	10.9
	Shortspine thornyhead	0.3	0.1	0.0	54.3	46.8	64.2
	Shortraker/rougheye	0.8	0.7	0.7	47.6	43.8	71.9
	Demersal shelf rockfish	2.7	1.1	0.8	22.8	23.2	24.4
	Other slope rockfish	28.1	21.4	20.2	8.9	13.6	14.6
	Rockfish minus target	85.4	76.5	87.5	8.7	9.8	9.6
	Sablefish	12.0	2.0	3.0	20.1	26.5	34.9
	Pacific cod	4.5	5.5	4.9	18.0	25.2	20.7
	Walleye pollock	0.2	0.0	0.2	32.4	49.2	55.9
	Pacific halibut	9.6	5.3	4.5	15.9	27.6	18.3
	Rex sole	1.2	1.2	1.1	20.4	47.7	39.6
	Flathead sole	0.2	0.2	0.3	49.1	65.7	55.9
	Arrowtooth flounder	10.1	6.2	4.6	32.0	21.6	32.6
	Deepwater flatfish	1.1	0.9	0.1	25.3	64.8	43.2
	Shallow-water flatfish	0.1	0.1	0.3	32.3	59.9	67.1
	Number of Hauls	131	98	73			
Shortraker/rougheye rockfish	Pacific ocean perch	4.1	11.5	8.6	37.4	26.7	20.7
	Northern rockfish	0.1	0.2	0.3	44.8	43.0	38.3
	Pelagic shelf rockfish	0.2	0.1	0.7	43.6	50.5	56.9
	Shortspine thornyhead	11.9	9.3	8.6	16.1	13.7	11.5
	Demersal shelf rockfish	0.0	0.0	0.0	100.2	101.2	52.6
	Other slope rockfish	0.2	0.1	0.3	70.6	60.0	46.5
	Rockfish minus target	17.4	22.2	24.1	17.4	17.1	14.3
	Sablefish	21.1	22.4	17.8	16.8	15.0	12.6
	Pacific cod	0.4	0.2	2.0	53.4	52.8	36.8
	Walleye pollock	0.6	1.0	1.0	33.4	35.3	38.2
	Pacific halibut	4.3	4.2	3.5	39.4	24.8	26.6
	Rex sole	1.8	2.1	1.3	22.6	22.5	24.4
	Flathead sole	0.2	0.1	0.2	53.4	42.8	62.8
	Arrowtooth flounder	42.4	43.4	29.3	23.8	17.2	23.1
	Deepwater flatfish	9.6	4.8	5.0	25.8	22.0	23.3
	Shallow-water flatfish	0.0	0.0	0.1	101.4	59.8	84.6
	Number of Hauls	89	99	97			
Shortspine thornyhead	Pacific ocean perch	8.2	23.9	20.8	41.8	26.6	34.1
	Northern rockfish	0.7	2.7	3.3	100.2	67.2	72.3
	Pelagic shelf rockfish	0.2	0.3	0.2	96.6	101.5	75.7
	Shortraker/rougheye	23.6	25.0	22.5	25.9	30.3	26.5
	Demersal shelf rockfish	0.0	0.0	0.0	103.6		
	Other slope rockfish	0.1	0.0	0.1	103.6		104.3
	Rockfish minus target	35.7	52.9	48.8	21.9	26.0	23.1
	Sablefish	48.5	29.7	29.0	9.9	23.4	26.8
	Pacific cod	0.9	1.8	4.0	47.9	69.5	54.0
	Walleye pollock	11.7	5.8	13.0	34.2	36.5	49.1
	Pacific halibut	6.1	16.2	11.4	25.7	54.5	34.8
	Rex sole	9.1	11.2	20.4	26.8	37.7	29.5
	Flathead sole	0.3	2.5	1.0	98.3	50.6	34.7
	Arrowtooth flounder	67.1	93.4	120.1	16.5	44.1	21.5
	Deepwater flatfish	18.2	38.1	31.6	21.5	26.9	27.8
	Shallow-water flatfish	0.0	0.1	0.2		101.5	52.7
	Number of Hauls	38	15	25			

Computation of Bycatch Rates

We used survey and fisheries data to estimate natural bycatch rates of NPFMC-managed species in rockfish fisheries of the Gulf of Alaska and in the Pacific ocean perch and Atka mackerel fisheries in the Aleutian Islands. Natural bycatch rates are calculated based on the species composition of the total catch from individual hauls. The natural bycatch rates are calculated as the ratio of the total incidental catch of a particular species or assemblage to the total catch of the species or assemblage that is the target of a directed fishery (as listed in Table 1).

Letting C_{ijk} equal catch of species i in haul j where species k is the target, and T_{jk} equal the catch of target species k in haul j, the bycatch rate of species i when species k is the target is

$$B_{ik} = \frac{\sum_j C_{ijk}}{\sum_j T_{jk}} = \frac{\bar{C}_{ik}}{\bar{T}_k} \ . \qquad (1)$$

The approximate variance of such a ratio estimator can be derived using the delta method (Seber 1982) to give

$$Var(B_{ik}) = \frac{1}{n_k \bar{T}_k^2} (s^2_{T_k} B_{ik}^2 + s^2_{C_{ik}} - 2 r_{ik} s_{T_k} s_{C_{ik}} B_{ik}), \quad (2)$$

where n_k is the number of hauls where species k is the target, $s^2_{C_{ik}}$ and $s^2_{T_k}$ are the estimated variances of C_{ik} and T_k, respectively, and r_{ik} is the correlation between C_{ik} and T_k. We provide estimates of the coefficient of variation (CV) for all estimates. The CV is the standard deviation (i.e., square root of the estimated variance from Eq. 2) divided by the estimate. The CV allows comparisons of the precision of various estimates.

Analysis

Anecdotal information indicated that some rockfish fisheries operating in the Gulf of Alaska in July generally had low sablefish bycatch rates. However, some fishermen were topping off to increase the amount of sablefish in a trip to an amount approaching the MRB level, thus increasing overall sablefish harvest rates to levels that exceeded quotas. For instance, sablefish quotas in non-directed fisheries are frequently exceeded in the Central Gulf of Alaska management area (annual NMFS catch statistics are available at http://www.fakr.noaa.gov/sustainablefisheries/catchstats.htm). The NMFS observer data from individual vessels operating during 1994–1996 were analyzed spatially and temporally for indications of topping off. Data from 1995 and 1996 were used in a similar analysis of hauls in the Aleutian Islands fisheries for Pacific ocean perch or Atka mackerel to assess bycatch rates and the anecdotal evidence of topping off on shortraker–rougheye rockfish. One vessel was chosen for illustrative purposes. This vessel was generally representative of the other vessels, but vessel behavior varies because each vessel is unique as to target preference, reactions to anticipated management actions, areas fished, economic decisions, vessel configuration, and other factors. Because the hauls are vessel specific, and thus confidential, only general descriptions of target preferences are presented to protect vessel identities.

A primary temporal indicator of topping-off behavior is target switching, when several hauls in succession are made for one target and then one or more are made for another target. The spatial component of target switching is revealed using a geographical information system (GIS) when several hauls under one target are made in one location and then the location and target change for a brief period. Once temporal target switching was indicated, the hauls were examined with GIS (ArcView and ARC/INFO) to see if the hauls apparently made to top off were also spatially separated from the primary target hauls. A GIS was used to display the location of each haul from all vessels, including the example vessel, and to provide indications of a spatial component to the apparent patterns in targeting. Whereas a detailed analysis was conducted on individual hauls by individual vessels, all hauls from all vessels and gear types for multiple years were combined in maps so the individual fishing behavior or specific haul locations for individual vessels remains confidential.

RESULTS

Gulf of Alaska Rockfish Fisheries

In the survey data aggregated rockfish (the total across all rockfish target categories; rockfish minus target in Table 2) was the dominant species group for 619 hauls over 3 survey years (Table 2). Of these hauls Pacific ocean perch was the target species in 40% of the hauls, followed by shortraker–rougheye rockfish (18%), other slope rockfish (14%), northern rockfish (13%), shortspine thornyheads (11%), pelagic shelf rockfish (4%), and demersal shelf rockfish (1%). Demersal shelf

Table 4. Average bycatch rates of rockfish in the Aleutian Islands Atka mackerel fishery. Rates are defined as the ratio of bycatch weight to directed species catch weight.

		Rate (%)		CV (%)	
Bycatch Species	Area	1995	1996	1995	1996
Northern rockfish	Aleutian Islands (Total)	3.13	3.81	5.11	4.08
	Eastern Aleutians	2.25	1.90	11.75	11.83
	Central Aleutians	2.58	4.08	7.78	7.38
	Western Aleutians	4.98	4.90	7.69	5.21
Pacific ocean perch	Aleutian Islands (Total)	1.17	1.43	8.77	7.04
	Eastern Aleutians	1.26	0.39	29.82	12.30
	Central Aleutians	0.98	2.17	12.58	9.68
	Western Aleutians	1.56	1.57	10.75	11.40
Pelagic slope rockfish	Aleutian Islands (Total)	0.01	0.04	25.67	48.01
	Eastern Aleutians	0.02	0.03	50.38	20.55
	Central Aleutians	0.01	0.10	32.25	62.50
	Western Aleutians	0.00	0.01	72.36	34.87
Shortraker/rougheye rockfish	Aleutian Islands (Total)	0.09	0.09	15.51	16.51
	Eastern Aleutians	0.06	0.01	54.91	34.95
	Central Aleutians	0.08	0.16	19.48	15.71
	Western Aleutians	0.12	0.10	27.99	33.01
Other rockfish	Aleutian Islands (Total)	0.01	0.01	35.57	36.38
	Eastern Aleutians	0.01	0.00	79.06	41.86
	Central Aleutians	0.02	0.01	42.57	61.80
	Western Aleutians	0.01	0.01	50.37	45.57
Total rockfish	Aleutian Islands (Total)	4.42	5.40	4.77	3.80
	Eastern Aleutians	3.60	2.34	13.49	10.06
	Central Aleutians	3.68	6.54	7.20	6.40
	Western Aleutians	6.67	6.60	6.92	5.13
Number of Hauls	Aleutian Islands (Total)	1,211	1,653		
	Eastern Aleutians	143	392		
	Central Aleutians	715	596		
	Western Aleutians	353	665		

rockfish was eliminated from further analysis as a target species because too few hauls were categorized as demersal shelf rockfish.

Arrowtooth flounders and aggregated rockfish had the highest bycatch rates over all rockfish target species and years. This was true even for the more pelagic rockfish species groups, as would be expected from bottom-survey gear. The natural bycatch rates of the various species captured in the Gulf of Alaska rockfish hauls suggested 3 general groups: (1) hauls with relatively low bycatch of flatfish and demersal species, as in the northern and other slope rockfish hauls; (2) near-bottom hauls with relatively higher bycatch rates of demersal species, as in the Pacific ocean perch and pelagic shelf rockfish hauls; and (3) hauls with high catch of bottom-dwelling species, as in hauls for shortraker and rougheye rockfish and shortspine thornyheads. Bycatch rates of sablefish were highest when shortspine thornyheads, shortraker, and rougheye rockfish were the target species and lowest when northern rockfish was the target species. Bycatch rates of Atka mackerel, shallow-water flatfish, and demersal shelf rockfish were low (<2.2%) for all target species. Most estimates of bycatch rates were reasonably precise with CVs usually < 50% (Table 2). In general, high CVs were associated with low estimates of bycatch rates, which is often typical of ratio estimators.

Among the 2,108 observed rockfish hauls in the fishery data between 1994 and 1996, approximately 34% were categorized as northern rockfish hauls, 31% were categorized as Pacific ocean perch, 14% were pelagic shelf rockfish, 14% were shortraker–rougheye rockfish, 4% were other slope rockfish, and 4% were

Table 5. Average bycatch rates of rockfish in the Aleutian Islands Pacific ocean perch fishery. Rates are defined as the ratio of bycatch weight to directed species catch weight.

		Rate (%)		CV (%)	
Bycatch Species	Area	1995	1996	1995	1996
Northern rockfish	Aleutian Islands (Total)	2.75	2.46	25.25	18.55
	Eastern Aleutians	2.65	3.55	30.34	28.84
	Central Aleutians	2.09	3.77	39.19	42.39
	Western Aleutians		1.56		30.14
Pelagic slope rockfish	Aleutian Islands (Total)	0.08	0.04	25.07	32.33
	Eastern Aleutians	0.09	0.05	26.35	54.40
	Central Aleutians	0.02	0.12	72.39	38.08
	Western Aleutians		0.01		100.92
Shortraker/rougheye rockfish	Aleutian Islands (Total)	2.11	5.08	17.26	10.21
	Eastern Aleutians	2.30	3.71	20.25	25.45
	Central Aleutians	1.49	4.78	21.15	22.81
	Western Aleutians		5.85		12.59
Shortspine thornyhead	Aleutian Islands (Total)	0.04	0.25	31.70	18.10
	Eastern Aleutians	0.02	0.00	37.55	101.85
	Central Aleutians	0.12	0.17	45.72	39.90
	Western Aleutians		0.39		18.70
Other rockfish	Aleutian Islands (Total)	0.09	0.02	93.33	43.33
	Eastern Aleutians	0.12	0.00	97.46	
	Central Aleutians	0.02	0.10	97.11	50.98
	Western Aleutians		0.01		62.56
Total rockfish	Aleutian Islands (Total)	5.09	7.89	15.46	8.89
(without Pacific ocean perch)	Eastern Aleutians	5.19	7.37	17.48	18.64
	Central Aleutians	3.75	8.94	24.89	21.89
	Western Aleutians		7.86		11.27
Number of Hauls	Aleutian Islands (Total)	210	248		
	Eastern Aleutians	142	72		
	Central Aleutians	59	46		
	Western Aleutians	9	130		

shortspine thornyheads. Pacific ocean perch was a bycatch-only species in the Gulf of Alaska in 1994 with the exception of an Eastern Gulf area opening in late 1994. Directed fishing for Pacific ocean perch in 1995 began on July 3 and closed in the Central Gulf area on July 6, in the Eastern Gulf area on July 9, and in the Western Gulf area on July 20. Directed fishing for Pacific ocean perch in 1996 was closed for all areas on July 11. The increase in number of hauls within the Pacific ocean perch target is evident in Table 3 (from 104 hauls in 1994 to 330 hauls in 1996). Similarly, the observed catch of Pacific ocean perch when it was the target increased dramatically between 1994 and 1996 from approximately 200 metric tons observed in 1994 to 2,700 tons observed in 1995 and 3,400 tons in 1996. The catch of Pacific ocean perch in each year was primarily in hauls classified as Pacific ocean perch hauls due to the dominance of that species in the catch.

Bycatch rates of a species across years generally were similar within the various rockfish fisheries and generally were higher for rockfish species than for non-rockfish species. Similar to the survey results, the bycatch rates for Atka mackerel, shallow-water flatfish, demersal shelf rockfish, and flathead sole were low for all rockfish target species, and nearly all hauls with a bycatch rate > 5% had CVs < 50%.

As with the survey results, the bycatch rates of sablefish were highest when shortspine thornyheads and shortraker–rougheye rockfish were the target species and lowest when northern rockfish was the target. Observed sablefish bycatch rates in hauls targeting Pacific ocean perch were highest in 1994 when there was no directed fishery for Pacific ocean perch (11.5%),

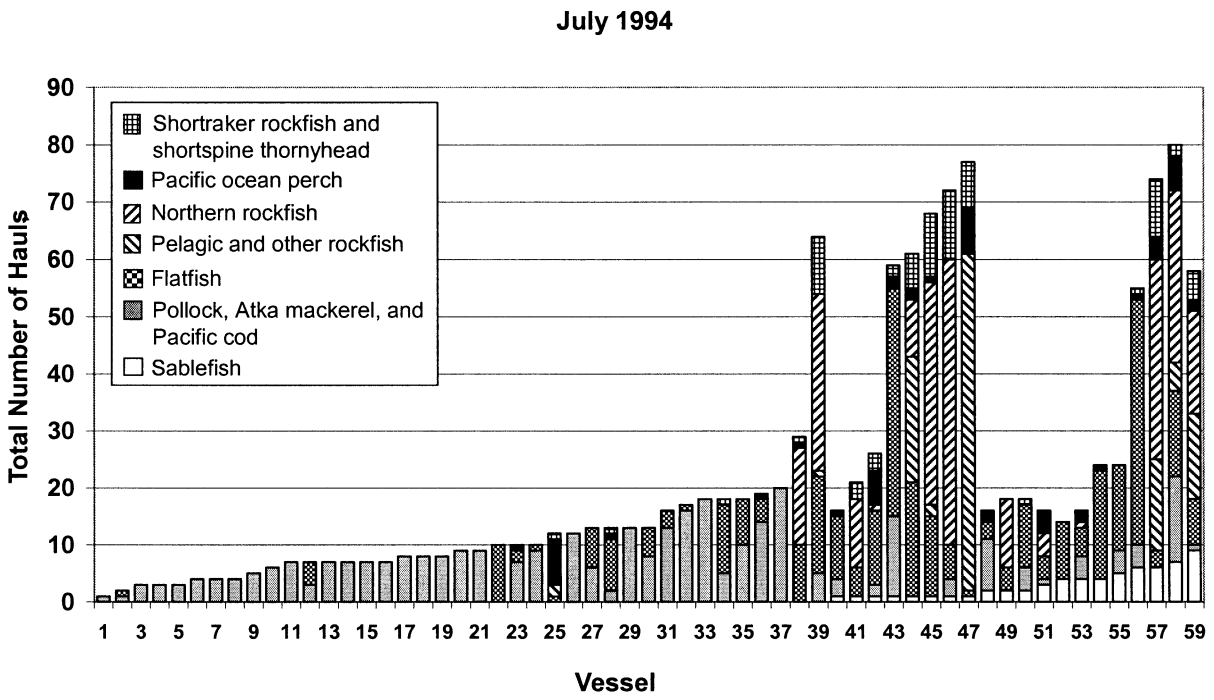

Figure 1. Numbers of observed hauls for vessels fishing in Gulf of Alaska rockfish fisheries, July 1994. Histobars are partitioned by dominant catch species (target), by weight, and sorted by increasing number of sablefish hauls and increasing total number of hauls.

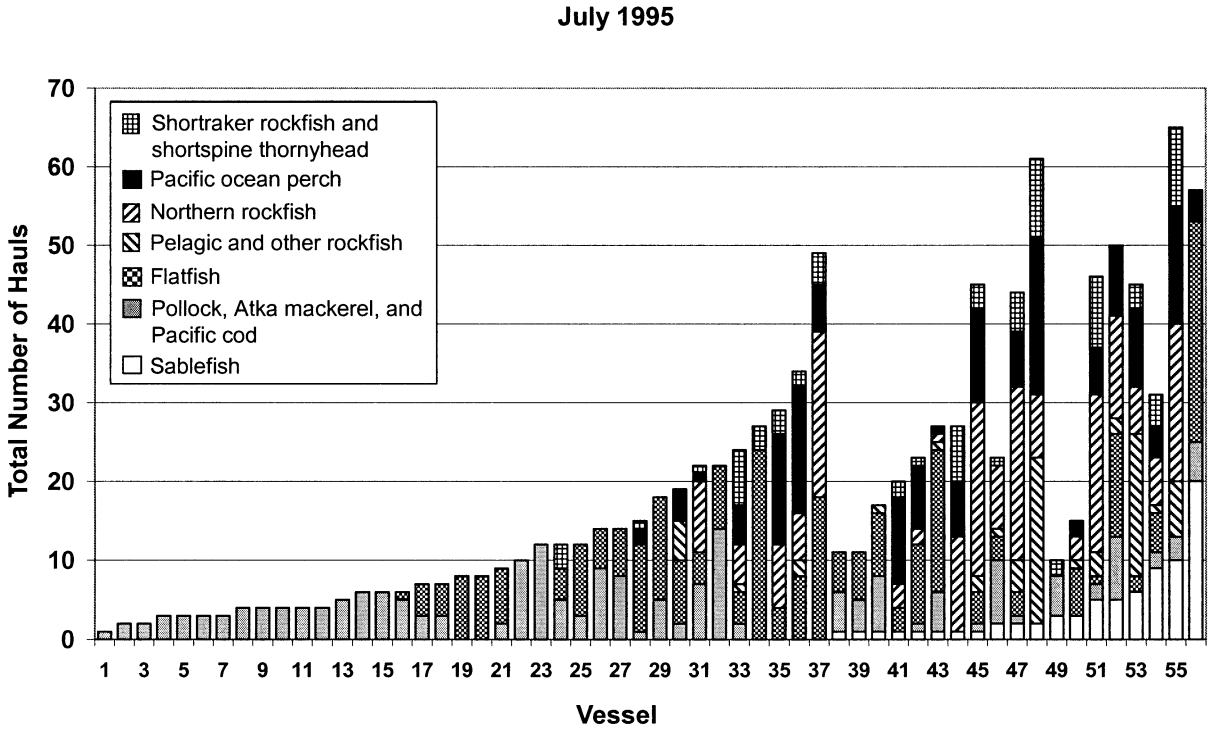

Figure 2. Numbers of observed hauls for vessels fishing in Gulf of Alaska rockfish fisheries, July 1995. Histobars are partitioned by dominant catch species (target), by weight, and sorted by increasing number of sablefish hauls and increasing total number of hauls.

and the rates were lower in 1995 (5.0%) and in 1996 (3.8%) when most of the observed hauls were made during directed Pacific ocean perch fisheries. The MRB rate for sablefish in rockfish fisheries was 15% in 1994, and 7% in 1997.

Aleutian Islands Atka Mackerel and Pacific Ocean Perch Fisheries

The overall observed fishery bycatch rates of various rockfish species in the Aleutian Islands are provided in Table 4 for the Atka mackerel fishery and in Table 5 for the Pacific ocean perch fishery. The overall natural rate of shortraker–rougheye rockfish bycatch in the Atka mackerel fishery was 0.09% in both 1995 and 1996 (Table 4). The overall rate of aggregated rockfish bycatch in this fishery was 4.42% and 5.40% in 1995 and 1996, respectively, approximately the established MRB rate of 5%. The MRB for rockfish applies to the catch of all rockfish species combined. Within the Aleutian Islands, the eastern portion (NMFS statistical area 541) had the lowest bycatch rates of shortraker–rougheye rockfish (0.06% in 1995 and 0.01% in 1996) and aggregated rockfish (3.60% in 1995 and 2.34% in 1996) in the Atka mackerel fishery. The western Aleutian Islands (NMFS statistical area 543) generally had the highest rates with 0.12% for shortraker–rougheye rockfish in 1995, and 6.67% and 6.60% for aggregated rockfish in 1995 and 1996, respectively. Similar rates occurred in the central Aleutian Islands (NMFS statistical area 542) in 1996. The primary rockfish bycatch species in the Atka mackerel fishery was northern rockfish.

The bycatch rate of shortraker–rougheye rockfish in the Pacific ocean perch fishery more than doubled between 1995 and 1996 (Table 5). The 1995 bycatch rate was 2.11%, and the 1996 bycatch rate was 5.08%. Although similar to the bycatch rate for northern rockfish in 1995 (2.75%), shortraker–rougheye was the rockfish group caught at the highest rate in 1996. The overall bycatch rate for aggregated rockfish bycatch in the Pacific ocean perch fishery was 5.09% in 1995 and 7.89% in 1996. The eastern Aleutian Islands had the highest bycatch rates for shortraker–rougheye rockfish (2.30%) and aggregated rockfish bycatch (5.19%) in 1995. The TAC for Pacific ocean perch in the Aleu-

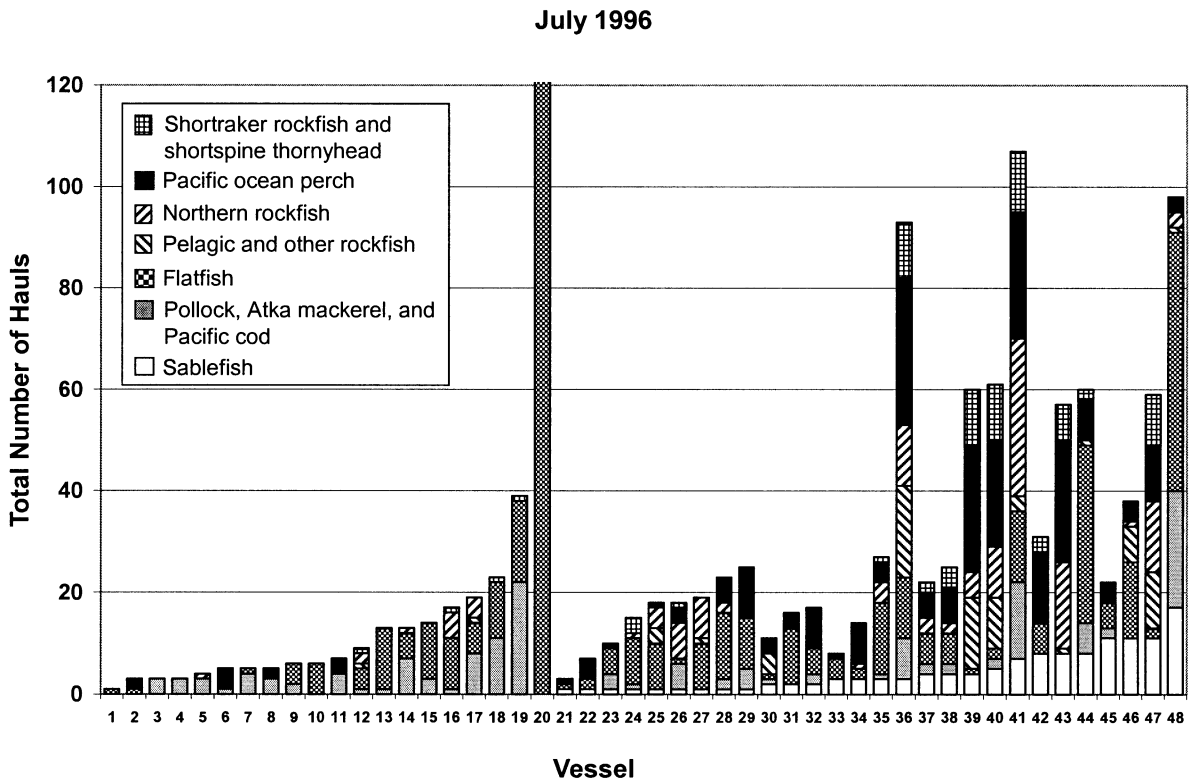

Figure 3. Numbers of observed hauls for vessels fishing in Gulf of Alaska rockfish fisheries, July 1996. Histobars are partitioned by dominant catch species (target), by weight, and sorted by increasing number of sablefish hauls and increasing total number of hauls.

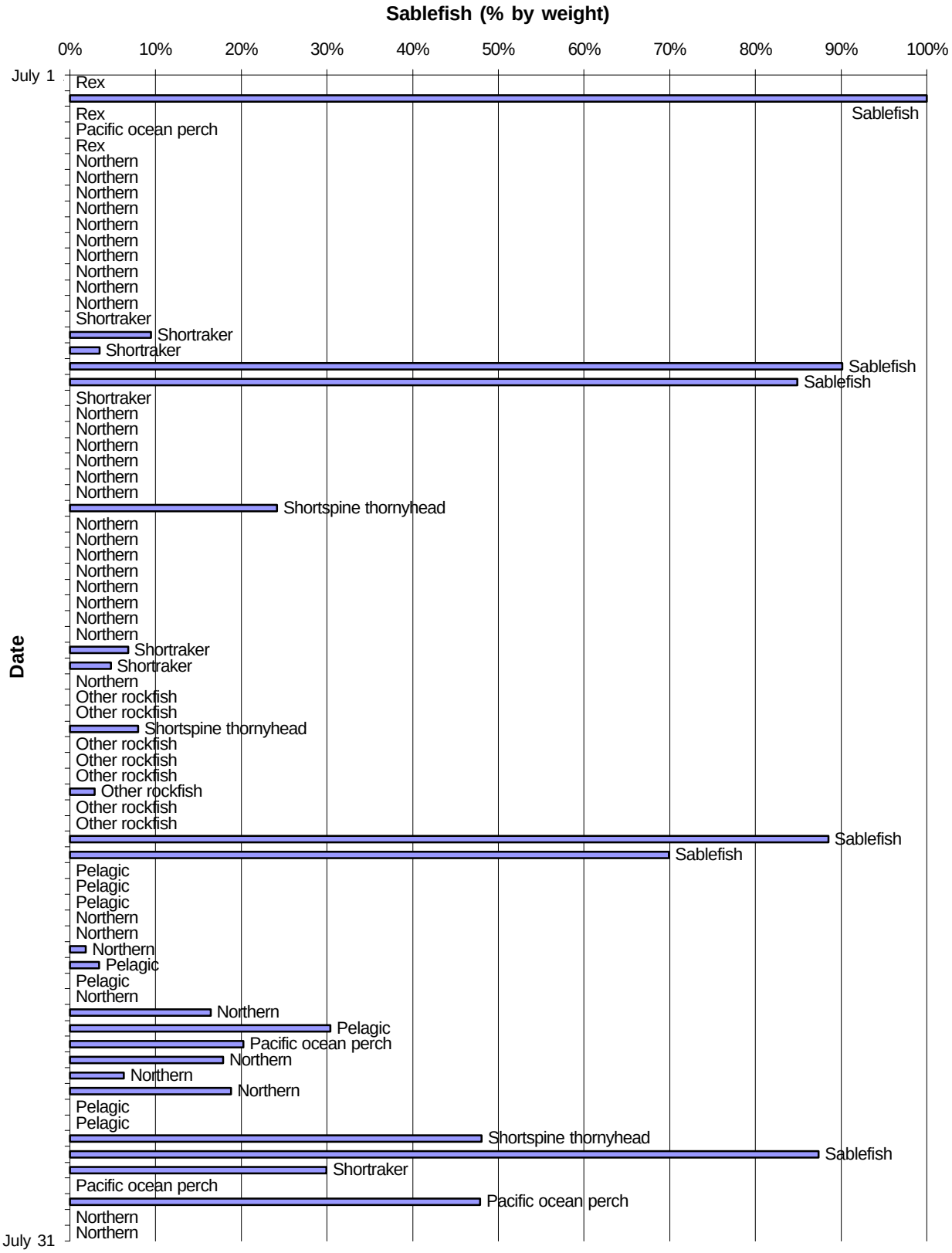

Figure 4. Percent weight of sablefish in sequential hauls by a single vessel with dominant species target of each haul identified. Hauls were made in the Gulf of Alaska in July 1994.

tian Islands in 1995 was areawide, but catch was concentrated in the eastern portion, with very little effort (9 observed hauls) in the western Aleutians. In 1996 the TAC was divided by areas, with 50% of the TAC designated for the western Aleutian Islands and 25% of the TAC each for the central and eastern Aleutian Islands, respectively. The bycatch rate for shortraker–rougheye rockfish in 1996 increased from east to west and was 3.71% in the eastern area, 4.78% in the central area, and 5.85% in the western area. In contrast, the aggregated rockfish bycatch was highest in the central Aleutian Islands (8.94%).

Sablefish Bycatch in the Gulf of Alaska Rockfish Fisheries

The primary fishing period for rockfish in the Gulf of Alaska is during July. The directed sablefish fishery was closed during this period, but sablefish was available under MRB limits. Vessel fishing patterns in July

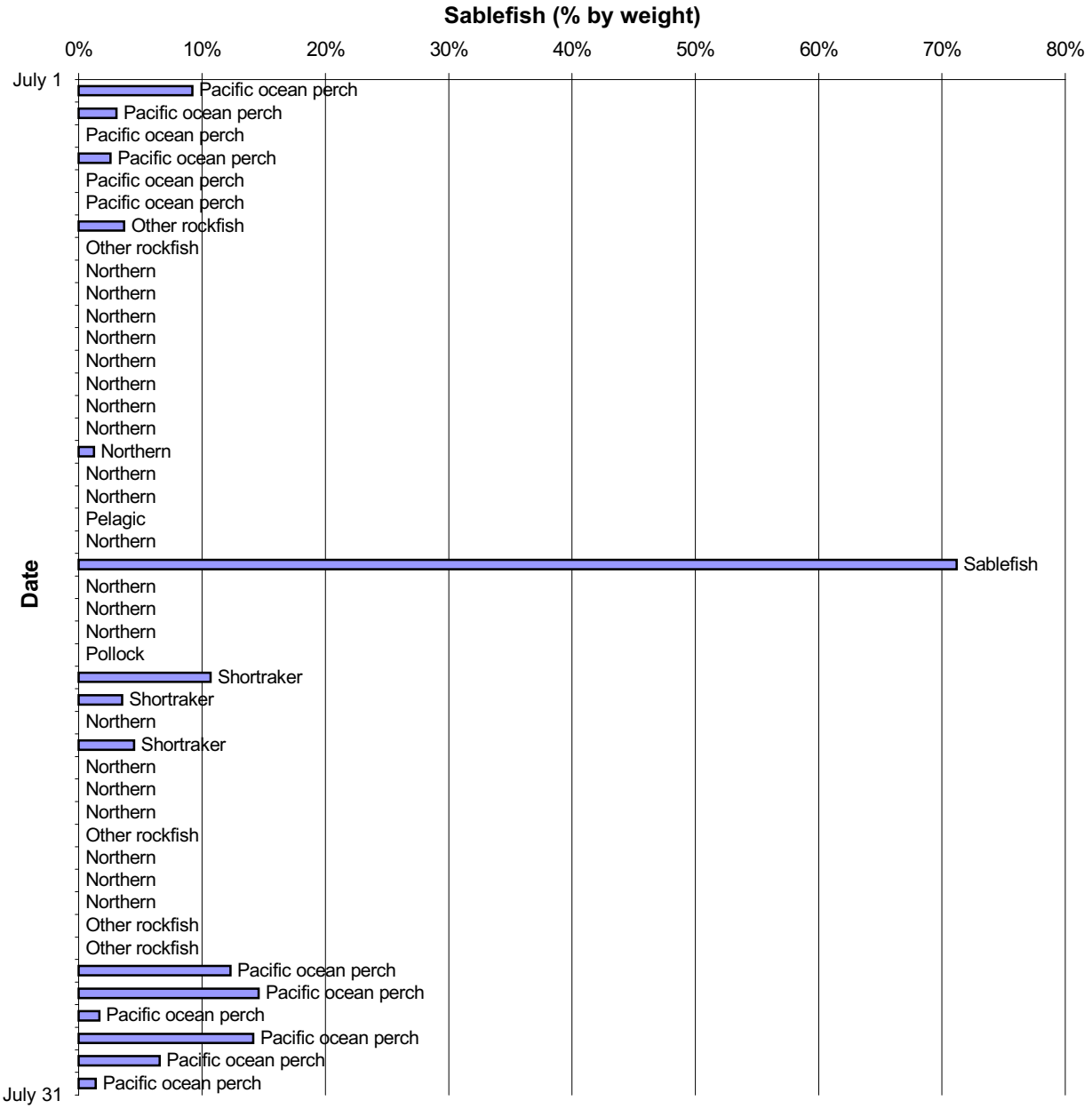

Figure 5. Percent weight of sablefish in sequential hauls by a single vessel with dominant species target of each haul identified. Hauls were made in the Gulf of Alaska in July 1995.

1994–1996 were examined as counts of observed hauls by target species and vessel (Figures 1–3). Because rockfish are primarily taken by trawl gear, only trawl gear types (bottom and pelagic) are included in Figures 1–3. In total, 59 vessels were observed in July 1994, and 20 vessels had at least one haul designated as a sablefish target. Similarly, 56 vessels were observed in July 1995 with 25 vessels having at least one sablefish haul, and 48 vessels were observed in 1996 with 28 vessels having at least one sablefish haul. Among the many vessels with hauls targeting sablefish in July, those with the greatest number of total hauls generally

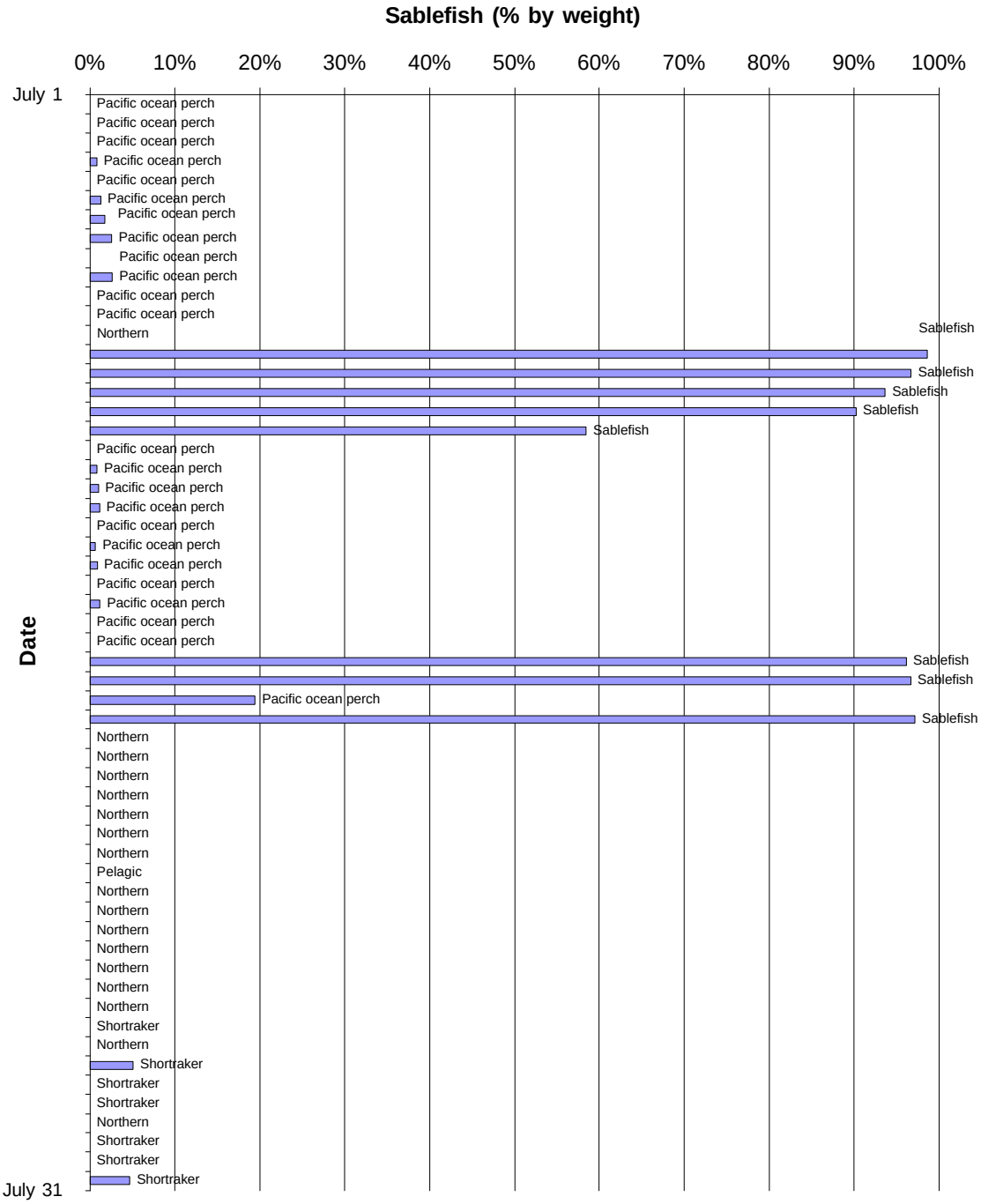

Figure 6. Percent weight of sablefish in sequential hauls by a single vessel with dominant species target of each haul identified. Hauls were made in the Gulf of Alaska in July 1996.

targeted rockfish. For some vessels more than 10% of the hauls were designated as sablefish-targeted hauls. In 1994 the Pacific ocean perch fishery was closed to directed fishing, and few hauls fell within this target relative to the other years.

To explore sablefish bycatch and targeting, we analyzed rockfish and sablefish catch from individual vessels, especially those assigned either sablefish or rockfish targets. Individual vessel hauls in July were sorted by date and haul number. For illustrative purposes, the annual haul information from a single vessel is provided in Figures 4–6 for the years 1994–1996. The proportions of sablefish catch to total rockfish catch in each haul indicated whether adjacent hauls had similar sablefish-to-rockfish ratios. Hauls targeting rockfish with a high natural incidental catch of sablefish (as is the case in shortraker–rougheye rockfish or shortspine thornyhead hauls) would be expected to have a relatively high sablefish percentage under the rockfish target.

In 1994 the vessel targeted primarily northern rockfish in the first half of July, other slope rockfish or pelagic shelf rockfish in the second half of July, and sablefish in a sporadic pattern (Figure 4). The northern rockfish hauls in the first half of the month were followed by hauls for shortraker–rougheye rockfish. These hauls had some sablefish bycatch, as would be expected, and were followed by 2 hauls with enough sablefish to assign sablefish as the haul target. Sablefish hauls were associated with other slope rockfish or shortraker–rougheye rockfish and shortspine thornyhead hauls in the second half of the month. We cannot determine whether the targeting of sablefish was intended or was due to targeting of rockfish with

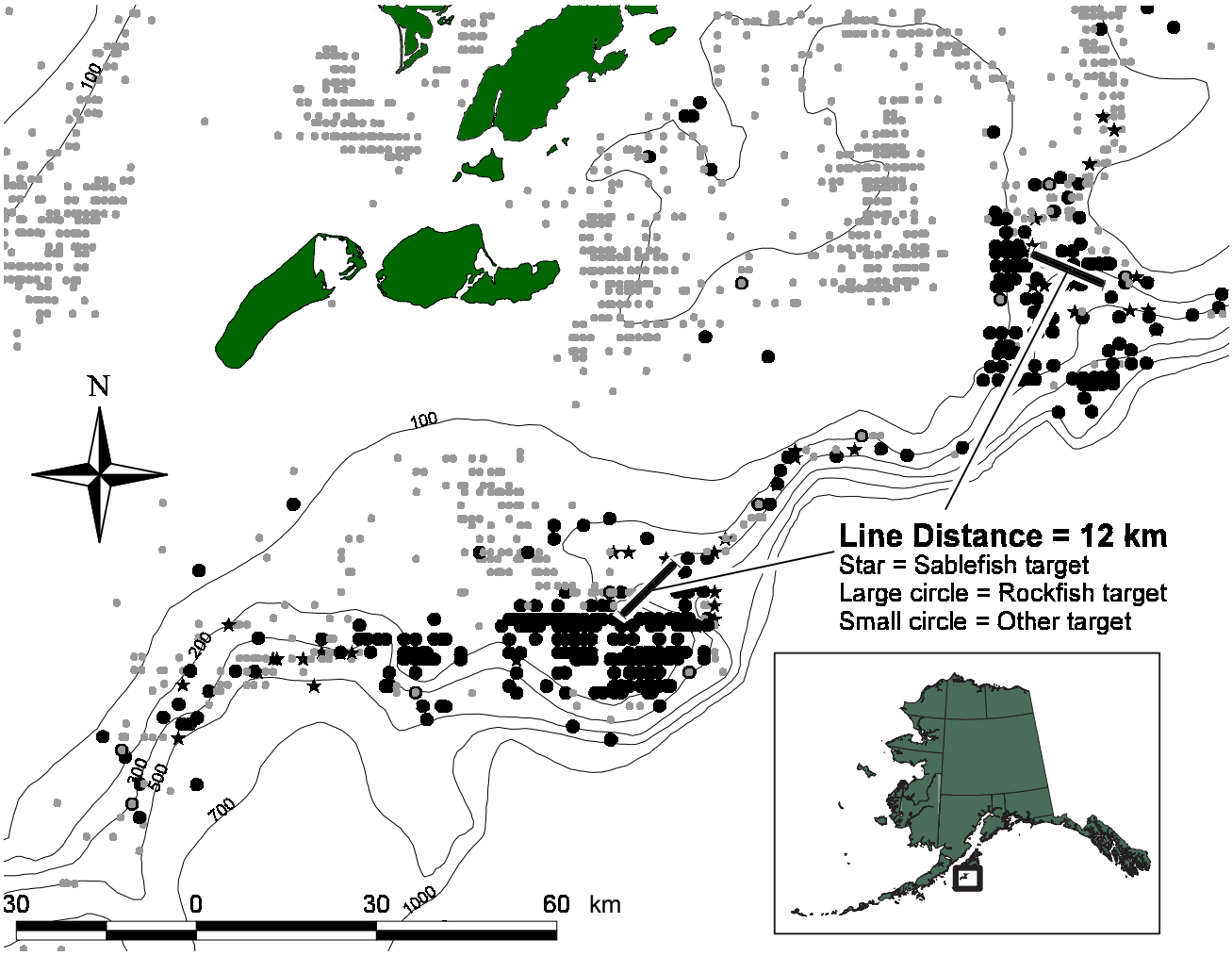

Figure 7. Location of all observed trawl hauls to the south of Kodiak Island during the years 1994–1996. Stars indicate hauls with sablefish as the dominant catch, and large circles denote hauls with rockfish as the dominant catch.

higher natural sablefish bycatch. In 1995 and 1996 (Figures 5 and 6) hauls targeting sablefish occurred between hauls for either northern rockfish or Pacific ocean perch, both of which have relatively low natural bycatch rates of sablefish. Hauls such as these indicate topping-off behavior in which sablefish are specifically sought out within the MRB guidelines.

Employing GIS is a useful addition to the temporal analysis. This is especially true because topping-off behavior is ultimately driven by the intentions of the vessel skipper and impossible to identify for certain from the data. Often hauls which temporally appeared to indicate topping-off behavior were questionable when viewed in a GIS context. For example, the high sablefish hauls by one vessel appeared to exhibit topping-off behavior because they occurred among hauls for northern rockfish. When displayed on a map of haul locations to the south of Kodiak Island, the hauls for sablefish were in close proximity to the hauls for rockfish (Figure 7). The movement of the vessel between the rockfish and sablefish hauls occurred generally along the 2 lines in Figure 7 and represented a distance of only 10–15 km. It is possible that topping off was intended since the rockfish catch locations tend to be concentrated; however, the close proximity between rockfish and sablefish hauls probably indicates that the sablefish were taken in the further pursuit of rockfish. Note that the sablefish hauls at depth are generally made by longline gear. A similar case was found in vessels fishing off of Yakutat Bay for rockfish (Figure 8). Temporally the hauls seemed to indicate topping-off behavior, but the sablefish hauls occurred along a shallow trench with vessel movement of approximately 30 km maximum between hauls. There is a gradation from hauls which are mainly rockfish at the deeper haul locations to hauls which

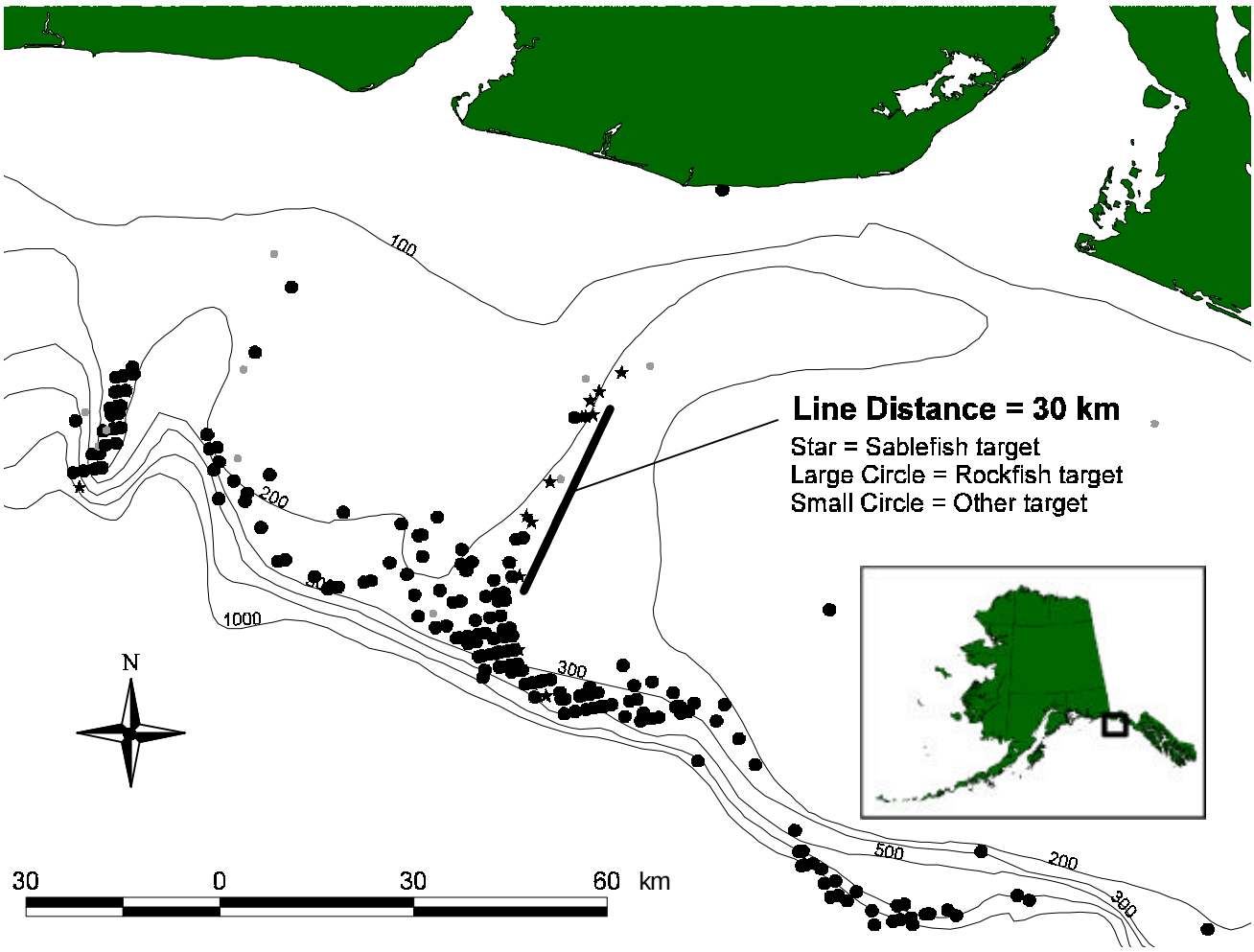

Figure 8. Location of all observed trawl hauls near Yakutat Bay during the years 1994–1996. Stars indicate hauls with sablefish as the dominant catch, and large circles denote hauls with rockfish as the dominant catch.

are mostly sablefish at more northerly locations. The targeting intention is difficult to verify in such hauls since it is possible more sablefish bycatch was encountered as the search area for rockfish expanded.

Topping off is more evident in other cases, and the spatial analysis confirmed the temporal analysis. Haul locations from the central Gulf of Alaska south of the Kenai Peninsula for 1994–1996 are presented in Figure 9. The sablefish haul locations from longline fishing are apparent along the deeper waters of the steep continental slope. An area of intense rockfish fishing is indicated at approximately the middle of the map at the edge of the continental slope (large circles on eastern edge). An analysis of individual vessel hauls revealed that several vessels engaged in what is almost certainly topping-off behavior: fishing for rockfish within the fairly concentrated area described above and then moving a distance of 50–60 km or more. After a few tows for sablefish in the new area, the vessels returned to the concentrated rockfish area. Several vessels alternated between the 2 areas several times during the open rockfish period. Interestingly, the area of high sablefish catches accounted for approximately 7% of the observed sablefish taken by bottom trawl gear in 1995 and approximately 13% in 1996.

In another example of topping-off behavior, the sequential graph of hauls in July 1996 (Figure 6) indicated that the vessel fished for Pacific ocean perch then made several sequential sablefish hauls. The vessel then resumed Pacific ocean perch fishing before switching to northern rockfish. Plots of vessel hauls indicated a marked change in fishing locations when the target switched from rockfish to sablefish and back. Without identifying specific locations, the vessel be-

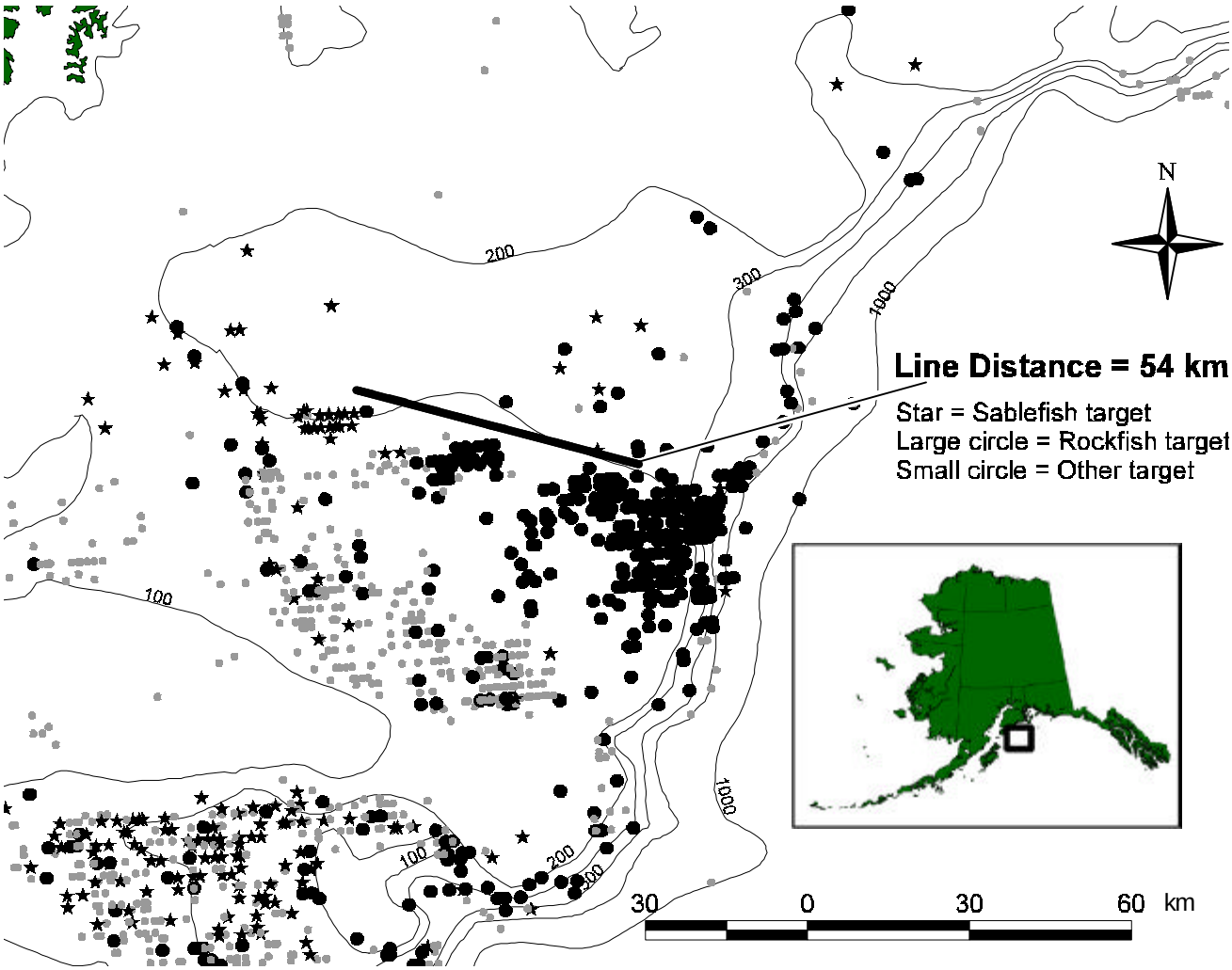

Figure 9. Location of all observed trawl hauls to the south of the Kenai Peninsula during the years 1994–1996. Stars indicate hauls with sablefish as the dominant catch, and large circles denote hauls with rockfish as the dominant catch.

gan fishing for Pacific ocean perch in one location (at the southern end of one of the heavy lines, Figure 10). The vessel then traveled to the northern end of the heavy lines, a location popular for obtaining sablefish, and made 5 hauls that were categorized as sablefish targets. The vessel then moved to one of the more southerly locations and fished for Pacific ocean perch, returned to the northern sablefish location, and finished by moving again to the south for northern rockfish. The vessel traveled 120–380 km to obtain sablefish, clearly suggesting that the vessel changed locations specifically to target sablefish, which was allowed under the MRB percentages.

Bycatch of Shortraker–Rougheye Rockfish in the Aleutian Islands

There is no directed fishery for shortraker–rougheye rockfish; however, hauls assigned this target had shortraker–rougheye rockfish as the dominant rockfish catch. In total 16 hauls were in this category in 1995 and 17 hauls in 1996, indicating that few hauls were specifically targeting shortraker–rougheye rockfish to the extent that it could be classified as a target. The topping off of shortraker–rougheye rockfish was anecdotally reported in the Aleutian Islands Pacific ocean perch and Atka mackerel trawl fisheries. Only 7 of the 16 shortraker–rougheye rockfish hauls in 1995 were trawl hauls, and no trawl vessel had more than 2 hauls categorized as shortraker–rougheye rockfish target. In 1996, 12 of the 17 shortraker–rougheye rockfish hauls were trawl hauls, and 2 vessels each had hauls designated as shortraker–rougheye rockfish targets 3 or more times.

The hauls from 2 vessels in 1996 were analyzed temporally in a manner similar to that for vessels in the Gulf of Alaska. Individual vessel hauls were sorted by date and haul number, and are presented in a temporal sequence in Figures 11 and 12. Rather than actual catch amounts, the percentage contributions of

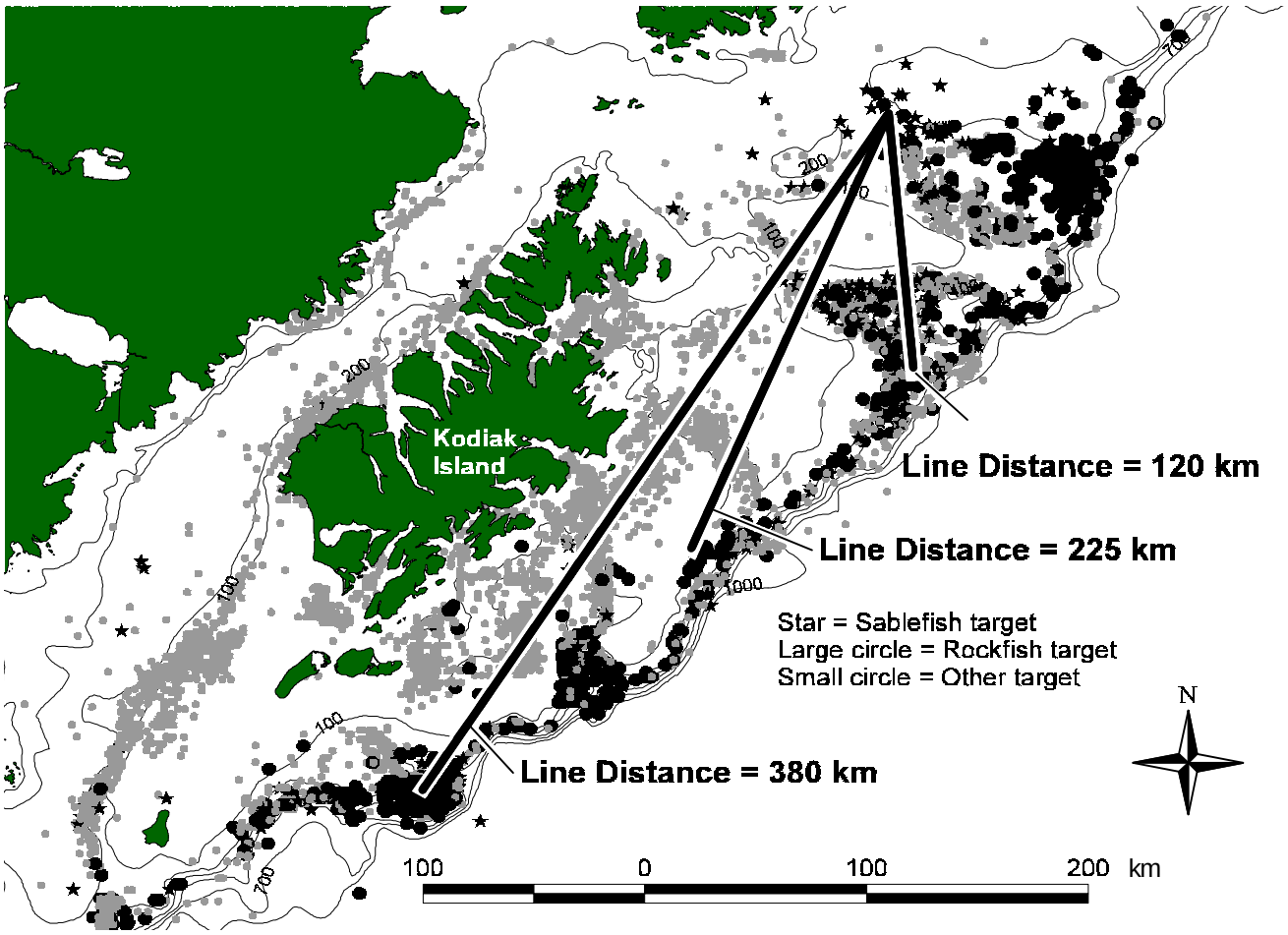

Figure 10. Location of all observed trawl hauls in the vicinity of Kodiak Island during the years 1994–1996. Stars indicate hauls with sablefish as the dominant catch, and large circles denote hauls with rockfish as the dominant catch.

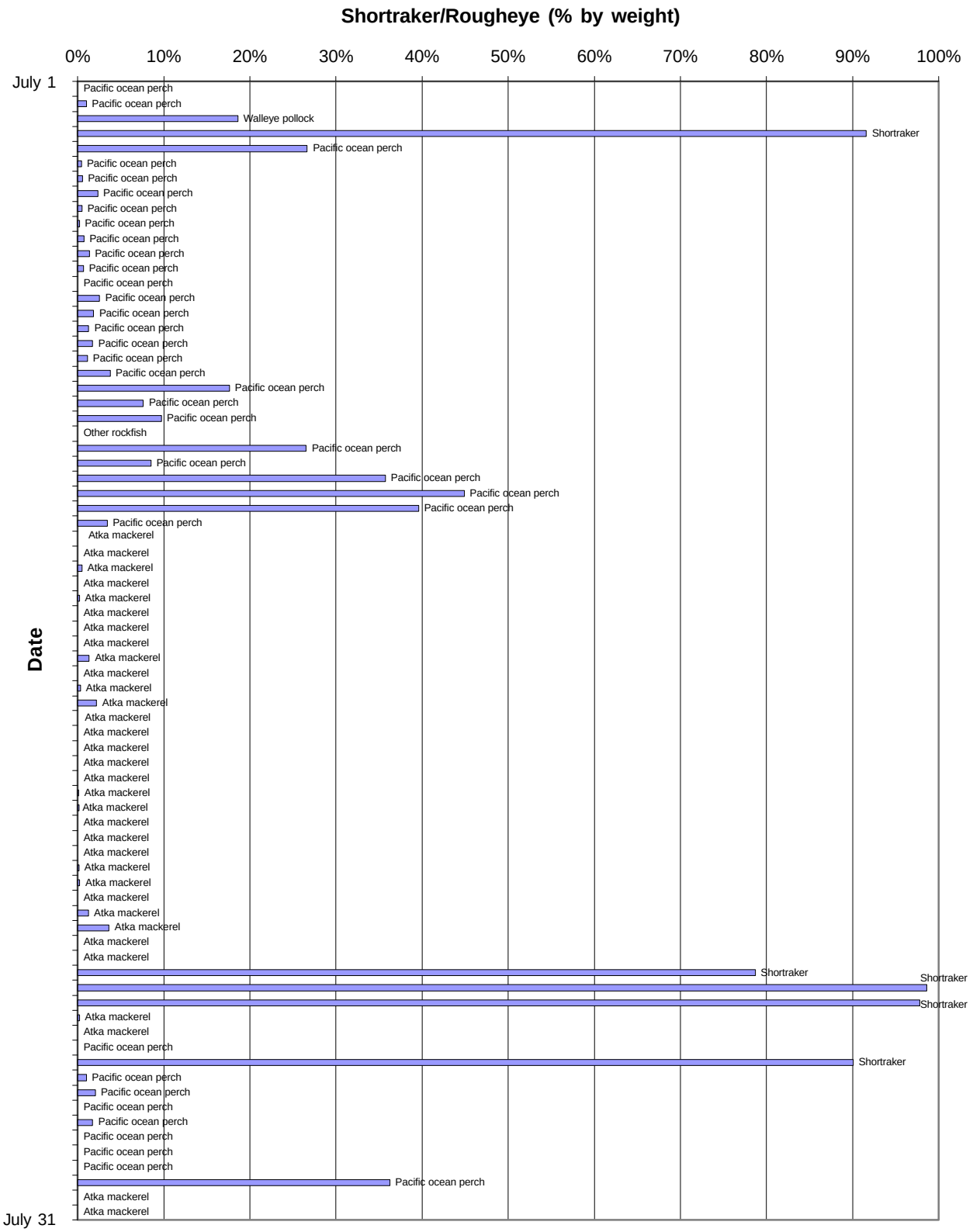

Figure 11. Percent weight of shortraker–rougheye rockfish in sequential hauls by a single vessel (Vessel 1) with dominant species target of each haul identified. Hauls were made in the Aleutian Islands during July 1996.

shortraker–rougheye rockfish of the combined Atka mackerel, Pacific ocean perch, and shortraker–rougheye rockfish weight were calculated. A few hauls were not Atka mackerel, Pacific ocean perch, or shortraker–rougheye rockfish targets. One vessel fished first for Pacific ocean perch and then switched to Atka mackerel with some shortraker–rougheye rockfish hauls occurring near the end of Atka mackerel fishing. A second vessel encountered shortraker–rougheye rockfish at the beginning of Pacific ocean perch fishing. In either case, it is difficult to determine whether topping off was intended, especially in the case of the second vessel in which the adjacent Pacific ocean perch hauls also had shortraker–rougheye rockfish bycatch.

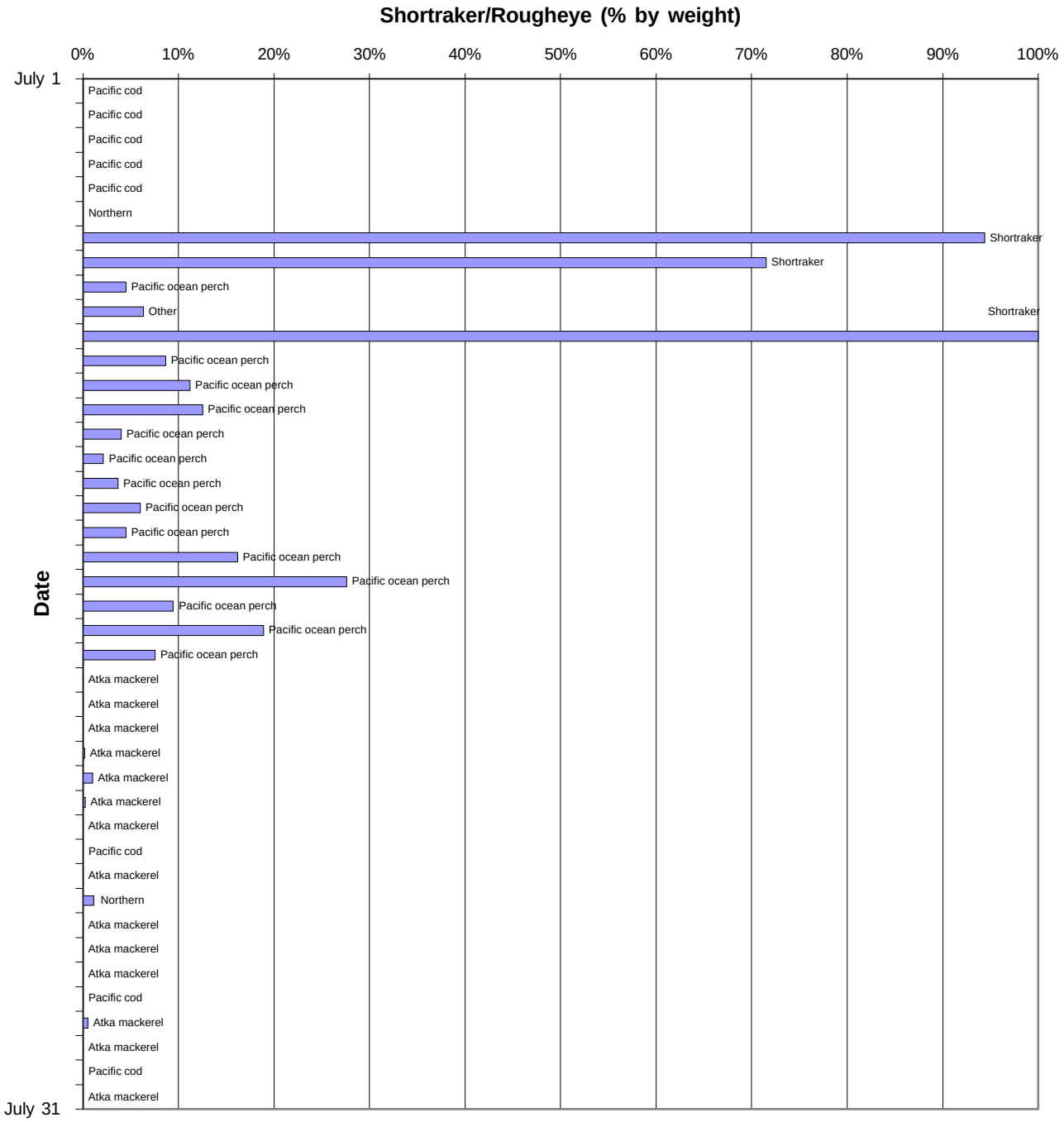

Figure 12. Percent weight of shortraker–rougheye rockfish in sequential hauls by a single vessel (Vessel 2) with dominant species target of each haul identified. Hauls were made in the Aleutian Islands during July 1996.

Spatial patterns in the hauls designated as shortraker–rougheye rockfish were not evident. The Aleutian Islands fisheries occur within very limited areas, and fishery hauls under various targets overlap within these areas. Although most of the shortraker–rougheye rockfish hauls (Figure 13) occurred between Attu and Kiska Islands, there were no particular "hot spots" nor were there patterns of spatial shifting to encounter shortraker–rougheye rockfish.

DISCUSSION

Vessels which target rockfish with low natural bycatch rates of sablefish appear to periodically target sablefish. Because sablefish is a valuable product, these vessels apparently take sablefish under the allowable bycatch percentages while fishing for rockfish even when sablefish are not being naturally encountered in the course of rockfish fishing.

Maximum retainable bycatch percentages were not intended to accurately match natural bycatch rates but were implemented to slow harvest rates of a species while providing fishing operations with the ability to retain a reasonable amount of species taken incidentally to directed fishing for a specific target (Sue Salveson, NMFS, Juneau, personal communication). Ideally, MRB percentages do not constrain normal fishing operations but are in place to account for incidental catch and to discourage the harvest of large amounts of species for which directed fishing has been closed. For economic reasons, fishing operations may maximize the catch of valuable non-target species within the allowable MRB percentages. When there is a large difference between the natural bycatch rates and the MRB allowances, hauls can be specifically directed at the valuable species closed to directed fishing to top off the trip catch with other species up to the MRB allowances.

Within the context of MRBs, we estimated the natural bycatch rates of species groups in the rockfish fisheries of the Gulf of Alaska and in the Pacific ocean perch and Atka mackerel fisheries in the Aleutian Islands. Knowledge of the natural bycatch rates provided a framework to evaluate hauls and identify those with unexpected bycatch rates or fluctuations in target designations over time. Given incentives to top off due to low natural bycatch rates and higher MRB rates, we demonstrated cases of topping-off behavior based on fisheries data.

Similar to other multispecies fisheries (e.g., Babcock and Pikitch 2000), in Alaska's groundfish fisheries the species mix in the catch of an individual vessel during a trip depends upon targeting and discarding decisions, not just the TACs. Within a trip, targets of individual vessel hauls change due to specific targeting practices or to variations in the spatial distribution of fish (Sampson 1997). In our analysis targets were assigned to individual hauls by dominant catch, but MRBs are based on trips consisting of many hauls. An analysis of individual trips would have been useful in identifying patterns in target selection; however, a trip-based analysis is not possible from the fisheries data because trip parameters such as duration of trip, number of hauls, general targeting intentions, and economic considerations are unknown. Therefore, we

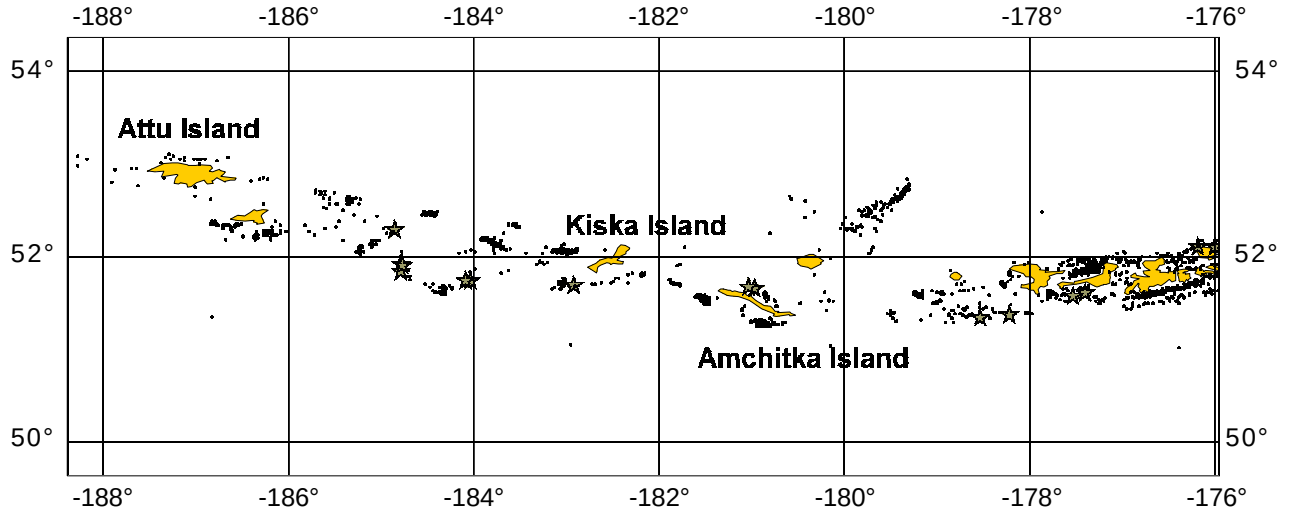

Figure 13. Location of all observed hauls in a portion of the Aleutian Islands during the year 1996. Stars indicate hauls with shortraker–rougheye rockfish as the dominant catch.

examined the sequential pattern in haul targets without categorizing individual trips. The proximity of hauls with low natural bycatch rates to hauls that specifically targeted sablefish, for instance, indicated possible augmentation of the trip catch of sablefish under MRB guidelines. A fishing strategy model similar to that constructed for the multispecies trawl fishery off Oregon and Washington (Babcock and Pikitch 2000) may enable better understanding of the fishing process.

The vessel operator's intended targets were not available to us. Because species complexes overlap spatially, and hauls are usually composed of a mix of species, the intended target of the fishing operation cannot be determined from catch data alone. The added information of both the time the haul was made and the geographic location of the haul were used to illustrate that topping off with sablefish occurs in the Gulf of Alaska rockfish fisheries. A similar analysis of vessels participating in the Aleutian Islands Atka mackerel and Pacific ocean perch fisheries did not show topping-off behavior with shortraker–rougheye rockfish because of extensive overlap of target fishing locations in the Aleutian Islands fisheries.

Historical data are useful in describing bycatch rates and patterns in bycatch in the Alaskan groundfish fisheries. However, several limitations exist in using historical fisheries data to describe the effects of MRB levels. Historical data are collected on a haul-by-haul basis, and are difficult to use to describe or characterize an entire trip or fishing week. Because MRBs are used to cap the retainable bycatch in a fishing week, an examination of individual hauls has limited utility. The observer database can quantify only observed hauls, and no information is available for unobserved hauls, further confounding the utility of observer data in describing a full fishing week. Another limitation of the observer data is that the total catch for each haul is recorded, but not amount retained, whereas MRBs apply to retained catch only. A major caveat is that historical data were collected from fisheries that were prosecuted under MRBs. Given that it is not possible to know if a haul target was selected to constrain bycatch, or at the opposite extreme, to top off up to the allowable MRB level, the data have limitations in describing either avoidance or topping-off behavior. The Pacific ocean perch fishery in the Aleutian Islands, for instance, operated under an MRB of 15% in 1995 and 1996. This may have provided an incentive to top off on other more valuable rockfish species, such as shortraker or rougheye rockfish. However, it is very difficult to distinguish the top-off hauls from hauls that would normally encounter shortraker–rougheye rockfish.

In target fisheries where the TAC is set well below the allowable biological catch, or where stock concerns are not a problem, the similarity between the MRB and the natural bycatch rate is not of great concern. However, when there is demand or competition for a stock that may be affected by unexpected or undue fishing pressure, the difference between the MRB and the natural bycatch rate may warrant inspection, and a change in the MRB to more closely reflect natural bycatch rates might be desirable. Based on our analyses, some MRB percentages in 1997 were reduced by the North Pacific Fishery Management Council to minimize topping-off behavior, and to minimize the risk of exceeding the TAC (1997 Council Newsletters available at http://www.fakr.noaa.gov/npfmc/default.htm).

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