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Two Demersal Trawl Surveys in the Gulf of Alaska: Implications of Survey Design and Methods

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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

In 1984 and 1987, demersal trawl surveys of fish stocks in the western and central Gulf of Alaska were executed by the National Marine Fisheries Service in cooperation with the Fisheries Agency of Japan. Details of the survey design and sampling methods are presented. Fishing power differences resulted from differences among vessels, gears, and trawling procedures. Chartered fishing vessels from the United States and Japan performed the sampling using modified commercial trawls as sampling gear. Nets used by the U.S. vessels were standardized to produce data appropriate for estimation of indices of fish abundance. In both surveys the nets used by the Japanese vessels departed markedly from that standard. Methods of estimating those fishing power differences, and applying the estimates to calibrate catches to a standard, have evolved through varied and conflicting strategies. To decide the most appropriate strategy for estimating and applying Fishing Power Corrections (FPCs). we defied a notion of negligibility. Based on this notion, final estimates of FPC were developed.

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INTRODUCTION

Bottom trawl surveys of groundfish stocks in the Gulf of Alaska are executed on a triennial basis as a joint responsibility of the Resource Assessment and Conservation Engineering (RACE) Division and the Auke Ray Laboratory (ABL). both of the Alaska Fisheries Science Center (AFSC). A comprehensive survey of such a large area strains fiscal and logistic resources. The first two such surveys in 1984 and 1987 were cooperative efforts with the Fisheries Agency of Japan. Japanese participation allowed the entire Gulf of Alaska to be surveyed in one season.

We shall report design and execution of the 1984 and 1987 surveys of a region of the Gulf of Alaska from Cape St. Elias to the Islands of Four Mountains. between 144° 30’and 170° 00’W long. (Fig. 1). We shall also report the evolution of our treatment of differences in catch data due to differences in efficiency among the several fishing vessels that served as sampling systems.

The 1984 and 1987 surveys comprise initial observations in a long-term triennial series. Bottom trawls were employed to obtain catch-per-unit-effort (CPUE) data as indices of fish abundance. These indices are used to monitor trends in abundance for a variety of fish species. Data to estimate a number of biological parameters or changes in those parameters, including age compositions, were also collected in these surveys.

Each survey was executed by two U.S. vessels and one Japanese vessel. The AFSC chartered the U.S. vessels directly. The Japanese vessels, chartered by the Fishery Agency of Japan,’were operated under the direction of AFSC scientists, following standard methods and taking station assignments from the U.S. principal investigator.

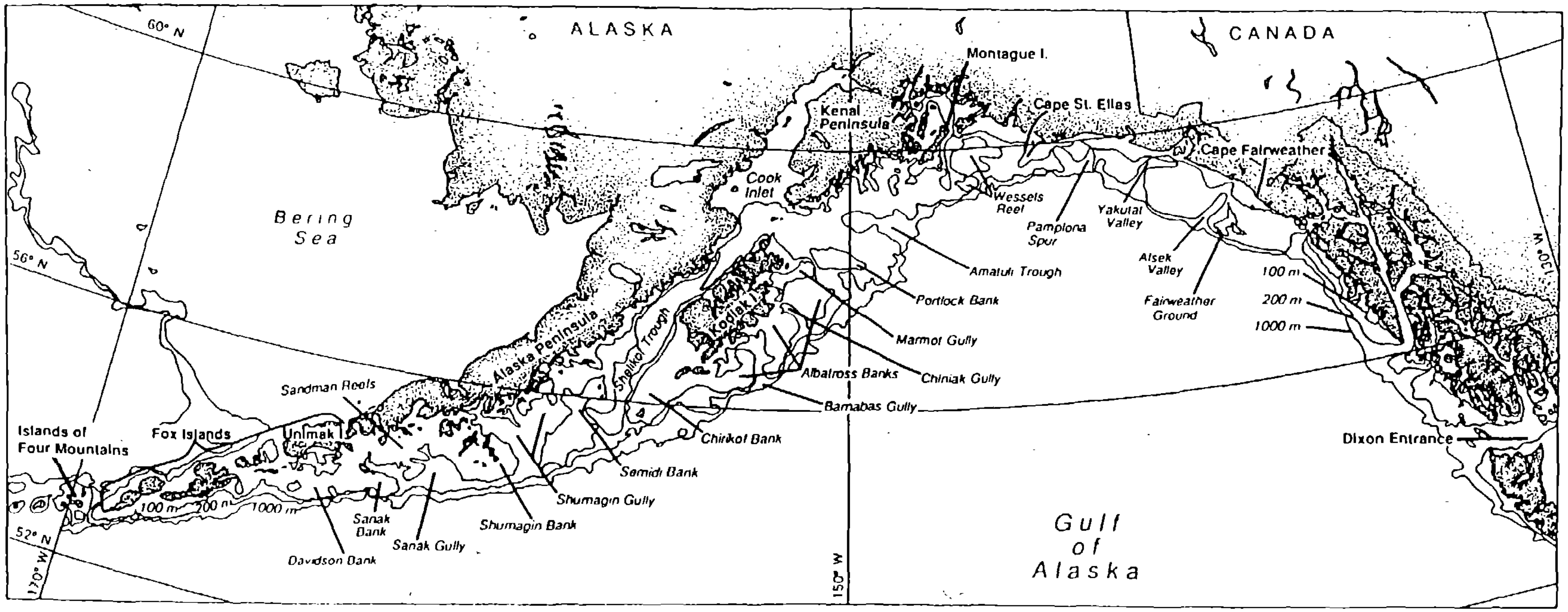


Figure 1 .--Gulf of Alaska.

Within each year, variation among participating sampling systems was of sufficient magnitude to present a strong likelihood that fishing power differed. Differences included those in vessel size and power, gear, expertise of captains and crews, and survey responsibilities and assignments. Correction for relative differences in fishing efficiency became an important consideration.

Inconsistencies in design, implementation, and execution between years also needed to be evaluated. These included slight changes in strata definitions and sample allocations. a change in station selection criteria, and changes in how stations were assigned to vessels after having been selected. However, such inconsistencies were thought to be less influential on survey results than were differences in vessel fishing power.

For each survey, we will describe its design, the methods used to execute the survey, and methods of analysis that were applied to the data. We will provide the information an analyst needs to render these surveys comparable to each other and to future surveys. Also of importance is an account of the history of estimation of indices of abundance based on data from these surveys, particularly the history of the use of fishing power corrections (FPCs). Data from each survey have advanced through three analyses, each time reflecting a change in our understanding of the peculiarities of the surveys and changes in estimation methods, particularly with respect to FPCs. We will state the strategy for estimating and applying FPCs which has evolved, including a narrow definition of the term “negligible” as it refers to differences in fishing efficiency. We will outline elements of an ideal multispecies bottom trawl survey in the Gulf of Alaska.

METHODS

In both the 1984 and 1987 triennial surveys, essentially the Same stratification was followed. Sample allocation changed with the improved a *priori* knowledge gained through the first survey. Nominally, the two surveys were highly consistent in that they both incorporated the same sample unit, sampling gear, and sampling methods. However, troubling differences entered through the sample unit itself, namely through differences in fishing efficiency and the difficulty associated with calibrating such awkward instruments as commercial vessels and fishing nets.

Methods Common To Both Surveys

The surveys occurred during the summer. They followed a stratified, random design. Vessels were small U.S commercial fishing boats operating under charter to the AFSC and larger Japanese boats operating under charter to the Fisheries Agency of Japan. The U.S. sampling gear was a bottom trawl of commercial design that had been modified to meet sampling standards. The Japanese vessels used sampling gear that was at variance from AFSC standards. Catches were made using standard trawling methods, (Wakabyashi et al. 1985, Wilderbuer 1988). Once aboard, data was collected from the catch using standard methods, (Hughes 1976).

The Sample Unit

The sample unit was the catch made by towing a trawl net over the bottom, standardized by a measure of the effort expended to make it: that is CPUE. Catch was measured by mass and counts. Effort was measured as “area swept" by the trawl: the width of the net opening tunes the length of the tow (Alverson and Pereyra 1969). Dividing catch by effort produces a measure of fish density which serves as an index of abundance.

Sampling Gear

Complete descriptions of the demersal trawls used as sampling gear can be found in Appendix A. The standard sampling trawl for Gulf of Alaska triennial surveys is a high-opening, four-seam Noreastern trawl constructed of polyethylene and rigged with rubber bobbin roller gear. This particular net was designed to be a rough-bottom, rockfish trawl. It was chosen because of its capacity to sample species which school slightly above the bottom, often over rough terrain, such as walleye pollock (Theragra *chalcogramma)* or rockfish species *(Sebastes* spp.) (Feldman and Rose 1981). This trawl became the standard when the first of the regional triennial surveys was developed for the West Coast of the continental United States (Gunderson and Sample 1980). At that time this gear design was in common use among rockfish trawlers in those waters and had proven to be useful in the varied submarine terrain found there as well as in the Gulf of Alaska. (Trawl design has evolved and very few vessels still employ this gear.) The Noreastern trawl is also capable of fishing on flat or soft bottoms but is not considered as effective in sampling species which dwell on the bottom (Feldman and Rose 1981). The Nor-eastern trawl was originally constructed of nylon, but during 1984 a switch was made to a polyethylene version with a different footrope and a lower wing design. These modifications were intended to reduce damage to the gear.

The Noreastern trawl was towed behind 1.000 kilogram. 1.8 X 2.7 m steel V-doors. Three 54.9 m (30 fathom) dandylines connected the net to each door. Again, in both surveys, the Japanese gear configuration deviated from this.

Taking the Sample

Towing methods followed those of AFSC trawl surveys in waters off the West Coast of the continental United States and the Bering Sea, (Gunderson and Sample 1980, Wakabyashi et al. 1985, Wilderbuer 1988). Before the fishing gear was deployed the station was surveyed by echo sounder to determine whether the bottom was suitable for trawling. The tow was attempted whenever there was a chance of successfully completing it, even if the bottom was considered only marginally trawlable. If the preselected tow site was to be too rough to trawl, then an additional one-half hour was allowed to search for trawlable bottom adjacent to the original station. If suitable bottom was not located in the allotted time the station was abandoned and the vessel moved to the next site.

An ideal tow was defined as having a 30 minute duration, a towing speed of 5.56 km per hour (3 knots), and with a straight course that did not vary in depth. Duration was measured from the time the net had stabilized on the bottom in its fishing configuration to the time the winches began retrieval. Proper fishing configuration was determined by net mensuration gear described below or by the skipper's judgment. While waiting for the net to sink to the bottom, the vessel kept no more headway than was necessary to maintain steerage.

Because most tows deviated to some degree from these standards, valid observations were defined to be from hauls that lasted a minimum of 10 minutes, varied in depth by 20 m or less, and were completed without significantly damaging the gear. Damage was considered significant if it could have caused a major loss of catch, such as a hole in the codend or a tom belly. There were tows during which the net or the doors hung up but were considered valid, even though the net may have sustained slight damage. Tows which could not be made in a straight line because of rugged bottom topography or because currents shifted the net or the boat to one side were defined as valid. Under influence of those same factors, towing depth sometimes varied as much as 20 m. Likewise, some tows were cut short because of too much change in depth or to avoid damaging the gear on some obstacle revealed by the sonar. Such tows were considered valid if they lasted 10 minutes or longer. Some tows had the current either directly behind or against and the towing speed was too much or too little. Such tows were also considered valid.

How hard a trawl tends bottom may be, in part, a function of the scope, the ratio of the length of the trawl cable let out to the depth of the net. In both of these surveys the amount of cable let out was left to the best judgment of the skippers.

Measuring Effort

Because the effort expended to make each tow is measured as area swept. the width of the net opening is necessary information. Data to calculate net width were collected differently in each year. Those methods will be described in pertinent sections. Distance fished, the other dimension of the area swept, was inferred from the position of the boat at the start and end of the tow. We assumed that the distance the vessel travelled during the tow was also the distance that the net travelled. Start and end positions were measured by Loran instrumentation.

Survey Design

The geography and, in part, the distribution of demersal fish populations of the central and western Gulf of Alaska have been previously described (Ronholt et al.. 1978). The highly varied geography of the Gulf lent itself to a stratified design. Because delineation of large scale topographic features was often quite sharp, sampling strata could be defined without the benefit of a comprehensive pilot survey. Some of these features can be discerned even from a chart with a scale as small as that of Figure 1. Smaller pilot surveys that confirmed associations of habitat types and species assemblages with particular geographic features provided adequate background data. (Ronholt et al. 1978, Feldman and Rose 1981).

Table 1 and Figures 2 - 5 define and illustrate the sampling strata. There were five basic categories of strata: nearshore. flats or shelves, gullies or troughs, slope breaks, and the continental slope. Near-shore strata were those that were bordered by land. Sometimes nearshore strata were the margins of otherwise broad regions of water less than 100 m in depth. Flats or shelves were broad areas over which depth changed slowly or not at all. Gullies or troughs were underwater valleys or canyons, sometimes of quite large dimension. A slope break is the portion of a shelf or gully that forms the transition zone to the continental slope. Even though these transition zones may be in the same depth range as the shelf or gully, they often appeared to have higher fish concentrations, as though there were some physical or biological attribute that distinguished them. Slope breaks were the hardest strata to define because there were few natural features to mark the point at which a shelf or gully changed nature to become more slope-like. Continental slope strata were those of the survey area that sloped steeply down to the abyss.

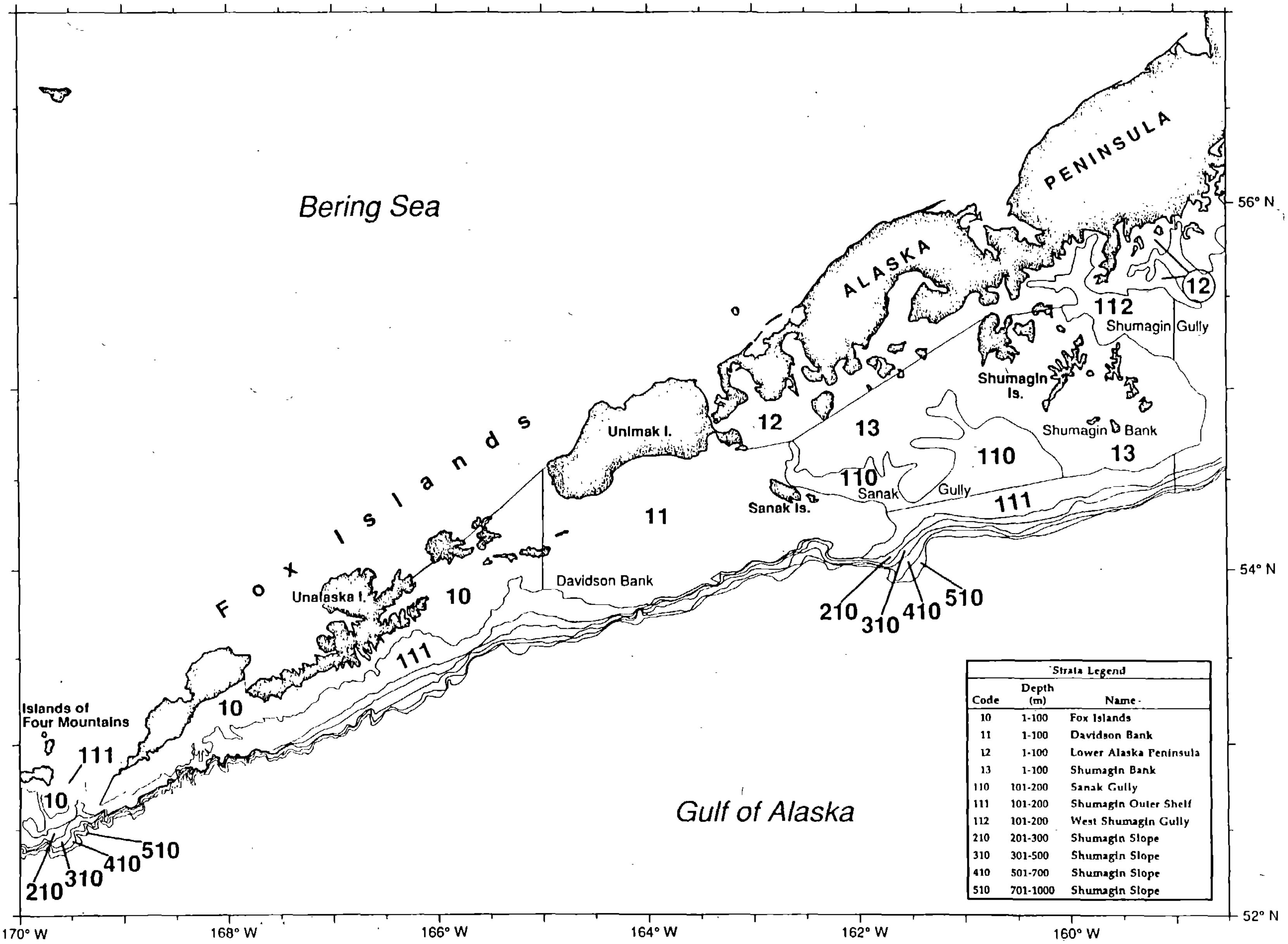
These five types of strata were further divided by depth contours at 100 m. 200 m, 300 m, 500 m, and 700 m. We did not survey deeper than 1,000 m. Not all classes of strata occurred in every depth. Waters less than 100 m deep had only nearshore and flat strata. Depths of 100-200 m had flats, gullies, and occasional slope breaks. Depths of 200-300 m had flat, gully, slope break, and slope strata. Depths of 300-500 m and depths greater than 500 m had only slope strata. Because we suspected that the east-west fish distribution was not uniform, we further divided these strata by International North Pacific Fisheries Commission boundaries (Ronholt et al. 1978). There were a total of 44 sampling strata in the central and western Gulf of Alaska.

Table 1.--Sampling strata in the western and central Gulf of Alaska triennial trawl surveys. grouped by International North Pacific Fisheries Commission statistical regions.

INPFC Area	Stratum	Area (square km)	Description
Shumagin	10	8,616	1 - 100 m: Fox Islands
	11	13,679	1 - 100 m: Davidson Bank
	12	7,443	1 - 100 m: Lower Alaska Penninsula
	13	14,626	1 - 100 m: Shumagin Bank and Sandman Reefs
	110	4,233	101 - 200 m: Sanak Gully
	111	8,036	101 - 200 m: Shumagin Outer Shelf
	112	2,267	101 - 200 m: West Shumagin Gully
	210	2,737	201 - 300 m: Shumagin Slope
	310	2,528	301 - 500 m: Shumagin Slope
	410	2,010	501 - 700 m: Shumagin Slope
	510	1,873	701 - 1,000 m: Shumagin Slope
		68,048	All sampling strata in the Shumagin INPFC Area
Chirikof	20	8,283	1 - 100 m: Upper Alaska Penninsula
	21	7,299	1 - 100 m: Semidi Bank
	22	10,993	1 - 100 m: Chirikof Bank
	120	11,082	101 - 200 m: East Shumagin Gully
	121	7,673	101 - 200 m: Shelikof Strait, (edge)
	122	4,994	101 - 200 m: Chirikof Outer Shelf
	220	9,967	201 - 300 m: Lower Shelikof Gully
	221	1,533	201 - 300 m: Chirikof Slope
	320	1,633	301 - 500 m: Chirikof Slope
	420	1,897	501 - 700 m: Chirikof Slope
	520	3,018	701 - 1,000 m: Chirikof Slope
		68,372	All sampling strata in the Chirikof INPFC Area

Table 1 .--Continued

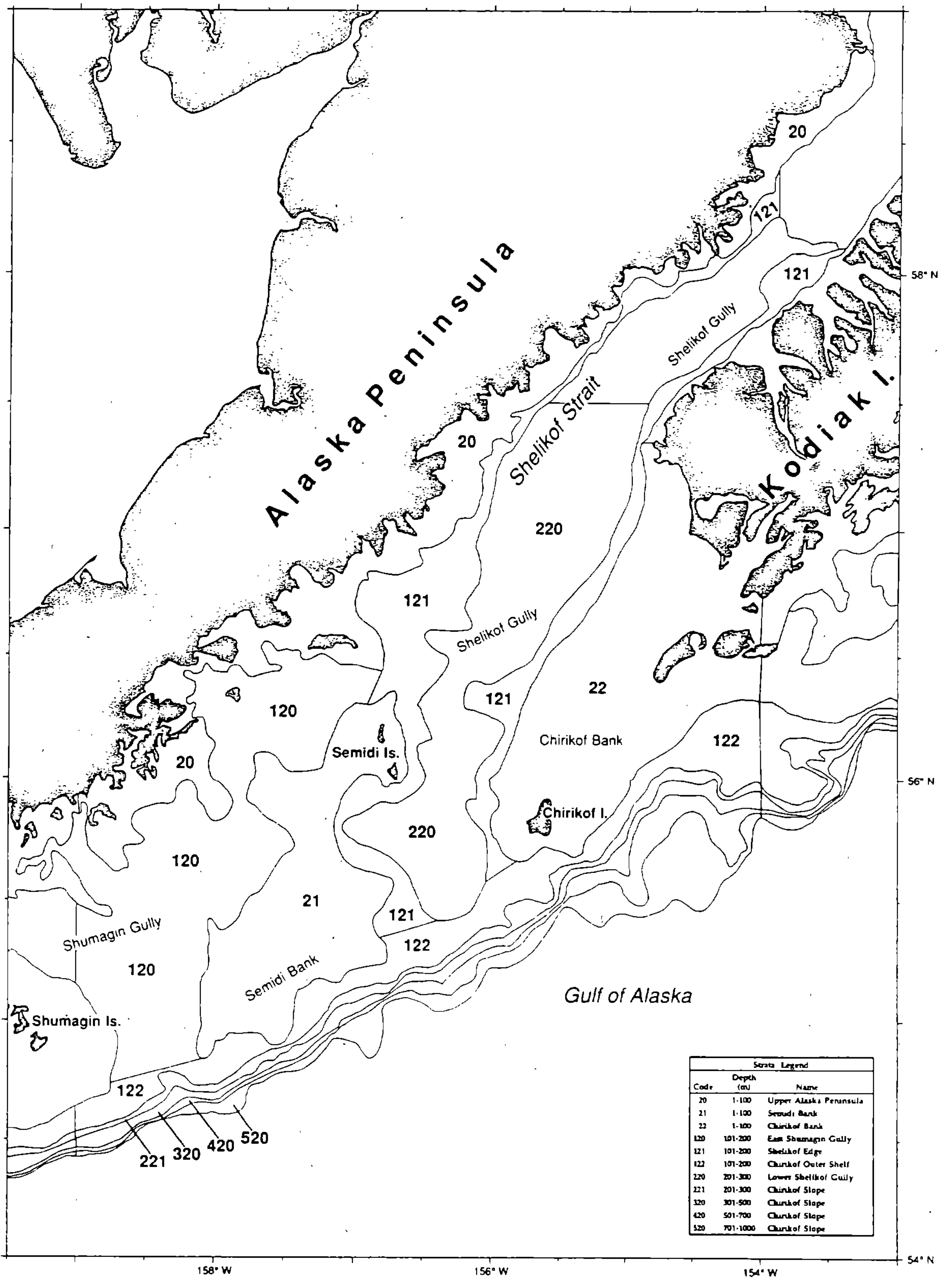
INPFC Area	Stratum	Area (square km)	Description
Kodiak	30	6,119	1 - 100 m: Albatross Shallows
	31	15,339	1 - 100 m: Albatross Banks (including Portlock Bank)
	32	10,472	1 - 100 m: lower Cook Inlet
	33	5,512	1 - 100 m: nearshore Kenai Penninsula
	35	2,401	1 - 100 m: northern Kodiak Shallows
	130	7,837	101 - 200 m: Albatross Gullies
	131	7,319	101 - 200 m: Portlock Flats
	132	10,948	101 - 200 m: Barren Island Flats
	133	12,001	101 - 200 m: Kenai Flats
	134	5,076	101 - 200 m: Kodiak Outer Shelf
	230	6,729	201 - 300 m: Kenai Gullies
	231	1,626	201 - 300 m: Kodiak Slope
	232	3,190	201 - 300 m: Upper Shelikof Gully
	330	2,960	301 - 500 m: Kodiak Slope
	430	1,550	501 - 700 m: Kodiak Slope
	530	3,444	701 - 1,000 m: Kodiak Slope
		102,523	All sampling strata in the Kodiak INPFC Area
Yakutat (west of 144° 30')	41	8,475	1 - 100 m: Middleton Shallows
	140	7,800	101 - 200 m: Middleton Shelf
	243	350	201 - 300 m: Middleton Slope
	343	542	301 - 500 m: Middleton Slope
	443	309	501 - 700 m: Middleton Slope
	543	984	701 - 1,000 m: Middleton Slope
		18,460	All sampling strata in the Yakutat INPFC Area, west of 144° 30' W longitude



Strata Legend

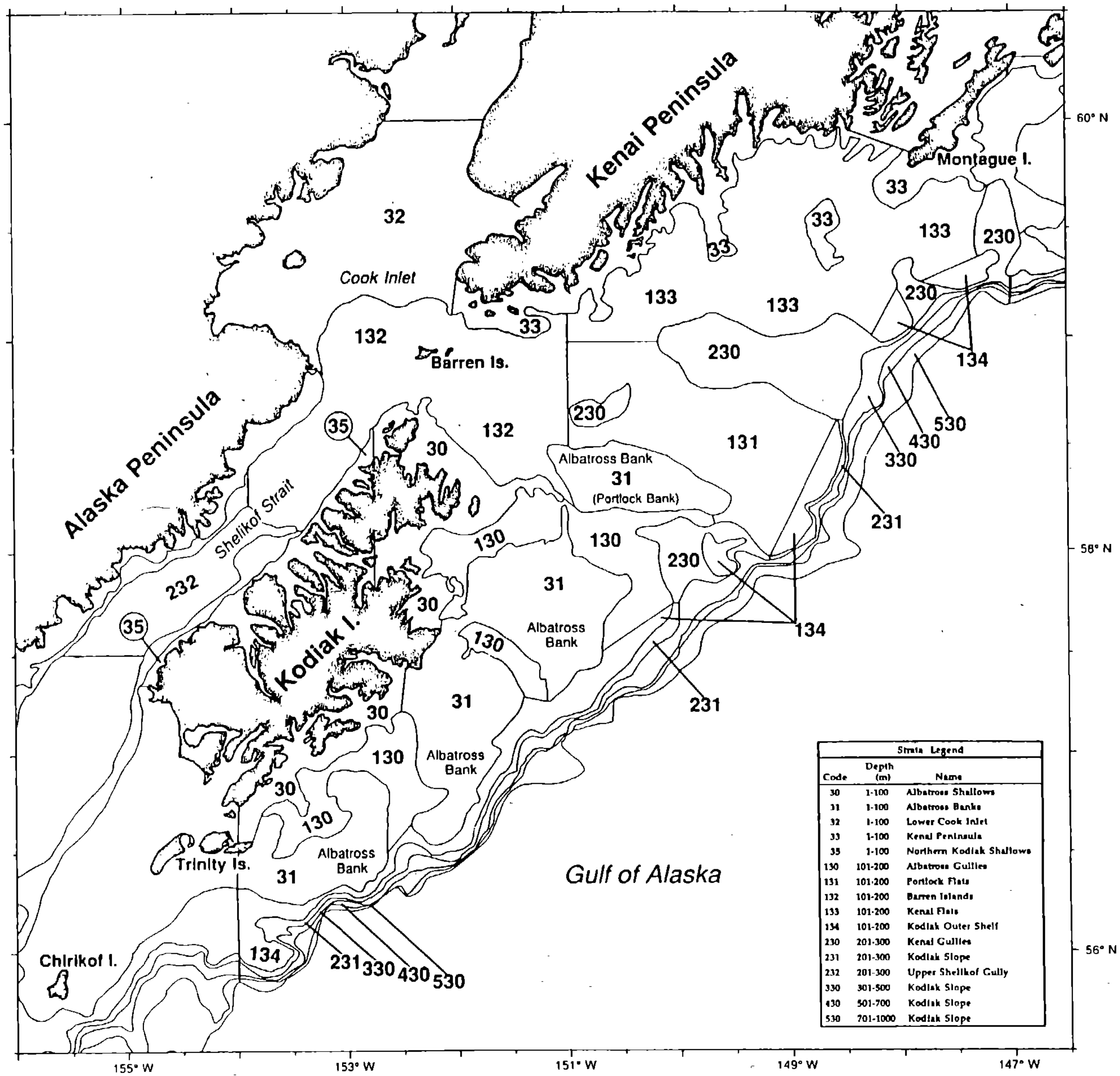
Code	Depth (m)	Name
10	1-100	Fox Islands
11	1-100	Davidson Bank
12	1-100	Lower Alaska Peninsula
13	1-100	Shumagin Bank
110	101-200	Sanak Gully
111	101-200	Shumagin Outer Shelf
112	101-200	West Shumagin Gully
210	201-300	Shumagin Slope
310	301-500	Shumagin Slope
410	501-700	Shumagin Slope
510	701-1000	Shumagin Slope

Figure 2.--Shumagin INPFC Area with strata boundaries.



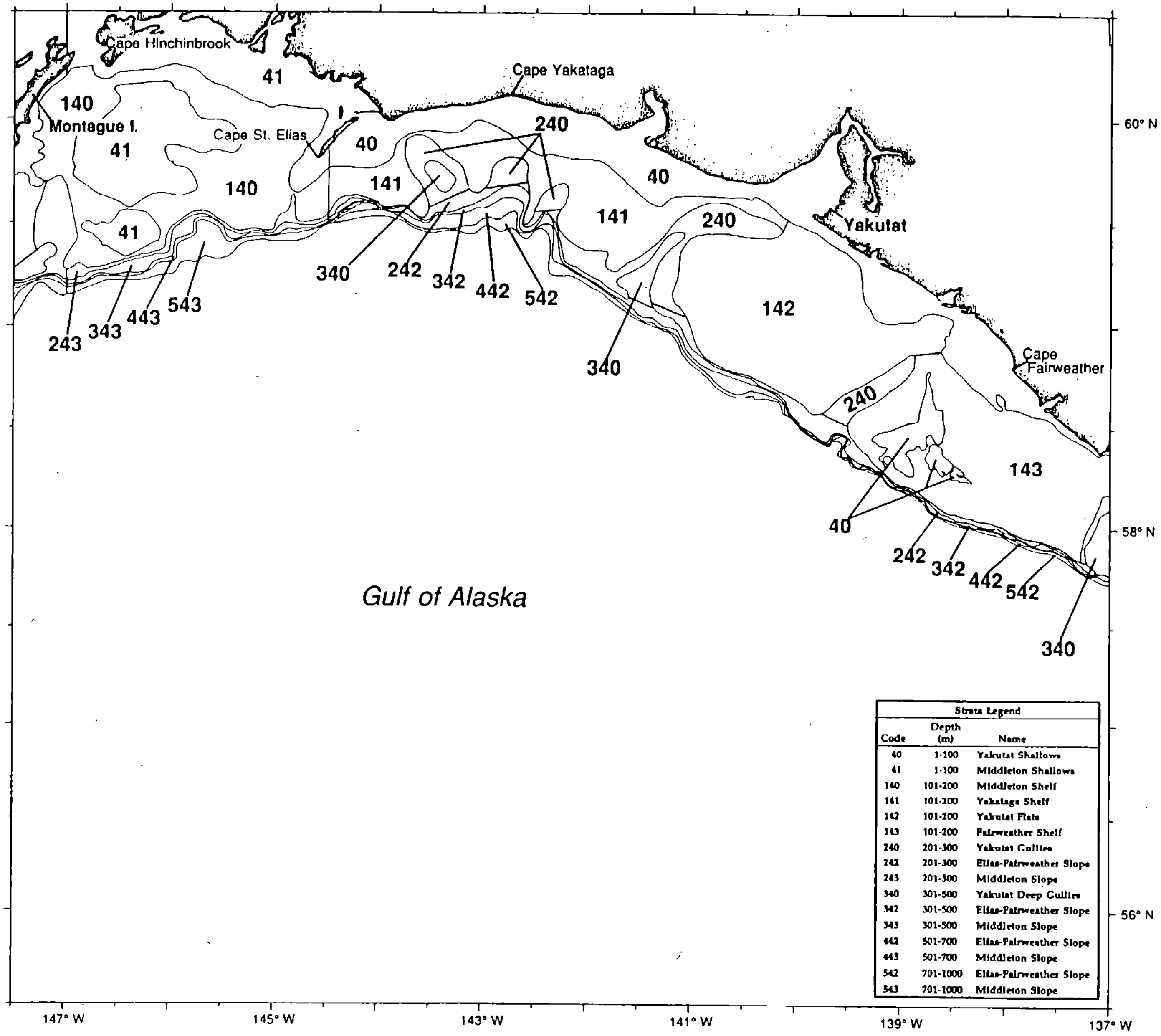
Strata Legend		
Code	Depth (m)	Name
20	1-100	Upper Alaska Peninsula
21	1-100	Semidi Bank
22	1-100	Chirikof Bank
120	101-200	East Shumagin Gully
121	101-200	Shelikof Edge
122	101-200	Chirikof Outer Shelf
220	201-300	Lower Shelikof Gully
221	201-300	Chirikof Slope
320	301-500	Chirikof Slope
420	501-700	Chirikof Slope
520	701-1000	Chirikof Slope

Figure 3.-Chirikof INPFC Area with strata boundaries.



Strata Legend		
Code	Depth (m)	Name
30	1-100	Albatross Shallows
31	1-100	Albatross Banks
32	1-100	Lower Cook Inlet
33	1-100	Kenai Peninsula
35	1-100	Northern Kodiak Shallows
130	101-200	Albatross Gullies
131	101-200	Portlock Flats
132	101-200	Barren Islands
133	101-200	Kenai Flats
134	101-200	Kodiak Outer Shelf
230	201-300	Kenai Gullies
231	201-300	Kodiak Slope
232	201-300	Upper Shelikof Gully
330	301-500	Kodiak Slope
430	501-700	Kodiak Slope
530	701-1000	Kodiak Slope

Figure 4.--Kodiak INPFC Area with strata boundaries.



Strata Legend		
Code	Depth (m)	Name
40	1-100	Yakutat Shallows
41	1-100	Middleton Shallows
140	101-200	Middleton Shelf
141	101-200	Yakataga Shelf
142	101-200	Yakutat Flats
143	101-200	Fairweather Shelf
240	201-300	Yakutat Gullies
242	201-300	Elias-Fairweather Slope
243	201-300	Middleton Slope
340	301-500	Yakutat Deep Gullies
342	301-500	Elias-Fairweather Slope
343	301-500	Middleton Slope
442	501-700	Elias-Fairweather Slope
443	501-700	Middleton Slope
542	701-1000	Elias-Fairweather Slope
543	701-1000	Middleton Slope

Figure 5.--Yakutat INPFC Area with strata boundaries.

Allocating Samples in Multispecies Surveys

One critical aspect of a synoptic demersal trawl survey of the Gulf was the need to assess abundance of a multiplicity of species. Table 2 lists a number of commercially or ecologically important species that live in the Gulf which are vulnerable to sampling by a bottom trawl. Several species of commercially important crabs. scallops, and shrimps also live in the Gulf of Alaska and may be, to some slight degree, vulnerable to a bottom trawl like the type employed in these surveys;

Optimal allocation for any one species was compromised by conflicts with optimal allocations for other species. We responded in two ways. First, allocation assessments were based on a priori data pooled over a number of biologically and economically important species, Second, we tried to over-sample in as many strata as possible: that is, we tried to have a higher than optimal concentration of stations. We tried to do this for strata we believed to be more biologically productive. We hoped that by over-sampling with respect to most species in a particular stratum, we would avoid undersampling for the one or two species with high abundance in that stratum. Oversampling proved difficult, however, simply because of the large size strata in the Gulf.

Vessels

The vessels used in Gulf triennial surveys had to possess the following features: They must be large enough to provide a stable working platform up to at least moderate gale conditions. Adequate deck space for handling the fishing gear and for five scientists to collect data from the catch was also required. Each vessel must possess sufficient power to pull the net over the bottom at 5.56 km/hr (3 knots). The vessels were required to be able to stay at sea for as long as 25 days, providing berth space and living quarters for the vessel crew and a field party of five. The typical vessel operating under charter to the U.S.

Table 2.--Some of the commercially important finfish species in the Gulf of Alaska which are vulnerable to some degree to sampling by a demersal trawl.

Species Group	Species	(Common Name)
flatfish:	*Atheresthes stomias*	arrowtooth flounder
	Hippoglossus stenolepis	Pacific halibut
	Hippoglossoides elassodon	flathead sole
	Parophrys vetulus	English sole
	Microstomus pacificus	Dover sole
	Errex zachirus	rex sole
	Pleuronectes asper	yellowfin sole
	Pleuronectes bilineatus	rock sole
roundfish:	*Anoplopoma fimbria*	sablefish
	Gadus macrocephalus	Pacific cod
	Theragra chalcogramma	walleye pollock
rockfish:	*Sebastolobus alascanus*	shortspine thornyhead
	Sebastes aleutianus	rougheye rockfish
	Sebastes alutus	Pacific ocean perch
	Sebastes borealis	shortraker rockfish
	Sebastes polyspinis	northern rockfish

Government has been between 32 m and 40 m in length and driven by 500 to 850 horsepower engines.

Modem navigation and communications instruments were employed on all boats in both surveys. Positions were determined by Loran. While this technology is quite accurate, it is not without error. Errors in position may have been exacerbated in several survey strata because they were in close proximity to Loran signal stations. Locations of sample sites and distances fished may be in error for a number of the tows.

Executing:

The surveys were executed during the summer months. This is the feeding season for most species and we expected to see a wider, more even distribution than the heightened patchiness associated with spawning aggregations. Summer surveys also allowed the small charter vessels to avoid as much rough weather as possible. The surveys were collapsed into as small a time frame as possible so that the resulting data might have as synoptic a character as could be.

Logistics constrained the Japanese vessel to work from west to east and then back, east to west. U.S. vessels progressed through the region from west to east, attempting to synchronize their efforts with that of the Japanese vessel: in each year. one U.S. vessel was able to stay in the same stratum as the Japanese vessel at the same time during the first half of the period of Japanese involvement. However, in neither year was there a period where all three vessels worked in the same stratum. A few strata were represented with tows made by only one of the boats.

Processing the Catch

Methods for collecting data from the catch once it was aboard followed those of other AFSC trawl surveys (Hughes 1976, Wakabyashi et al. 1985, Wilderbuer 1988). On US. vessels, subsamples were taken from catches that were greater than 1.000 kg. Catches of 1,000 kg or less on U.S. vessels, and all catches on the Japanese vessels, were processed completely. Weights and counts were taken for each species once the catch or subsample had been sorted.

Fork lengths (tip of snout to end of middle rays of the caudal fin) were measured for each species except squid and grenadiers. Mantle lengths were recorded for squid and the distance from snout to anus was used as an index of size for grenadiers. Length frequencies were taken from a randomly selected subsample of a species if it was present in large numbers. Methods for selecting such subsamples have been described elsewhere (Hughes 1976).

Age structures were collected for a number of species. Individuals were chosen randomly. After choosing the random subsample, length and weight data were taken as well as otolith, scale, or fin ray specimens for determining age.

Estimation

Estimating *the index* of abundance -- Following established methods of estimation (Gunderson and Sample 1980 Wakabyashi et al. 1985). mean fish density was inferred from mean CPUE. Mean CPUE was estimated as a stratified, arithmetic mean of observed CPUEs. weighted by stratum area. This estimator reduces variation due to differences among strata (Cochran 1977). Though we will not include estimates of abundance indices in this report, this is the context for the discussions of FPCs and their estimators which follows.

Fishing power -- Fishing power is an inherent concept within the notion of CPUE as a measure of fish abundance. Fishing power is some measure of the effectiveness of a fishing system in actually catching fish. Following a standard conceptual model for CPUE (Ricker 1975) we let

$$CPUE_i = (q_i)(N_i)$$

where q_i = the fraction of the population encountered at station that is removed by exactly one unit of effort at that station,

and N_i = the total population encountered by that one unit of effort at station i.

Here, fishing power is represented by the quantity "q." It is often called the catchability coefficient. Note that this model of CPUE defines N as “encountered N” rather than the "total N" that one might employ when modelling commercial fishery CPUE. In our presentation, q simply equates to the probability of capturing a fish that has been encountered, rather than some ii-action of the total population. Henceforth when we use the phrase “probability of capture,” we refer to the quantity “q” defined here.

To estimate absolute abundance, we must have a value for q. In past analyses, we have assumed q = 1. However, data for testing this assumption or estimating q are currently beyond our technological capability to collect. It seems highly likely that q is quite different from 1.0, either greater or less than, for most species. Hence it would also seem likely that estimates of absolute abundance made from demersal trawl data are incorrect.

Inference can still be drawn regarding trends in abundance by assuming that q equals some constant, albeit unknown. With a constant probability of capture, we would be able to support a hypothesis that change in an observed abundance index reflects either change in true abundance, change in the distribution of that fish, or both. By assuming constant q. observed change in abundance indices could be assumed real and not an artifact of change in relative fishing power.

The probability of capture is a function of many variables. It may be subject to change due to change in fishing gear. fishing methods, acoustic attributes of a vessel, or some synchronous combination of these effects. By standardizing sampling gear (the net, doors, and bridles) and methods of trawling, we tried to hold these effects constant. We then assumed that the probability of capture was constant with respect to these variables. Fortunately, though true q is inestimable for these data, relative differences in q are. Because of this, we can assess the validity of the assumption that q is constant between vessels and estimate a factor to force this weaker assumption to be true.

It is important to note that the probability of capture may also be subject to change due to variation in fish behavior with respect to the trawl or change in preferred habitat from year to year (which may, in turn, be linked to some spurious factor such as shift in prey distribution or abundance). We were forced to assume that q was constant with respect to such effects.

Estimating FPCs -- Before a mean CPUE could be calculated, observed catches were adjusted, for the relative fishing power differences described above. This was done by multiplying the catches made by one vessel with a correction factor, or FPC. to calibrate them to those of another vessel. The FPC has been estimated in two ways at the AFSC. Early analyses estimated FPC with FPC', a ratio of arithmetic

where

$$\overline{CPUE_1} = \frac{1}{n_1}\sum CPUE_{1j}$$

and

$$\overline{CPUE_2} = \frac{1}{n_2}\sum CPUE_{2j}$$

are the mean CPUEs for vessels 1 and 2, respectively. To correct catches for relative fishing power differences, we multiplied a catch made by vessel 2 with FPC' which degradesthat catch from an observation to an estimate of what would have been caught had vessel 1 made exactly the same tow at exactly the same time:

$$FPC' \times C_{2j} = \frac{\overline{CPUE_1}}{\overline{CPUE_2}} \times C_{2j} .$$

Final analyses employed a different estimator of a FPC. Concern over the instability of the ratio of arithmetic means and the disproportionate influence of rare, large catches led to the development of a new estimator (Kappenman 1992). The Kappenman FPC achieves robustness by transforming the highly skewed CPUE distributions through a power function into symmetric distributions. The estimator itself is a function of the scale and shape parameters of the transformed distribution. The critical assumption is that the shapes of the CPUE distributions of each vessel are identical.

Negligibility -- When there is a true fishing power difference between two vessels, we are forced to choose between systematic and random error. If we do not correct for the difference the systematic error in the data produces a bias in the estimated mean CPUE. If we do correct with an estimate of the difference, we remove the error due to bias, but we increase the error due to randomness: that is. the variance of the mean CPUE because we have introduced another random variable. We defined a fishing power difference to be negligible when the latter error is greater than the former. By this definition. it becomes possible for a true fishing power difference to be quite large but still be negligible. This would happen anytime the variance of the difference or the variance of the estimated difference is high.

We developed this definition because, as analyses of these surveys unfolded, we began to question the automatic application of an FPC every time we perceived a relative fishing power difference. Instability of the ratio of means, particularly the sensitivity of this estimator to infrequent but large CPUE observations, convinced us that our estimates of the FPC had an extremely high variance (Robson 1960. Robson 1961. Munro 1989). We were concerned that, by corrupting observed CPUEs into high variance estimates with an estimated correction factor, we were introducing unacceptably large and unaccounted uncertainty into estimates of mean CPUE.

Determining negligibility requires computation of the mean square error (MSE) of the mean CPUE as estimated with and without an FPC. A simple decision rule would then be:

"Use the estimate with the lower MSE." Unfortunately, we had neither the time nor the capacity to pursue a study of MSEs at the time of these analyses. Consequently the process for determining negligibility was entirely subjective; we were without rigorous decision rules. The magnitude of the FPC estimates themselves did influence our decisions. However, unless there was some clear factor that could explain a large FPC estimate, such as radical differences in vessel, gear, or towing characteristics, we deemed even large FPCs negligible. Generally, given the very unstable nature of a ratio of means, the higher the variance of mean CPUE for a species the less likely we were to apply an FPC.

When we adopted the Kappenman FPC estimator, we maintained previous assumptions of negligibility. We did this because at present the variance of the estimate of the Kappenman FPC is not completely developed and preliminary indications suggest that, though it is much more stable than a ratio of means, its variance is still high (Kappenman pers. commun.).

Methods Peculiar to 1984

Stratification and Survey Design

The 1984 survey used a slightly different stratification than that presented above. At that time stratum 30 included what is now stratum 35. These strata are defined by the nearshore waters, 0 - 100 m depth. of Kodiak and Afognak Islands. (See Table 1. Fig. 4.)

We considered three potential sampling densities for each stratum. A *priori* data did not permit finer division of sampling densities. (These levels are presented below as part of the station selection methods.) The allocation was based on demersal trawl data from surveys of the central Gulf of Alaska in 1978 and 1979 (Feldman and Rose 1981). Scarcity of data forced us to assume that the 1978 and 1979 surveys yielded the mean and the variance of measures of CPUEs that were representative of those in the western Gulf. Table 3 gives station allocation for each stratum. Table 4 shows the assignment of stations to vessels.

Stations were chosen from a grid of points laid over the survey area. Each point in the grid was 5 nautical miles from its nearest neighbor along lines of latitude and longitude. For a stratum expected to have high fish density the sample allocation was one out of every four points on the grid that fell within that stratum. For a stratum expected to have moderate fish density the sample allocation was one out of every six points on the grid. For a stratum expected to have low fish density the allocation was one grid point out of every nine. Once the number of stations was determined for each stratum their sites were selected systematically after randomly choosing a starting point,

This selection procedure worked well in the strata of the continental shelf which were generally broad in shape. However, another selection method was necessary for the extremely long and slender strata of the continental slope because so few grid points actually fell in these strata. Slope stations were chosen to correspond to index stations that had already been established as part of the U.S. Japan cooperative longline survey which had been taking place annually since 1979 (Sasaki et al. 1982). A total of 30 transect lines spaced between 35 and 80 km apart were sampled from the Islands of Four Mountains to Cape St. Elias. Along each transect one or more tows were attempted by each of two vessels working together. The exact location along the transect, within a depth zone. was randomly determined, If the longline survey vessel was working a station at the same time as the trawlers, the two trawlers made sure that their tow sites were at least 3 nautical miles from the transect. This was done to avoid influencing catch rates observed in the longline survey. One hundred eighty stations were allocated to the 100-200 m slope strata. Sixty stations

Table 3.--Design of the 1984 triennial bottom trawl survey of the Gulf of Alaska:'Allocated and successful stations in each sampling stratum.

INPFC Region	Stratum	Numbers of Stations Allocated	Attempted	Successful	Stratum Area (km^2)	Stations per 1,000 km^2
Shumagin	10	32	19	15	8,616	1.70
	11	52	60	53	13,679	3.90
	12	12	15	14	7,443	1.90
	13	47	23	22	14,626	1.50
	110	26	26	26	4,233	6.10
	111	20	48	46	8,036	5.70
	112	10	10	9	2,267	4.00
	210	20	23	23	2,737	8.40
	310	20	18	17	2,528	6.70
	410	20	16	15	2,010	7.50
	510	20	7	5	1,873	2.70
Chirikof	20	11	8	8	8,283	1.00
	21	22	17	17	7,299	2.30
	22	26	19	19	10,993	1.70
	120	62	53	53	11,082	4.80
	121	20	10	10	7,673	1.30
	122	12	23	20	4,994	4.00
	220	26	27	27	9,967	2.70
	221	12	17	16	1,533	10.40
	320	12	12	11	1,633	6.70
	420	12	11	10	1,897	5.30
	520	12	6	6	3,018	2.00
Kodiak	30	17	6	6	6,119	1.00
	31	58	49	45	15,339	2.90
	32	12	10	9	10,472	0.90
	33	8	3	3	5,512	0.50
	35	*	7	7	2,401	2.90
	130	42	39	39	7,838	5.00
	131	20	21	20	7,350	2.70
	132	28	20	20	10,949	1.80
	133	30	29	28	12,002	2.30
	134	20	25	25	5,076	4.90
	230	16	19	18	5,804	3.10
	231	20	20	20	1,626	12.30
	232	8	5	5	3,190	1.60
	330	20	21	20	2,960	6.80
	430	20	15	15	1,550	9.70
	530	20	6	6	3,444	1.70
Yakutat	41	10	9	8	8,476	0.90
	140	10	16	12	7,800	1.50
	243	12	3	3	350	8.60
	343	12			542	
	443	12			309	
	543	12			919	

* When originally assigning stations, stratum 35, nearshore Kodiak Island, Shelikof Strait side, had not been separately defined so stations were not assigned explicitly to it.

Table 4.-Assignment of stations and numbers of stations successfully sampled by vessel and sampling stratum in the 1984 triennial bottom trawl survey of the Gulf of Alaska

		Planned Number of Samples (tows)			Successful Number of Samples (tows)		
INPFC Area	**Stratum**	***Morning Star***	***Ocean Spray***	***Daikichi Maru No. 37***	***Morning Star***	***Ocean Spray***	***Daikichi Maru No. 37***
Shumagin	10	16		16	14		1
	11	26		26	22		31
	12	12			14		
	13	33		14	19		3
	110	13		13	15		11
	111	10		10	22		24
	112	5		5	6		3
	210	10		10	10		13
	310	10		10	8		9
	410	10		10	7		8
	510	10		10	2		3
Chirikof	20	6	5		4	3	1
	21		11	11		7	10
	22		13	13		13	6
	120	31		31	29	3	21
	121		10	10		6	4
	122	6		6	10		10
	220		13	13	2	13	14
	221	6		6	8		8
	320	6		6	6		5
	420	6		6	5		5
	520	6		6	3		3
Kodiak	30		17			5	1
	31		29	29		15	30
	32		12			9	
	33		8			2	1
	35		•	•		5	2
	130		21	21		20	19
	131		10	10		9	11
	132		14	14		13	7
	133		15	15		13	15
	134	10		10	13		12
	230		8	8		9	9
	231	10		10	11		9
	232		4	4		5	
	330	10		10	10		10
	430	10		10	8		7
	530	10		10	3		3
			10				
Yakutat	41		10			8	
	140				1	8	3
	243	6		6	1		2
	343	6		6			
	443	6		6			
	543	6		6			

• When originally assigning stations, stratum 35, nearshore Kodiak Island, Shelikof Strait side, had not been separately defined so stations were not assigned explicitly to it.

were planned for each of the three depth intervals between 200 and 700 m. Twenty-nine stations were planned between 700 and 1,000 m. This resulted in a sampling density in the slope portion of the survey which exceeded the original allocations. This was accepted because it would improve the precision of estimates of commercially important rockfish stocks that dwell on the slope.

Vessels and Gear

The *two* U.S. vessels, *the 37* m F/V *Morning Star* and the 28 m F/V Ocean *Spray, were* both house-forward style crabber/trawlers powered with main engines developing 1,125 and 565 continuous horsepower, respectively. Each U.S. vessel operated with a crew of five, including the captain and a scientific complement of four or five.

Noreastern trawls were supplied to the U.S. vessels by the AFSC. Two versions were sent out: one constructed of nylon and another constructed of polyethylene. The nylon net was an older style that had been used in previous AFSC surveys. Not only did it differ in material, it also differed slightly in design. The differences between nylon and polyethylene nets are well documented as part of a gear comparison study (Wilderbuer 1988). Diagrams of key differences have been reproduced from his thesis in Appendix A. The polyethylene net, the new standard, was essentially of the same design as the older, nylon net except that it had a slightly shorter headrope. a slightly longer footrope. and a section of webbing in the lower wing section had been replaced by a single cable to avoid damage that frequently occurs to meshes there.

The *F/V Daikichi Maru* No. 37 was a 50 m, land-based, stem trawler of 349 gross tons powered by a 2,500 horsepower main engine. The crew numbered 25. including fishing master and captain. The Daikichi Maru No. 37 had engaged in commercial fishing in these waters for a number of years previous to the survey. Consequently the captain and crew were very knowledgeable concerning the grounds and the effective use of their gear. The scientific party consisted of two Japanese scientists and one U.S. scientist.

The Daikichi Maru No. 37 used a considerably different net from the Noreastern. It was a much larger net with a relatively wider, lower opening. It was a two-seam trawl with roller gear constructed of automobile tires and bobbins made of steel and rubber. The trawl was constructed of polyethylene webbing. Mesh sizes were considerably larger than those of the Noreastern. Rather than a small-mesh codend liner, as used with the standard sampling gear, the Japanese codend consisted of three layers of webbing, each having 100 mm meshes. The three layers reduced the effective mesh size. Biologists aboard during operations felt that this worked fairly well to retain smaller items of the catch, though perhaps not as well as the liner used on the U.S. nets. This trawl was spread by doors constructed of wood and steel that weighed 2,931 kg each. The net was joined to the doors with a combination single and double dandyline arrangement totaling 120 m. As opposed to the Noreastern. a high-opening rockfish trawl, this net was designed to catch Greenland turbot *Reinhardtius hippoglossoides* in a fishery that takes place over steep, hard grounds and in which there is much less to be gained by maintaining a large vertical opening.

Net Mensuration

Width of the Noreastern trawl mouth was estimated from data collected during other surveys. Net mensuration studies (Wahtne 1977) indicated, the Noreastem trawl had a wingtip-to-wingtip spread of 13.4 m. However, this work was done with much smaller vessels, which had much narrower beams, using notably smaller doors. Based on unpublished data and qualitative assessments of the vessels, doors, and fishing conditions, (Wahtne pers. commun.). we concluded that a net width of 18.3 m was more realistic. This path width was used in the first analysis of 1984 data. Later, a more refined estimate of 16.43 m was developed from net mensuration data collected during a gear comparison experiment (Wilderbuer 1988). In either case, we applied one estimated net width to all U.S. tows regardless of depth. No variance of that estimate was incorporated in the CPUE observations.

Height and width of the Japanese trawl was measured by mounting a commercially available headrope transducer in a sideways configuration on one wingtip and mounting a sonically reflective plate on the opposite wingtip (Wakabyashi 1984). Area swept was computed for each tow based on the observed net width. The net width varied between 21 and 29 m and increased as depth increased (Wakabyashi 1984). Tows that were not measured in this way had their net widths estimated from tows made at similar depths that did provide mensuration data. No variances of these estimates were incorporated in the CPUE observations.

Collecting Data To Estimate FPCs

Data to test for fishing power differences which might have resulted between nylon and polyethylene Noreastern trawls were collected aboard the Morning Star. This vessel alternated tows between the net types to produce a set of data for each net within each stratum. The Ocean Spray used only the nylon net.

Differences in relative fishing power were estimated from a subset of the survey data. The Daikichi Maru No. 37 and the Morning *Star* worked together along the continental slope and did some side-by-side tows on Davidson Bank, producing 123 pairs of comparable tows, from similar places and times. This pairing served only to ensure equal weighting between U.S. and Japanese data under a variety of fishing conditions. Mean CPUEs for FPC ratios were estimated from pooled observations within each vessel’s subset. Consequently, it was not true pairing; we had a two-sample situation rather than a single sample of pairs.

Executing the Survey

Eight hundred twenty-three tows were made between the Islands of Four Mountains (170” W) and Cape St, Elias (143° 30’W) and between the depths of 16 m and 768 m. Of these tows, 749 were considered to have produced valid observations. Of these, 334 were completed by the *Daikichi Maru* No. 37. 249 by the Morning Star, and 166 by the Ocean *Spray*. Table 3 shows the number of tows taken in each stratum. Table 4 shows these tows broken down by vessel. Table 5 summarizes allocated, attempted, and successful tows over INPFC areas and depth zones. Table 6 summarizes the biological data taken in the course of the survey.

The *Morning* Star began sampling shelf strata in the vicinity of the Semidi Islands (157° W) on 20 June 1984 and worked westward to the Islands of Four Mountains, arriving 13 July. The Morning Star was joined there by the Daikichi Maru No. 37 on 14 July. The two vessels worked together in an easterly direction, sampling slope strata and completing side-by-side tows on Davidson Bank. Both vessels reached the eastern boundary of the survey area, Cape St. Elias. on 18 August. The Morning *Star* continued working toward the east, completing tows in the eastern Gulf as part of the survey run by the ABL. The *Daikichi Maru* No. 37 turned back toward the west, completing tows on shelf stations, ending its work at the Islands of Four Mountains on 2 October. The *Ocean Spray* began trawl operations at the eastern boundary of the survey region on 27 June. The vessel completed tows in shelf strata along the Kenai Peninsula and the east side of Kodiak Island and on toward the Semidi Islands, arriving there *29* July. The *Ocean Spray* turned at that

Table 5.--Summary of the design of the 1984 triennial bottom trawl survey of the Gulf of Alaska: Allocated and successful stations in each INPFC Region and depth zone within each region.

	Numbers of Stations				Stations per
INPFC Region and depth	Allocated	Attempted	Successful	Area (km^2)	1,000 km^2
Shumagin (Total)	279	265	245	68,048	3.60
1 - 100 m	143	117	104	44,364	2.30
101 - 200 m	56	84	81	14,536	5.60
201 - 300 m	20	23	23	2,737	8.40
301 - 500 m	20	18	17	2,528	6.70
501 - 700 m	20	16	15	2,010	7.50
701 - 1,000 m	20	7	5	1,873	2.70
Chirikof (Total)	227	203	197	68,372	2.90
1 - 100 m	59	44	44	26,575	1.70
101 - 200 m	94	86	83	23,749	3.50
201 - 300 m	38	44	43	11,500	3.70
301 - 500 m	12	12	11	1,633	6.70
501 - 700 m	12	11	10	1,897	5.30
701 - 1,000 m	12	6	6	3,018	2.00
Kodiak (Total)	339	295	286	101,632	2.80
1 - 100 m	95	75	70	39,843	1.80
101 - 200 m	140	134	132	43,215	3.10
201 - 300 m	44	44	43	10,620	4.00
301 - 500 m	20	21	20	2,960	6.80
501 - 700 m	20	15	15	1,550	9.70
701 - 1,000 m	20	6	6	3,444	1.70
Yakutat (Total)	68	28	23	18,396	1.30
1 - 100 m	10	9	8	8,476	0.90
101 - 200 m	10	16	12	7,800	1.50
201 - 300 m	12	3	3	350	8.60
301 - 500 m	12			542	1.80
501 - 700 m	12			309	
701 - 1,000 m	12			919	
Total over all INPFC regions and depths	913	791	751	256,448	2.93

Table 6.--Summary of biological data collected during the 1984 Gulf of Alaska triennial bottom trawl survey. Units are numbers of observations for each species.

Species	Length	Weight	Age	Sexual Maturity
Arrowtooth flounder	39,637	1,058	2,561	0
Flathead sole	23,419	944	1,837	0
Rock sole	19,870	460	2,113	0
Rex sole	12,008	621	621	0
Dover sole	9,385	530	530	530
Pacific halibut	7,044	0	0	0
Yellowfin sole	3,698	334	334	334
Butter sole	1,468	45	45	45
Greenland turbot	43	0	0	0
English sole	53	0	0	0
Starry flounder	356	0	0	0
Sand sole	165	0	0	0
Alaska plaice	8	0	0	0
Sablefish	15,929	0	916	0
Walleye pollock	24,229	1,848	2,567	0
Pacific cod	16,826	1,113	1,592	0
Pacific tomcod	200	0	0	0
Pacific ocean perch	9,228	877	1,297	0
Shortspine thornyhead	13,866	122	482	0
Northern rockfish	4,312	417	747	0
Rougheye rockfish	4,080	534	744	0
Shortraker rockfish	939	43	131	0
Dusky rockfish	939	177	168	9
Sharpchin rockfish	371	0	0	0
Harlequin rockfish	269	0	0	0
Giant grenadier	3,539	0	0	0
Popeye grenadier	1,595	0	0	0
Atka mackerel	473	154	154	0
Pacific herring	131	0	0	0
Eulachon	85	0	0	0
Chinook salmon	10	0	0	0
Coho salmon	13	0	0	0
Chum salmon	162	0	0	0
Red squid	1,152	0	0	0
Bairdi tanner crab	264	0	0	0
Dungeness crab	13	0	0	0
Red king crab	9	0	0	0

point and worked northeastwardly through Shelikof Strait and on into lower Cook Inlet, finishing there on 22 August.

Tables 7 - 10 present data on four measures of vessel and tow performance: towing speed, distance fished, area swept by the trawl, and scope ratio. Data are pooled across INPFC areas but segregated by depth. Means in these tables are arithmetic and the standard error of the mean is the usual sample standard deviation divided by the square root of the sample size. These tables may be used to assess the degree to which each of the three vessels adhered to standardized towing procedures. On the *Morning Star.* a commercially available headrope transducer was used to determine when the net had reached bottom and that the tow should commence. No such instrument was available on the Ocean *Spray;* on that vessel, we depended on the judgment of the skipper. On the *Daikichi Maru* No. 37, net mensuration instruments were used to determine when the net was on bottom and ready to fish.

Methods Peculiar to 1987

The experience gained during the 1984 triennial survey enabled us to improve the survey design for 1987. There were slight modifications of the underlying stratification scheme and sample allocation changed between the two surveys. The sample unit and the sampling methodology remained unchanged. The sampling gear was also the same, though only the polyethylene Noreastern trawl was used: no nylon nets were used. None of the participating vessels had been involved in the 1984 survey. The Japanese vessel, again, provided its own sampling gear, which was different from the standard and was also quite different from that used by the Japanese vessel of 1984. Different net mensuration instruments were used. An important difference was that an independent investigation provided data for estimating FPCs.

Table 7.--Mean trawling speeds and their standard errors for each of the three vessels participating in the 1984 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are kilometers per hour. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Trawling Speeds (km/hour)		
Depth Zone		***Morning Star***	***Ocean Spray***	***Daikichi Maru No. 37***
1 - 100 m	**mean**	**5.59**	**5.53**	**5.47**
	standard error	**0.0506**	**0.0547**	**0.0620**
	sample size	**61**	**64**	**83**
101 - 200 m	**mean**	**5.59**	**5.58**	**5.44**
	standard error	**0.0279**	**0.0875**	**0.0558**
	sample size	**107**	**73**	**141**
201 - 300 m	**mean**	**5.61**	**5.67**	**5.45**
	standard error	**0.0937**	**0.0524**	**0.0791**
	sample size	**31**	**28**	**57**
301 - 500 m	**mean**	**5.54**	**5.56**	**5.45**
	standard error	**0.0997**	**---**	**0.1165**
	sample size	**24**	**1**	**25**
501 - 700 m	**mean**	**5.61**		**5.36**
	standard error	**0.1749**		**0.1069**
	sample size	**20**	**0**	**19**
701 - 1,000 m	**mean**	**5.05**		**5.09**
	standard error	**0.1915**		**0.1895**
	sample size	**8**	**0**	**9**

Table 8.--Mean distances fished and their standard errors for each of the three vessels participating in the 1984 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are kilometers. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Distances Fished (km)		
Depth Zone		***Morning Star***	***Ocean Spray***	***Daikichi Maru No. 37***
1 - 100 m	mean	2.58	2.64	2.65
	standard error	0.0650	0.0551	0.0386
	sample size	61	64	83
101 - 200 m	mean	2.70	2.76	2.68
	standard error	0.0379	0.0516	0.0324
	sample size	107	73	141
201 - 300 m	mean	2.62	2.84	2.71
	standard error	0.0920	0.0254	0.0408
	sample size	31	28	57
301 - 500 m	mean	2.38	2.78	2.71
	standard error	0.1235	---	0.0634
	sample size	24	1	25
501 - 700 m	mean	2.70		2.66
	standard error	0.0710		0.0547
	sample size	20	0	19
701 - 1,000 m	mean	2.49		2.54
	standard error	0.0897		0.0947
	sample size	8	0	9

Table 9.--Mean efforts, (area swept). and their standard errors for each of the three vessels participating in the 1964 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are square kilometers. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance. Net width was 16.43 m for the U.S. boats.

		Efforts (area swept: km^2)		
Depth Zone		***Morning Star***	***Ocean Spray***	***Daikichi Maru No. 37***
1 - 100 m	**mean**	**0.0423**	**0.0434**	**0.0572**
	standard error	**0.001068**	**0.000905**	**0.001054**
	sample size	**61**	**64**	**83**
101 - 200 m	**mean**	**0.0443**	**0.046**	**0.0665**
	standard error	**0.000623**	**0.000566**	**0.000886**
	sample size	**107**	**73**	**141**
201 - 300 m	**mean**	**0.043**	**0.0466**	**0.0725**
	standard error	**0.001511**	**0.000417**	**0.001166**
	sample size	**31**	**28**	**57**
301 - 500 m	**mean**	**0.0391**	**0.0456**	**0.0749**
	standard error	**0.002029**	**---**	**0.001808**
	sample size	**24**	**1**	**25**
501 - 700 m	**mean**	**0.0444**		**0.0731**
	standard error	**0.001167**		**0.001949**
	sample size	**20**	**0**	**19**
701 - 1,000 m	**mean**	**0.0409**		**0.0704**
	standard error	**0.001474**		**0.0028**
	sample size	**8**	**0**	**9**

Table l&--Scope ratios and their standard errors for each of the three vessels participating in the 1984 triennial bottom trawl survey of the Gulf of Alaska. The scope ratio is the ratio of trawl wire deployed to depth. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Scope Ratio		
Depth Zone		*Morning Star*	*Ocean Spray*	*Daikichi Maru No. 37*
1 - 100 m	mean	3.8566	3.4659	3.2413
	standard error	0.1163	0.08228	0.05892
	sample size	61	64	83
101 - 200 m	mean	2.6935	2.979	2.7899
	standard error	0.03192	0.02143	0.02514
	sample size	107	73	141
201 - 300 m	mean	2.415	2.8416	2.5318
	standard error	0.02462	0.01641	0.02738
	sample size	31	28	57
301 - 500 m	mean	2.2161	2.7108	2.384
	standard error	0.02531	---	0.03482
	sample size	24	1	25
501 - 700 m	mean	2.0642		2.2352
	standard error	0.01392		0.02784
	sample size	20	0	19
701 - 1,000 m	mean	2.0517		2.0123
	standard error	0.03531		0.01857
	sample size	8	0	9

Stratifacation and Survey Design

The stratification scheme used in the 1987 survey is shown in Table 1 and Figures 2 - 5. Stations were reallocated among strata based on the distributions of fish observed in the 1984 survey. Table 11 gives the allocations by stratum. Table 12 shows how these allocations were assigned among vessels.

As in 1984 sampling sites were chosen from a grid of points laid over the survey area. Each point in the grid was 5 nautical miles from its nearest neighbor along lines running north-south and east-west. Once the number of stations was determined for each stratum, their sites were selected systematically after randomly choosing a starting point.

This selection procedure worked well in the strata of the continental shelf which were generally broad in shape. However, another selection method was necessary for the extremely long and slender strata of the continental slope because so few grid points actually fell in these strata. We did not use the transect procedure employed in 1984 at the established longline stations. Instead, the 300-500 m. 500-700 m, and 700-1006 m slope strata were broken longitudinally into segments, each segment being the equivalent of 85.7 km^2 areas, the area represented by each point on the original grid. A set of these areas was chosen for sampling systematically after randomly choosing a starting area. The tow was to be taken from the center of each area.

Vessels and Gear

The U.S. vessels were the F/V *Lets Go* and the F/V *Nore-Dick*. Both were small, house-forward stem-trawlers. The *Lets Go* was 26 m in length and powered by a main engine that developed 565 continuous horsepower. The *Nore-Dick* was 24 m in length and

Table 11.--Design of the 1987 triennial bottom trawl survey of the Gulf of Alaska: Allocated and successful stations in each sampling stratum.

INPFC Region	Stratum	Numbers of Stations			Stratum Area (km^2)	Stations per 1,000 km^2
		Allocated	Attempted	Successful		
Shumagin	10	41	32	28	8,616	3.20
	11	47	39	35	13,679	2.60
	12	21	19	18	7,443	2.40
	13	35	30	25	14,626	1.70
	110	7	9	9	4,233	2.10
	111	40	38	38	8,036	4.70
	112	8	8	8	2,267	3.50
	210	10	7	7	2,737	2.60
	310	7	5	5	2,528	2.00
	410	4	3	3	2,010	1.50
	510	3	2	2	1,873	1.10
Chirikof	20	30	26	20	8,283	2.40
	21	8	11	11	7,299	1.50
	22	24	26	24	10,993	2.20
	120	90	76	75	11,082	6.80
	121	29	22	22	7,673	2.90
	122	26	21	21	4,994	4.20
	220	12	14	13	9,967	1.30
	221	5	4	4	1,533	2.60
	320	5	5	5	1,633	3.10
	420	3	4	4	1,897	2.10
	520	5	4	4	3,018	1.30
Kodiak	30	29	14	12	6,119	2.00
	31	30	29	27	15,339	1.80
	32	10	8	8	10,472	0.80
	33	12	5	5	5,512	0.90
	35	*	6	6	2,401	2.50
	130	48	41	41	7,838	5.20
	131	35	27	27	7,350	3.70
	132	35	34	31	10,949	2.80
	133	39	35	35	12,002	2.90
	134	21	15	15	5,076	3.00
	230	9	11	11	5,804	1.90
	231	6	5	5	1,626	3.10
	232	6	6	6	3,190	1.90
	330	8	8	8	2,960	2.70
	430	3	6	6	1,550	3.90
	530	5	1	1	3,444	0.30
Yakutat	41	12	9	9	8,476	1.10
	140	22	21	21	7,800	2.70
	243	2	1	1	350	2.90
	343	1	1	1	542	1.80
	443	1			309	
	543	1			919	

* When originally assigning stations, stratum 35, nearshore Kodiak Island, Shelikof Strait side, had not been separately defined so stations were not assigned explicitly to it.

Table 12.--Assignment of stations and numbers of stations successfully sampled, by vessel and sampling stratum in the 1987 triennial bottom trawl survey of the Gulf of Alaska.

		Planned Number of Samples (tows)			Successful Number of Samples (tows)		
INPFC Area	Stratum	*Nore-Dick*	*Lets Go*	*Taisei Maru No. 35*	*Nore-Dick*	*Lets Go*	*Taisei Maru No. 35*
Shumagin	10	4	21	16	2	11	15
	11	5	7	35	6	5	24
	12		21			18	
	13	9	11	15	4	8	13
	110	2		5	3		6
	111	6	8	26	6	1	31
	112		4	4		4	4
	210	1	2	7			7
	310	1	1	5			5
	410			4			3
	510			3			2
Chirikof	20		30			19	1
	21	2	2	4		3	8
	22	13	4	7	1	8	15
	120	8	25	57	6	15	54
	121	5	8	16		8	14
	122	8		18		2	19
	220	3	4	5	2	5	6
	221	2		3		1	3
	320	1		4			5
	420			3			4
	520			5			4
Kodiak	30	11	18		5	7	
	31	7	4	19	3	2	22
	32		10			8	
	33	6	6		2	3	
	35	*	*	*		6	
	130	10	8	30	3	7	31
	131	2	14	19	2	5	20
	132		20	15		17	14
	133	10	4	25	10		25
	134	6	1	14		2	13
	230	3	1	5	3		8
	231	2		4			5
	232		4	2		3	3
	330	1	1	6			8
	430			3			6
	530			5			1
Yakutat	41	12			9		
	140	22			21		
	243	2			1		
	343	1			1		
	443	1					
	543	1					

* When originally assigning stations, stratum 35, nearshore Kodiak Island, Shelikof Strait side, had not been separately defined so stations were not assigned explicitly to it.

was powered by a main engine that developed 500 continuous horsepower. Each vessel carried a crew of four, including captain, and a scientific party of four.

Both U.S. vessels used standard polyethylene Noreastern trawl. Doors and dandyline characteristics were identical to those used in the 1984 survey. (See Appendix A.)

The Japanese vessel was the F/V *Taisei Maru* No. 35, a land-based, commercial stem trawler. This vessel was 50 m in length and displaced 350 gross tons. The vessel was powered by a 3,400 horsepower main engine. It carried a crew of 24, including the captain and the fishing master, and a scientific party of two Japanese scientists and one U.S. scientist.

The *Taisei Maru* No. 35 used a six-seam trawl of polyethylene webbing with roller gear constructed of automobile tires and bobbins made out of steel and rubber. See Appendix A for a more detailed description, It was a low opening net designed to maximize catches of shortraker rockfish *(Sebastes borealis).* a species which lives close to the bottom on grounds that are often both steep and very hard. This net was much larger than the Noreastern with headrope length of 55.6 m and a footrope length of 65.0 m. Mesh sizes were greater than those of the Noreastern. though mesh size differences between the Japanese net and the standard net were not as great as they were in 1984. Rather than a small-mesh codend liner, as used with the standard sampling gear, the Japanese codend again consisted of three layers of 100 mm webbing. The trawl doors were curved steel, weighed 3,200 kg each, and were attached to the net by combination single and double dandylines that each totaled 156 m in length.

Net Mensuration

An acoustic net mensuration system consisting of a headrope unit and two wing units was used to measure horizontal and vertical dimensions of the Noreastern trawl following standard methods (Rose and Walters 1990, Wilson and Armistead 1991). Path widths were either observed or estimated for each U.S. tow., Net mensuration data were successfully gathered in each of several depths. Table 13 gives mean net widths for each depth. A number of tows were without net mensuration data because the bottom was too rough to put the instruments at risk or the instruments were either malfunctioning or not available. Tows that were not measured in this way had their net widths estimated from tows made at similar depths that did provide mensuration data. No variance of these estimates was incorporated in the CPUE observations.

Height and width was measured on the Japanese trawl using the same methods employed in 1984. Again, path widths of tows with successful observations were used to estimate mean net width for each depth zone where mensuration information was unavailable (Table 13). No variance of these estimates was incorporated in the CPUE observations',

Collecting Data to Estimate FPCs: A Comparison Study

An independent experiment was done to collect data for estimating FPCs. All three vessels sampled together in four different depths off the east side of Kodiak Island. Tows in each depth stratum were taken from areas of very limited size so as not to confound depth effects with habitat effects. The four areas of the study were felt to be typical of many of the habitats for which a bottom trawl was an effective sampling gear. The areas were also chosen in the hope that nonzero catch rates could be observed for as many species as

Table 13.--Mean net widths for the vessels and nets involved/in the 1987 Gulf of Alaska triennial bottom trawl survey.

	Net widths (m)		
Depth Zone	*Nore-Dick*	*Lets Go*	*Taisei Maru No. 35*
1 - 100 m	14.06	14.50	26.58
101 - 200 m	14.80	14.76	28.19
> 200 m	14.85	15.45	30.00

possible. In each depth stratum the three vessels towed side-by-side to reduce the likelihood that just one vessel would strike a patch of fish and produce a unique and very large CPUE. thus confounding variation in fish density with relative fishing power differences. A pattern of repetition was established such that vessels switched position with respect to each other during every comparative tow.

Tables 14 through 17 show four measures of vessel and tow performance during the comparison study: towing speed, distance fished. area swept by the trawl, and scope ratio. Means in these tables are arithmetic and the standard error of the mean is the usual sample standard deviation divided by the square root of the sample size. These tables may be used to assess the degree to which each of the three vessels adhered to standardized towing procedures.

Executing the Survey

A total of 688 randomly selected tows were completed,' not including those of the comparison study. Of these 657 met the criteria for a valid tow and were used in estimating abundance indices. The number of successful hauls for each stratum is shown in Table 11. Of the successful tows, 399 were made by the *Taisei Maru No. 35,* 168 by the *Lets Go.* and 90 by the *Nore-Dick*. Summaries of this effort are given in Table 18 by depth zone and INPFC area. Table 19 summarizes the biological data taken in the course of the survey.

The Nore-Dick began sampling shelf strata at 170° W (Islands of Four Mountains) on 31 May and worked eastward, finishing at 143° 30' W (Cape St. Elias) on 25 July. The *Nore-Dick then* participated in the trawl survey of the eastern Gulf, directed by the ABL. The Lets Go began sampling shelf strata at 170° W (Islands of Four Mountains) on 31 May and worked eastward to 150° W. arriving there on 8 July. At that point the Lets Go left the survey of the

Table 14.--Mean trawling speeds and their standard errors for each of the three vessels participating in the fishing power experiment in the 1987 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are kilometers per hour. Means and their standard errors were computed only from tows that were of acceptable performance.

		Trawling Speeds (km/hour)		
Stratum (depth range)		***Nore-Dick***	***Lets Go***	***Taisei Maru No. 35***
I	mean	4.83	6.89	8.96
(62 - 125 m)	standard error	0.2745	0.2636	0.127
	sample size	19	18	18
II	mean	3.71	5.53	8.43
(142 - 171 m)	standard error	0.2347	0.1019	0.6555
	sample size	13	10	12
III	mean	4.20	5.55	8.65
(217 - 286 m)	standard error	0.1556	0.071	0.1098
	sample size	8	8	8
IV	mean	4.31	5.48	8.78
(290 - 360 m)	standard error	0.0828	0.6725	0.2211
	sample size	7	7	7

Table 15.--Mean distances fished and their standard errors for each of the three vessels participating in the fishing power experiment in the 1987 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are kilometers. Means and their standard errors were computed only from tows that were of acceptable performance.

Stratum (depth range)		Distances Fished (km)		
		Nore-Dick	*Lets Go*	*Taisei Maru No. 35*
I	mean	1.18	1.56	2.01
(62 - 125 m)	standard error	0.118	0.109	0.0962
	sample size	19	18	18
II	mean	1.01	1.38	2.11
(142 - 171 m)	standard error	0.1326	0.0255	0.1639
	sample size	13	10	12
III	mean	1.57	2.10	3.22
(217 - 286 m)	standard error	0.1953	0.2797	0.3765
	sample size	8	8	8
IV	mean	1.42	1.81	2.90
(290 - 360 m)	standard error	0.0273	0.2219	0.073
	sample size	7	7	7

Table 16.--Mean efforts, (area swept), and their standard errors for each of the three vessels participating in the the fishing power experiment in the 1987 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are square kilometers. Means and their standard errors were computed only from tows that were of acceptable performance.

		Efforts, (area swept: km^2)		
Stratum (depth range)		*Nore-Dick*	*Lets Go*	*Taisei Maru No. 35*
I	mean	0.0165	0.0227	0.0566
(62 - 125 m)	standard error	0.00166	0.001578	0.002703
	sample size	19	18	18
II	mean	0.0143	0.0201	0.0594
(142 - 171 m)	standard error	0.001868	0.000376	0.004614
	sample size	13	10	12
III	mean	0.0231	0.0591	0.0906
(217 - 286 m)	standard error	0.002882	0.007879	0.010635
	sample size	8	8	8
IV	mean	0.021	0.051	0.0816
(290 - 360 m)	standard error	0.000403	0.006274	0.002034
	sample size	7	7	7

Table 17.--Scope ratios and their standard errors for each of the three vessels participating in the fishing power experiment in the 1987 triennial bottom trawl survey of the Gulf of Alaska. The scope ratio is the ratio of trawl wire deployed to depth. Means and their standard errors were computed only from tows that were of acceptable performance.

		Scope Ratio		
Stratum (depth range)		***Nore-Dick***	***Lets Go***	***Taisei Maru No. 35***
I	mean	3.24	2.6551	3.6851
(62 - 125 m)	standard error	0.04397	0.04836	0.06207
	sample size	19	18	18
II	mean	3.054	2.564	3.4751
(142 - 171 m)	standard error	0.01836	0.04474	0.03425
	sample size	13	10	12
III	mean	2.6096	2.4755	3.1083
(217 - 286 m)	standard error	0.05719	0.04134	0.07331
	sample size	8	8	8
IV	mean	2.4106	2.2962	2.9599
(290 - 360 m)	standard error	0.06188	0.0154	0.04553
	sample size	7	7	7

Table 18.--Summary of the design of the 1987 triennial bottom trawl survey of the Gulf of Alaska: Allocated and successful stations in each INPFC Region and broken out by depth zone within each region.

INPFC Region and depth		Numbers of Stations Allocated	Attempted	Successful	Area (km^2)	Stations per 1,000 km^2
Shumagin	(Total)	223	192	178	68,048	2.60
	1 - 100 m	144	120	106	44,364	2.40
	101 - 200 m	55	55	55	14,536	3.80
	201 - 300 m	10	7	7	2,737	2.60
	301 - 500 m	7	5	5	2,528	2.00
	501 - 700 m	4	3	3	2,010	1.50
	701 - 1,000 m	3	2	2	1,873	1.10
Chirikof	(Total)	237	213	203	68,372	3.00
	1 - 100 m	62	63	55	26,575	2.10
	101 - 200 m	145	119	118	23,749	5.00
	201 - 300 m	17	18	17	11,500	1.50
	301 - 500 m	5	5	5	1,633	3.10
	501 - 700 m	3	4	4	1,897	2.10
	701 - 1,000 m	5	4	4	3,018	1.30
Kodiak	(Total)	296	251	244	101,632	2.40
	1 - 100 m	81	62	58	39,843	1.50
	101 - 200 m	178	152	149	43,215	3.40
	201 - 300 m	21	22	22	10,620	2.10
	301 - 500 m	8	8	8	2,960	2.70
	501 - 700 m	3	6	6	1,550	3.90
	701 - 1,000 m	5	1	1	3,444	0.30
Yakutat	(Total)	39	32	32	18,396	1.70
	1 - 100 m	12	9	9	8,476	1.10
	101 - 200 m	22	21	21	7,800	2.70
	201 - 300 m	2	1	1	350	2.90
	301 - 500 m	1	1	1	542	1.80
	501 - 700 m	1			309	
	701 - 1,000 m	1			919	
	Total over all INPFC regions and depths	795	688	657	256,448	2.56

Table 19.--Summary of biological data collected during the 1987 Gulf of Alaska triennial bottom trawl survey. Units are numbers of observations for each species.

Arrowtooth flounder	75,962	1,844	1,844	0
Flathead sole	36,875	1,356	1,356	0
Rock sole	16,411	685	685	0
Rex sole	14,955	702	702	0
Dover sole	7,683	490	0	0
Pacific halibut	12,466	0	0	0
Yellowfin sole	4,571	158	158	0
Butter sole	1,643	45	0	0
English sole	426	35	0	0
Starry flounder	510	0	0	0
Alaska plaice	210	0	0	0
Sablefish	13,109	1,137	1,137	0
Walleye pollock	44,018	1,447	1,447	440
Pacific cod	23,384	987	0	0
Pacific ocean perch	14,378	1,121	1,121	0
Shortspine thornyhead	11,829	416	416	0
Northern rockfish	9,557	730	730	0
Rougheye rockfish	3,208	465	465	55
Shortraker rockfish	837	129	0	0
Dusky rockfish	2,401	396	396	0
Sharpchin rockfish	200	0	0	0
Redstripe rockfish	127	0	0	0
Redbanded rockfish	103	0	0	0
Harlequin rockfish	2,080	333	0	0
Giant grenadier	2,535	0	0	0
Atka mackerel	593	280	280	0
Pacific herring	306	0	0	0
Eulachon	343	0	0	0
Capelin	106	0	0	0
Chinook salmon	336	0	0	0
Coho salmon	8	0	0	0
Chum salmon	479	0	0	0
Sockeye salmon	2	0	0	0
Prowfish	42	0	0	0
Red squid	1,359	0	0	0
Kelp greenling	4	0	0	0
Salmon shark	1	0	0	0
Pacific sleeper shark	1	0	0	0

western and central Gulf to participate in the survey of the eastern Gulf under the direction of the ABL. The Lets Go returned to the central Gulf on 31 July, working westward from 149° 30'W to 161° W. arriving there on 16 August. The *Lets Go* then turned and worked back eastward to 152° W, finishing there on 6 September. The *Taisei Maru* No. 35 began sampling in the Islands of Four Mountains (170° W), on 22 May and worked eastward to 148° 30'W. arriving there on 8 July. The *Taisei Maru* No. 35 then worked back westward, beginning at 147° W on 15 July and ending at 170° W (Islands of Four Mountains) on 29 August. Embedded in these operations was the independent comparison study.

Tables 20 - 23 show four measures of vessel and tow performance: towing speed, distance fished, area swept by the trawl, and scope ratio. Data are pooled across INPFC areas but segregated by depth. Means in these tables are arithmetic and the standard error of the mean is calculated as before.

HISTORY OF ANALYSES AND SELECTED RESULTS

In the years following the 1984 and 1987 surveys the data analyses have undergone three iterations. The analyses differed in the way FPCs were incorporated into the estimated mean CPUE, in the FPC estimator itself, or both. Also, with each analysis, corrections in the data have been incorporated as well as changes in stratum definitions. Results of these analyses exist in various documents which have been prepared as part of the management process. We present some of them here, though they are now out of date, to document estimation methods that produced quantities that were critical to important management decisions, This will also chart the development of our current strategy for applying FPCs as well as help frame the next set of questions regarding derivation and use of FPCs.

Table 20.--Mean trawling speeds and their standard errors for each of the three vessels participating in the 1987 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are kilometers per hour. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Trawling Speeds (km/hour)		
Depth Zone		***Nore-Dick***	***Lets Go***	***Taisei Maru No. 35***
1 - 100 m	**mean**	**4.22**	**5.93**	**8.22**
	standard error	**0.1487**	**0.067**	**0.0739**
	sample size	**30**	**86**	**97**
101 - 200 m	**mean**	**4.38**	**5.97**	**8.16**
	standard error	**0.0741**	**0.0458**	**0.0474**
	sample size	**47**	**66**	**229**
201 - 300 m	**mean**	**4.06**	**5.8**	**8.06**
	standard error	**0.1345**	**0.0832**	**0.1098**
	sample size	**12**	**16**	**35**
301 - 500 m	**mean**	**4.89**		**7.78**
	standard error	**---**		**0.1537**
	sample size	**1**	**0**	**18**
501 - 700 m	**mean**			**7.47**
	standard error			**0.1051**
	sample size	**0**	**0**	**13**
701 - 1,000 m	**mean**			**7.15**
	standard error			**0.3615**
	sample size	**0**	**0**	**7**

Table 21,--Mean distances fished and their standard errors for each of the three vessels participating in the 1987 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are kilometers. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Distances Fished (km)		
Depth Zone		***Nore-Dick***	***Lets Go***	***Taisei Maru No. 35***
1 - 100 m	**mean**	**2.07**	**2.74**	**4.01**
	standard error	**0.0772**	**0.0599**	**0.0508**
	sample size	**30**	**86**	**97**
101 - 200 m	**mean**	**2.15**	**2.88**	**4.07**
	standard error	**0.0504**	**0.0483**	**0.0274**
	sample size	**47**	**66**	**229**
201 - 300 m	**mean**	**2.03**	**2.74**	**4.03**
	standard error	**0.0673**	**0.1106**	**0.0549**
	sample size	**12**	**16**	**35**
301 - 500 m	**mean**	**2.44**		**3.95**
	standard error	**---**		**0.0804**
	sample size	**1**	**0**	**18**
501 - 700 m	**mean**			**3.72**
	standard error			**0.1469**
	sample size	**0**	**0**	**13**
701 - 1,000 m	**mean**			**3.91**
	standard error			**0.1807**
	sample size	**0**	**0**	**7**

Table 22.--Mean efforts, (area swept), and their standard errors for each of the three vessels participating in the 1987 triennial bottom trawl survey of the Gulf of Alaska. Units of measure are square kilometers. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Efforts (area swept: km^2)		
Depth Zone		***Nore-Dick***	***Lets Go***	***Taisei Maru No. 35***
1 - 100 m	**mean**	**0.029**	**0.0396**	**0.1065**
	standard error	**0.001119**	**0.000864**	**0.001352**
	sample size	**30**	**86**	**97**
101 - 200 m	**mean**	**0.0317**	**0.0425**	**0.1147**
	standard error	**0.000736**	**0.000713**	**0.000773**
	sample size	**47**	**66**	**229**
201 - 300 m	**mean**	**0.0302**	**0.0421**	**0.1209**
	standard error	**0.000992**	**0.001713**	**0.001647**
	sample size	**12**	**16**	**35**
301 - 500 m	**mean**	**0.0363**		**0.1186**
	standard error	**---**		**0.002413**
	sample size	**1**	**0**	**18**
501 - 700 m	**mean**			**0.1117**
	standard error			**0.004401**
	sample size	**0**	**0**	**13**
701 - 1,000 m	**mean**			**0.1173**
	standard error			**0.00542**
	sample size	**0**	**0**	**7**

Table 23.-Scope ratios and their standard errors for each of the three vessels participating in the 1987 triennial bottom trawl survey of the Gulf of Alaska. The scope ratio is the ratio of trawl wire deployed to depth. Means and their standard errors were computed only from tows that were randomly chosen and of acceptable performance.

		Scope Ratio		
Depth Zone		*Nore-Dick*	*Lets Go*	*Taisei Maru No. 35*
1 - 100 m	mean	3.2477	3.1449	3.718
	standard error	0.05589	0.0585	0.0601
	sample size	30	86	97
101 - 200 m	mean	2.9712	2.559	3.2332
	standard error	0.04612	0.0215	0.02059
	sample size	47	66	229
201 - 300 m	mean	2.4958	2.4785	2.9752
	standard error	0.05223	0.02751	0.02869
	sample size	12	16	35
301 - 500 m	mean	2.2487		2.737
	standard error	---		0.04062
	sample size	1	0	18
501 - 700 m	mean			2.4411
	standard error			0.03982
	sample size	0	0	13
701 - 1,000 m	mean			2.1519
	standard error			0.03216
	sample size	0	0	7

1984 - First Analysis: Adjusting to the Most Efficient Trawl

The goal of the first analysis of the 1984 triennial data was to produce an estimate of absolute abundance of each species in the Gulf of Alaska that were considered representatively sampled by a bottom trawl. Since we did not know the true value of q for any of these species we were forced to assume q = 1. We strongly doubted the validity of this assumption. However, following the methods of previous surveys (Gunderson and Sample 1980. Wakabyashi et al. 1985). we assumed that these observed CPUEs underrepresented true fish density, which is expressed as q less than 1.0. From this weaker assumption, it follows that the vessel/net combination with the greatest relative fishing power comes closest to representing that true density. To estimate a mean CPUE with the least negative bias, we applied an FPC to adjust all catches made by less efficient vessel/net combinations upwards to an estimate of what the catches would have been had the most efficient vessel made them. Henceforth, we shah refer to this strategy as “adjusting to the most efficient trawl.”

An FPC was estimated and catches were adjusted for those species that were abundant and commonly encountered throughout the survey area. No adjustment was made for species which had mostly zero catches. The FPC was estimated using the ratio of arithmetic means. No variance of the FPC estimate was computed or incorporated into the variance of the estimate of mean CPUE.

Because we wanted to correct for differences between nylon and polyethylene Noreastern trawls, between U.S. vessels, and between the U.S. vessel/net combination and the Japanese vessel/net combination, a series of comparisons and adjustments were done. Every application of an FPC followed the most efficient trawl strategy.

First, differences between nylon and polyethylene Noreasterns were resolved. Table *24* gives numbers of tows collected with the two nets in each stratum sampled by the *Morning Star.* FPCs were computed for those species that were reasonably well represented in these alternating tow data (Table 25). FPCs were computed after pooling over strata within each net type. All of the above computations were predicated on a mean trawl path of 18.3 m for a Noreastern trawl.

No data exists to calculate or adjust relative fishing power differences between the *Ocean Spray* and the Morning Star because there was little spatiotemporal overlap in their operations. Indeed, we had assumed, implicitly, that there was no difference between these two vessels when we originally assigned stations.

Differences between the two U.S. vessels and the Japanese vessel were investigated and resolved after correcting for nylon/polyethylene differences within the U.S. data. The "paired” subsets of tows by the Morning *Star* and *the Daikichi Maru No.* 37 were mapped through the FPC estimator, again with no variances being estimated (Table 26).

1984 - Second Analysis: Adjusting to the Standard Trawl

The second major analysis of the 1984 triennial data arose from the need to make comparisons with the results of the 1987 survey. Our goals in this analysis were different from those guiding the first:

1. We wanted to assess change in abundance between the two surveys. Our abundance estimators had to be consistent.
2. We wanted to incorporate a refined understanding of the role of FPCs in the overall estimation of our index of abundance.

Table 24.--Numbers of tows executed by the FV *Morning Star* using nylon and polyethylene Noreastern trawls, by stratum.

Stratum	Samples taken with a nylon trawl	Samples taken with a polyethylene trawl
10	5	7
11	11	11
12	6	8
13	9	9
20	2	2
110	7	8
111	13	9
112	3	3
120	14	15
122	5	5
134	6	7
140	0	1
210	3	7
221	4	4
231	9	2
243	0	1
310	6	2
320	2	4
330	4	6
410	2	5
420	3	2
430	6	2
510	1	1
520	1	2
530	0	3

Table 25.--original estimates of fishing power corrections, estimated as ratios of simple means of CPUEs observed in tows made by the FV *Morning Star* alternating use of nylon and polyethylene trawls. To adjust nylon catches to those that would have been made by a polyethylene net, multiply them by the quantity in the column called "Nylon to Polyethylene." To adjust polyethylene catches to those that would have been made by a nylon net, multiply them by the quantity in the column called 'Polyethylene to Nylon.'

Species	Nylon to Polyethylene	Polyethylene to Nylon
skates, unidentified	0.2869	3.4857
arrowtooth flounder	0.7492	1.3348
Pacific halibut	0.9398	1.0641
flathead sole	0.6042	1.6550
Dover sole	0.7368	1.3572
rex sole	0.5852	1.7089
yellowfin sole*	1.4031	0.7127
rock sole	1.0268	0.9739
butter sole*	3.4060	0.2936
giant grenadier	1.0770	0.9285
Coryphaenoides	1.7498	0.5715
yellow Irish lord*	0.8151	1.2268
bigmouth sculpin*	0.9362	1.0682
Pacific cod	0.6716	1.4890
walleye pollock	1.8790	0.5322
Atka mackerel*	1666.6667	0.0006
shortspine thornyhead	0.8271	1.2090
rougheye rockfish	0.9033	1.1070
Pacific ocean perch	2.8612	0.3495
dusky rockfish	3.8521	0.2596
northern rockfish	5.6497	0.1770
shortraker rockfish	1.9268	0.5190
squid, unidentified*	2.8247	0.4377

* An FPC was estimated but not applied

Table 26.--First-round estimates of FPCs for the 1964 triennial bottom trawl survey of the Gulf of Alaska. Estimates are to be used to correct for fishing power differences between the *Daikichi Maru No. 37* and the U.S. standard vessel. These estimates were derived from CPUE data that had already been corrected for differences between nylon and polyethylene Noreastern trawls. Data were pairs. of tows taken by *the Morning Star* and *the Daikichi Maru No. 37.*

	Estimated Fishing Power Corrections multiply against catches by:	
Species	**U.S. standard vessel**	***Daikichi Maru No. 37***
skates	1.30	1.00
arrowtooth flounder	1.71	1.00
Pacific halibut	1.04	1.00
flathead sole	1.79	1.00
Dover sole	1.31	1.00
rex sole	2.36	1.00
yellowfin sole	2.05	1.00
rocksole	1.00	1.05
butter sole	1.00	5.61
giant grenadier	4.52	1.00
popeye grenadier	1.24	1.00
Pacific cod	1.34	1.00
walleye pollock	1.00	1.97
shortspine thornyhead	4.03	1.00
rougheye rockfish	1.93	1.00
Pacific ocean perch	1.67	1.00
dusky rockfish	1.00	3.41
northern rockfish	2.37	1.00
harlequin rockfish	1.00	1.87
sharpchin rockfish	15.87	1.00
shortraker rockfish	3.61	1.00

3. We wanted to incorporate improvements in strata definitions and improved estimates of net width that had resulted from ongoing net mensuration studies.

In the second round of analysis, we assumed that the fishing power differences between nylon and polyethylene nets were negligible: that is, $q_{nylon} = q_{poly}$. It seemed that the difference in their designs was slight enough that to correct for small fishing power differences would provide little gain in accuracy while degrading many valid observations to estimates. We based this assumption of negligibility not on statistical tests but on the fundamental similarity between the two nets and the subjective assessment that their differences were slight.

The validity of this assumption was examined using the alternating tow data collected aboard the Morning *Star*. We computed mean CPUEs for each net type within each stratum and plotted nylon against polyethylene. We did this for six representative species: arrowtooth flounder, Pacific halibut, rock sole, Pacific cod, walleye pollock. and Pacific ocean perch. Medians, means, and coefficients of variation estimated from CPUEs in *the Morning Star* alternating-tow data are listed for these species in Appendix B by net type and stratum. These particular species were chosen to provide a variety of frequency distributions and because all six are important commercially or ecologically. Arrowtooth flounder was examined because it may have the largest biomass of all species vulnerable to our sampling gear. has large numbers in a wide range of sizes, is found in a wider depth range than most groundfish species, and favors bottom types where the Noreastern trawl performs reasonably well Pacific halibut was examined because it is a very large flounder, a powerful swimmer, and capable of reacting strongly to the gear: it is also found in less hostile bottom conditions. Rock sole was examined because it is a small flounder and. in the Gulf of Alaska, favors slightly harder bottoms.. It was also caught regularly even though its abundance didn't seem to be as great. Its CPUE frequency distribution didn't seem to be as skewed to the right as other species. Pacific cod was chosen because it is a roundfish that is vulnerable to our gear, though it has a somewhat contagious distribution due to a degree of schooling behavior. Both walleye pollock and Pacific ocean perch were examined specifically because of their highly contagious distributions and the extreme skewness to the right associated with such patchiness.

Results of this plotting exercise are given in Figures 6 - 11. Figure 6 shows a scatter plot of mean CPUE for Pacific halibut. Figure 7 shows scatter plots of mean CPUE for rock sole. Figure 7-A is a plot of means based on the full complement of data. Figure 7-B is a plot of means that were calculated after the four highest CPUEs had been removed. The latter plot indicates the influence of extreme observations. Figures 8 - 11 are scatter plots of mean CPUE for arrowtooth flounder, Pacific cod, walleye pollock. and Pacific ocean perch. For each of these species, three plots were required to show the influence of large catches. The first is a plot of means estimated from the full complement of data. The second is also from the full complement of data but the axes of the plot have been restricted. We did this to take a closer look at the cloud of points that was crowded into the lower left comer by including the largest mean CPUEs. The third plot is of mean CPUEs that were calculated after the four largest observed CPUEs had been culled.

Each plot has a line running through it with an intercept of zero and a slope of 1.0. It represents the relationship between the two nets were they perfectly devoid of fishing power differences and observed without random error. If there was no true fishing power difference between the net types, then the pairs of estimates should scatter evenly around this line. Had there been a discernable fishing power difference, then the majority of the plotted points would fall on one side of the line or the other, depending on which net was more efficient.

There was no clear case of this. Rather, it appeared that for all of these species the pairs of means were quite evenly scattered about the "equal efficiency line." This appeared to be the case even for those species that had a large FPC for nylon and polyethylene in the first analysis, such as arrowtooth flounder, Pacific cod. walleye pollock, and Pacific ocean perch (Table 25). In each of these cases, rare large CPUEs had levered the ratio of means in the first analysis well away from 1.0. We deduce this because these very large mean CPUEs had dramatic shifts of position (reductions of magnitude) when the four highest individual CPUE observations were eliminated from the estimation. This last exercise, eliminating the largest tows, was done only to illustrate the sensitivity of means and ratios of means to rare, large observations. Generally, it resulted in a marked contraction of the point cloud toward the equal efficiency line and an even more symmetric distribution around it.

While visual inspection of summary statistics hardly constitutes a definitive test for an effect, these plots of means convinced us that the relative fishing power differences that were apparent in the first analysis were likely the result of a small number of large CPUEs. The high leverage of rare, huge observations would very easily be heightened in an estimator as unstable as a ratio of arithmetic means. In turn, rare, large tows seem much more likely the result of chance and not actually a function of fishing power differences. We found that, though we could not show there to be <u>no</u> fishing power differences between nylon and polyethylene nets, the differences appeared small enough to be negligible, validating our assumption.

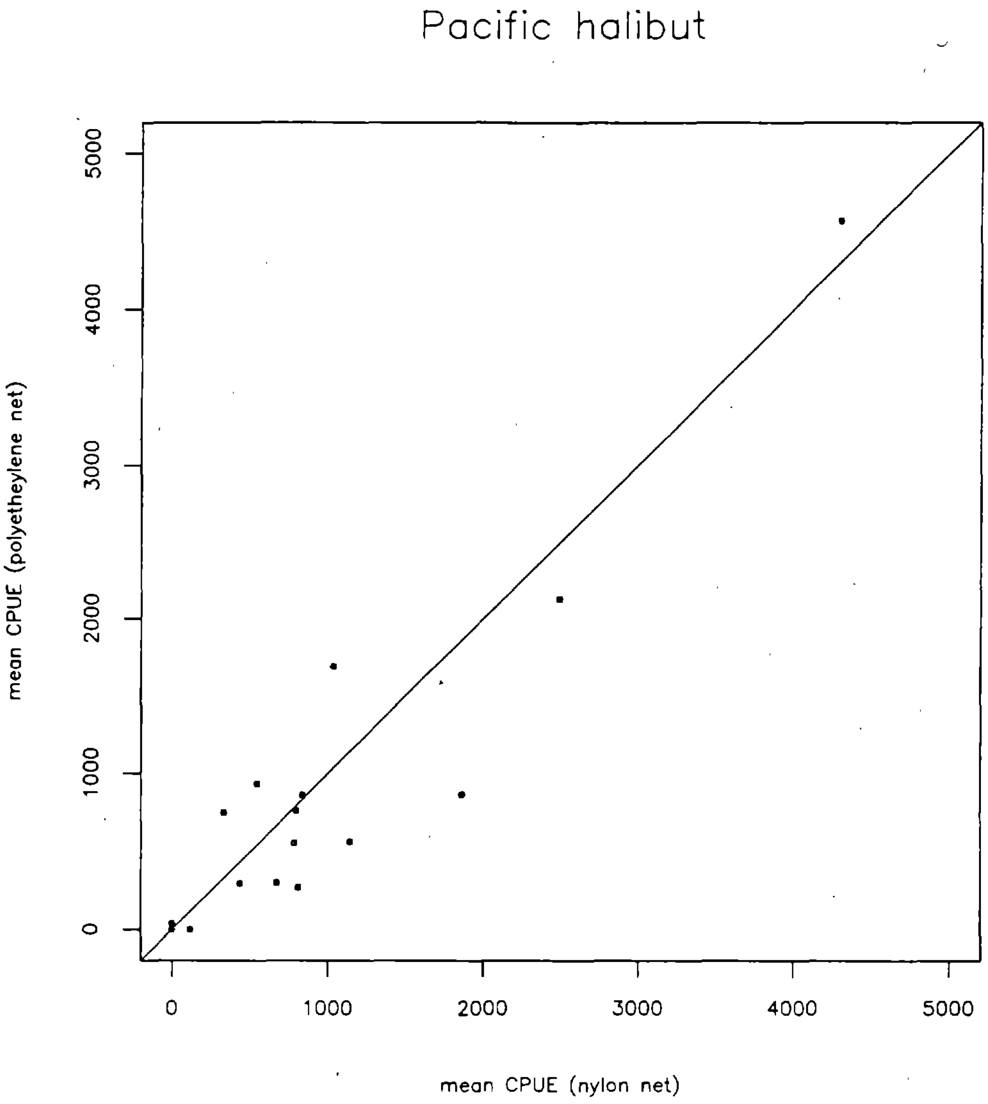


Figure 6.--Mean CPUEs for both nylon and polyethelene Noreastern trawls for Pacific halibut in a variety of sampling strata.

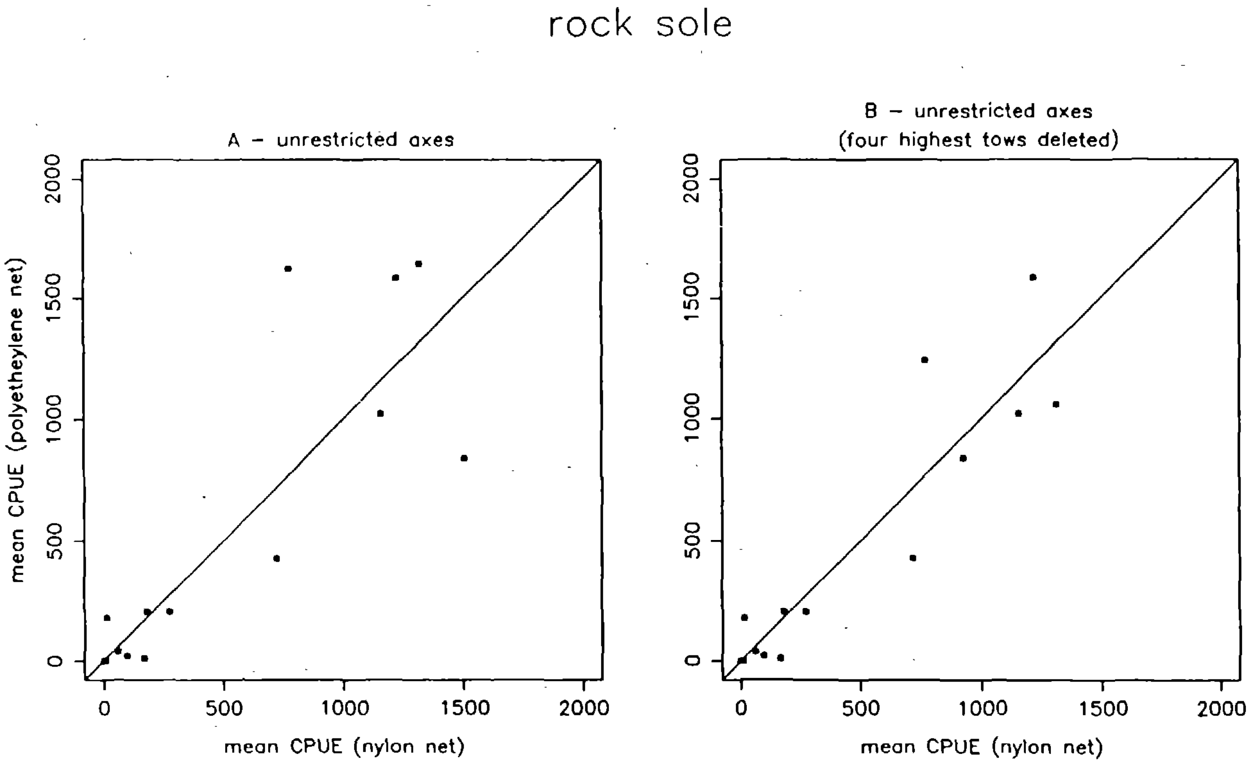


Figure 7.--Mean CPUEs for both nylon and polyethelene Noreastern trawls for rock sole in a variety of sampling strata. Plot A shows means estimated from all observed catches. Plot B shows means estimated after the four largest catches had been removed from the data.

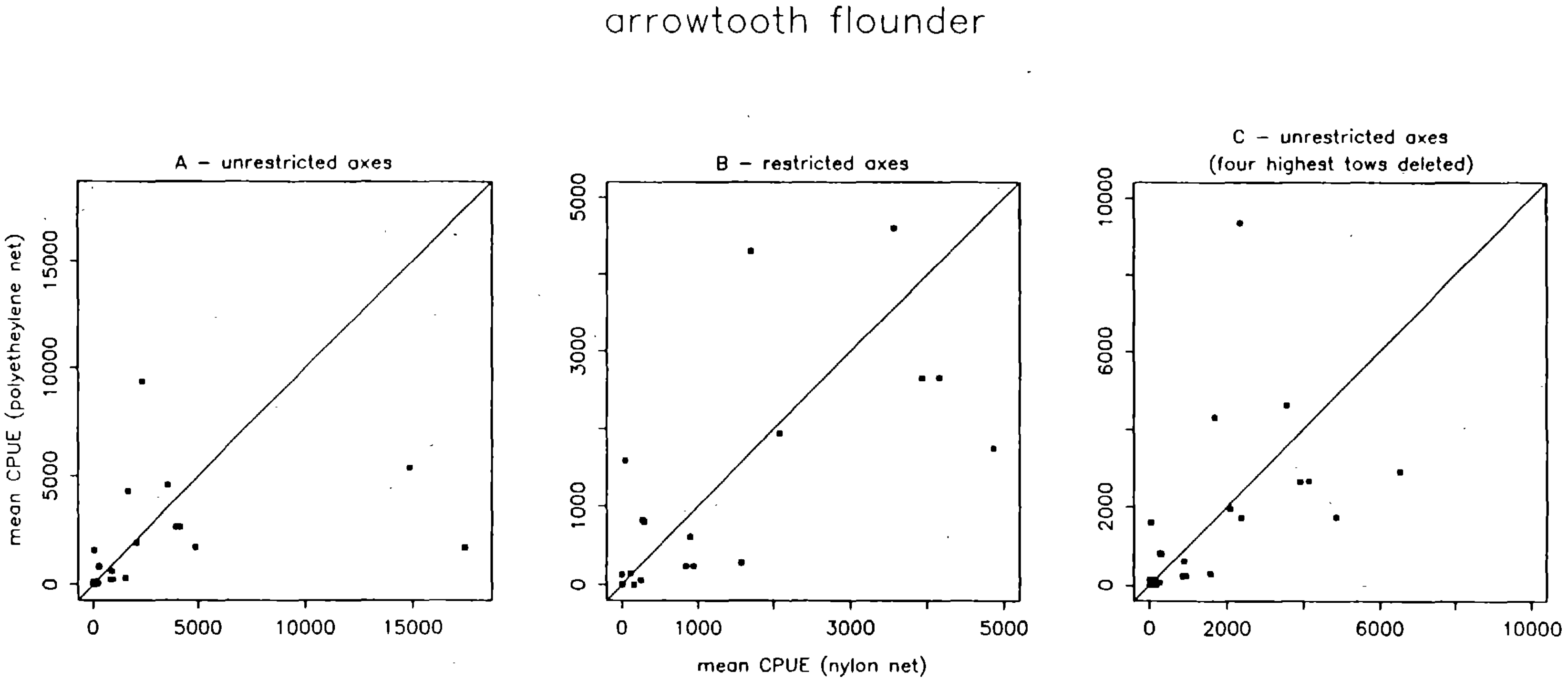
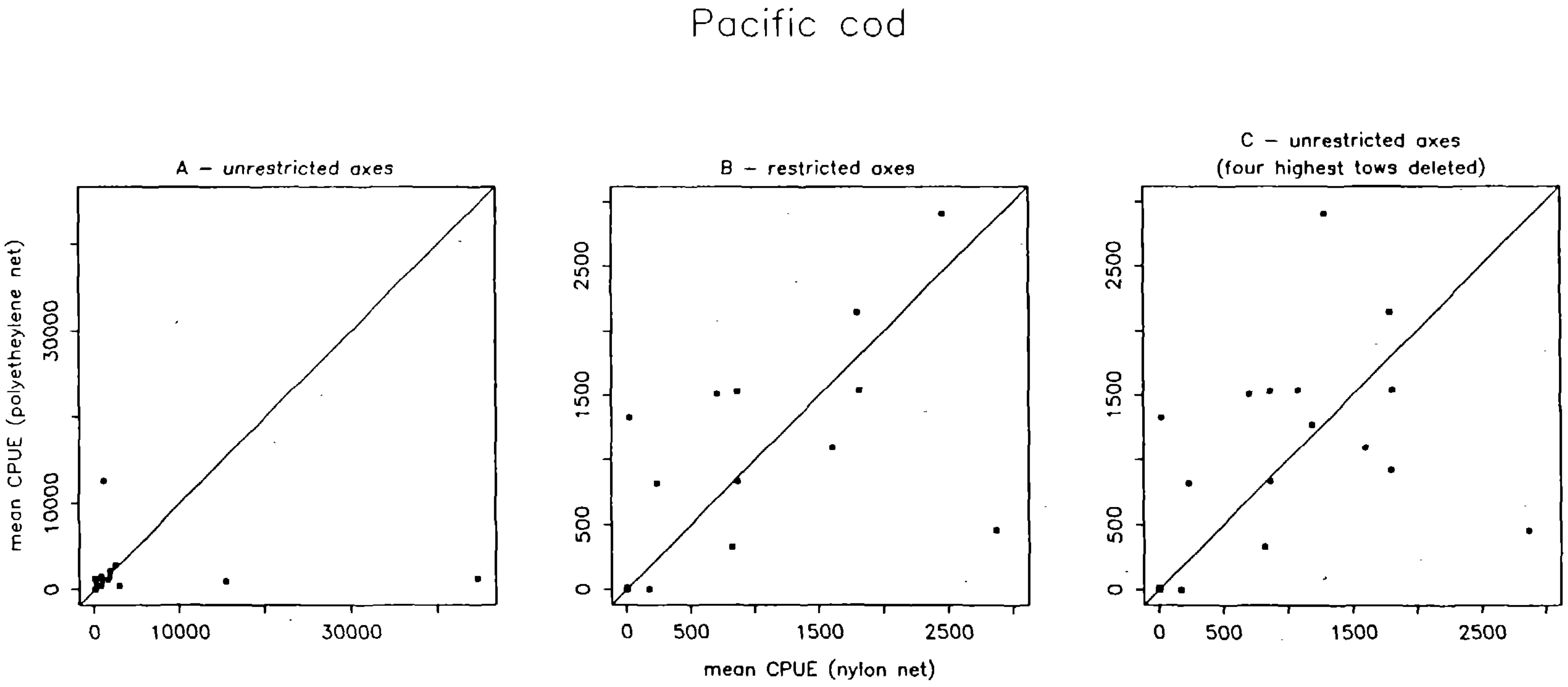


Figure 8--Mean CPUEs for both nylon and polyethelene Noreastern trawls for arrowtooth flounder in a variety of sampling strata. Plot A shows means estimated from all observed catches: axes are unrestricted. Plot B shows means estimated from all observed catches: restricted axes allow examination of details of the point cloud but three sets of estimates were out-of-bounds. Plot C shows means estimated after the four largest catches had been removed from the data: axes are unrestricted.



Pacific cod

A – unrestricted axes

B – restricted axes

C – unrestricted axes (four highest tows deleted)

Figure 9.--Mean CPUEs for both nylon and polyethelene Noreastern trawls for Pacific cod in a variety of sampling strata. Plot A shows means estimated from all observed catches; axes are unrestricted. Plot B shows means estimated from all observed catches; restricted axes allow examination of details of the point cloud but three sets of estimates were out-of-bounds. Plot C shows means estimated after the four largest catches had been removed from the data: axes are unrestricted.

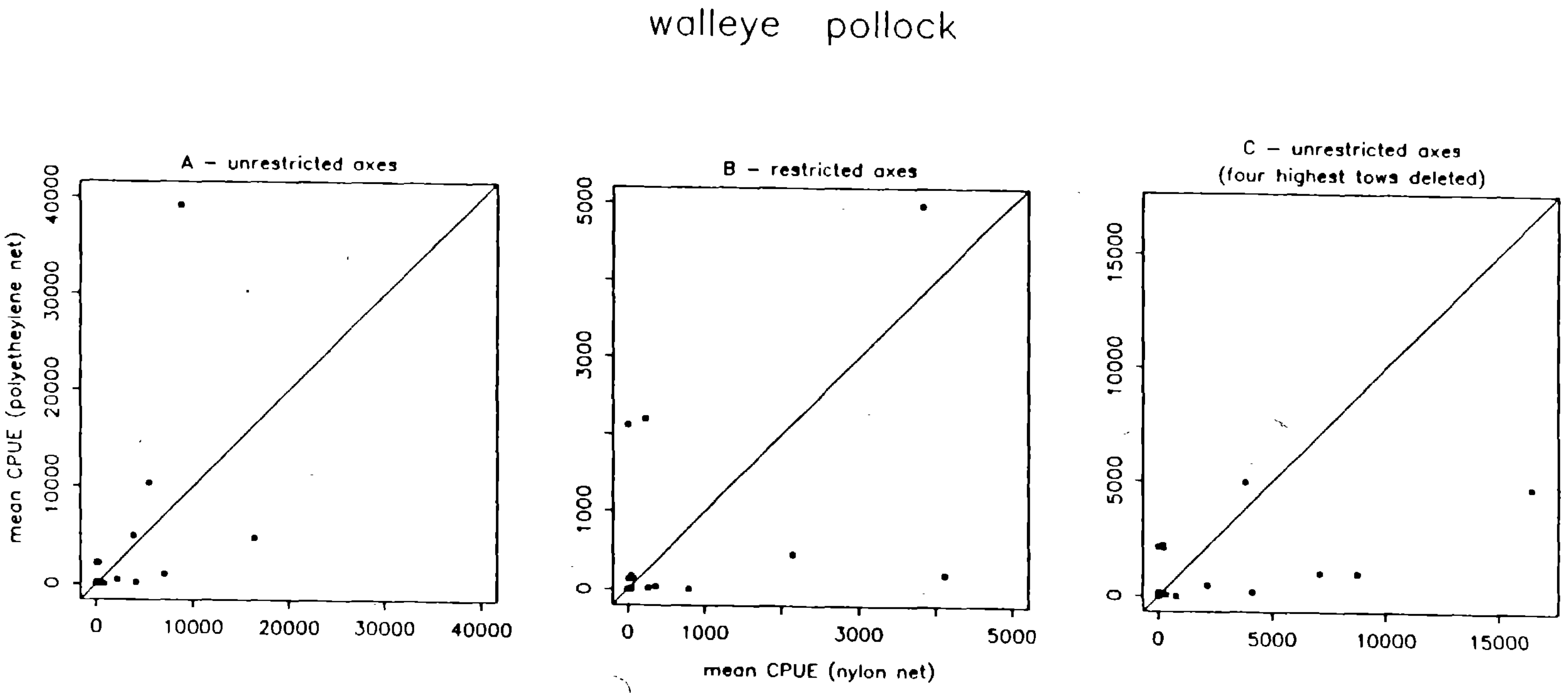


Figure 10.--Mean CPUEs for both nylon and polyethelene Noreastern trawls for walleye pollock in a variety of sampling strata. Plot A shows means estimated from all observed catches; axes are unrestricted. Plot B shows means estimated from all observed catches; restricted axes allow examination of details of the point cloud but three sets of estimates were out-of-bounds. Plot C shows means estimated after the four largest catches had been removed from the data; axes are unrestricted.

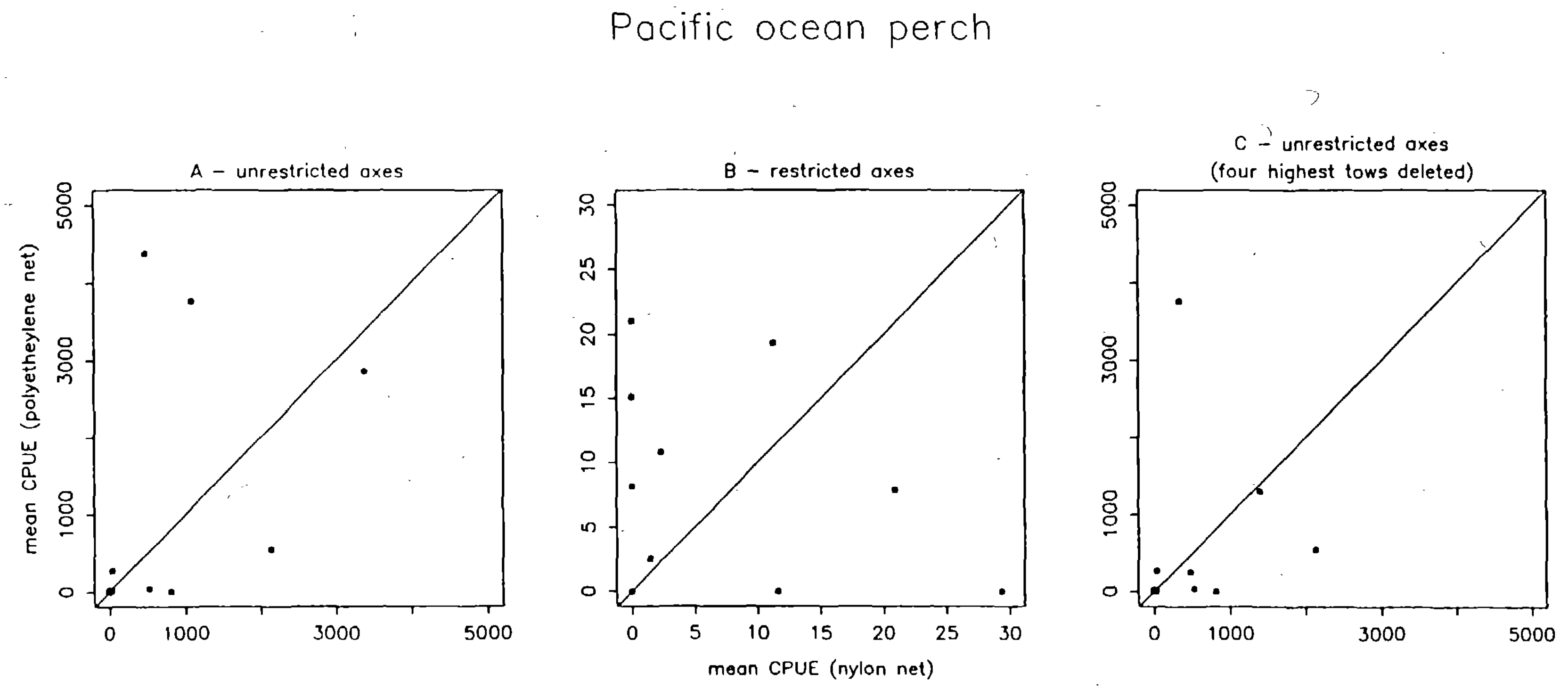


Figure 1l.--Mean CPUEs for both nylon and polyethelene Noreastern trawls for Pacific ocean perch in a variety of sampling strata. Plot A shows means estimated from all observed catches: axes are unrestricted.. Plot B shows means estimated from all observed catches: restricted axes allow examination of details of the point cloud but three sets of estimates were out-of-bounds. Plot C shows means estimated after the four largest catches had been removed from the data; axes are unrestricted.

Another argument against correcting catches by the nylon Noreastern to catches by the polyethylene Noreastern rises from the number of corrections that would be necessary. Note that because only the *Morning Star* used a polyethylene net and then only every other tow, just 126 of the U.S. observations were made with that net. Thus, because nylon catches were adjusted to polyethylene catches, 70% of the U.S. CPUEs were degraded from observations to estimates.

We could not directly estimate an FPC to correct for differences between the *Morning* Star and the Ocean Spray. Even if we had the data. we would have chosen not to estimate this quantity. Our reasoning was that nominally identical procedures, even if not strictly adhering to ideals, should result in vessel effects that were negligible: Again, by "negligible," we mean that the variation introduced by correcting the bias in the data would produce a more severe en-or than the bias itself. We consider these U.S. vessels to represent the "standard" vessel/net system.

We assumed that the fishing power difference between the *Daikichi Maru No. 37* and the standard vessel was not negligible and chose to correct for it with an estimated FPC. We did so because it appeared that the dissimilarity between the *Daikichi Maru* No. 37 and the U.S. standard was great. Again, this was a subjective judgment made not by'testing the CPUE data but based on our perceptions of how the two vessel types operated and how trawl design varied. Tables 7- 10 show that there were only minor differences in distances fished and trawling speeds, but the radical difference in the size and configuration of the Japanese net and doors did result in much different areas swept. While area swept is standardized in the CPUE, differences in herding effects with longer dandylines and bigger doors, differences in the way fish interact with different footropes, and differences in vertical opening of the net are not. Furthermore, the Japanese net was capable of fishing on much rougher grounds than the Noreastern trawl. Any consequent habitat effects would result in an apparent fishing power difference. Also, such intangibles as differences in fishing style and experience between captains and crews may have been great enough to make a difference to fishing efficiency.

FPCs were calculated with the same estimator as in the first analysis, a ratio of arithmetic means. We abandoned the most efficient trawl strategy. To estimate abundance indices that were comparable to those of the 1987 survey, we adjusted Japanese catches to those of the US. standard regardless of relative fishing power. For most species this meant a reduction in the magnitude of Japanese catches, Table 27 gives the FPC estimates.

Other important differences between the first and second analysis were the splitting of a sampling stratum and an improvement in the mean net width estimate used to compute the area swept. Stratum 30, near-shore Kodiak and Afognak Islands, became strata 35 and 30, with 35 being nearshore on the northwest side, 30 being the remainder of the old stratum, (Fig. 5 and Table 1). This division enabled us to discern concentrations of fish, particularly walleye pollock, associated with Shelikof Strait from concentrations associated with the Pacific side of Kodiak and Afognak Islands. All computations of CPUE in the second analysis were predicated on a net width of 16.43 m. as described earlier.

1984 - Third Analysis: The Kappenman Fishing Power Correction Estimator

The goals, assumptions, and strategy of the third analysis were the same as those of the second. The difference is in the FPC estimator, as well as the specific data to which it was applied. Using the Kappenman estimator, FPCs were estimated directly from the whole of the survey data instead of from the subsets of “paired tows.” The Kappenman estimator

Table 27.--Second round estimates of FPCs for 1984. Data *were “pairs”* of tows taken by the Morning Star and the *Dalkichi Maru No. 37.* It was assumed that there was no fishing power difference between nylon and polyethylene Noreastern trawls and no fishing power difference between the two U.S. vessels. Catches made by the *Daikichi Maru* No. 37 were adjusted to those made by the U.S. vessels.

	Estimated Fishing Power Corrections (Catch Multipliers)	
Species	U.S. standard vessel	*Daikichi Maru No. 37*
skates sp.	1	0.7665
arrowtooth flounder	1	0.5884
Pacific halibut	1	0.9607
flathead sole	1	0.5576
Dover sole	1	0.7646
rex sole	1	0.4241
rock sole	1	1.0495
giant grenadier	1	0.2215
popeye grenadier	1	0.8039
Pacific cod	1	0.7487
walleye pollock	1	1.9724
shortspine thornyhead	1	0.2480
rougheye rockfish	1	0.5188
Pacific ocean perch	1	0.6000
dusky rockfish	1	3.4130
northern rockfish	1	0.4218
shortraker rockfish	1	0.2774

uses only nonzero tows. The 'paired tow' subsets simply did not provide an adequate sample size under this constraint.

To prevent strata effects being confounded with vessel differences, a resampling scheme was employed to ensure a balance between the representation of the *Daikichi Maru* No. 37 data and data collected by the US. vessels. As the data in Table 3 shows, the Japanese vessel generally produced more observations than its U.S. counterpart in any stratum that it sampled. U.S. and Japanese tows were sufficiently interspersed to balance area effects within most strata. In each stratum all of the nonzero tows made by the least represented boat went into the data set that would be r-napped through the Kappenman estimator. The same number of tows was randomly selected, with replacement, from the nonzero tows of the better represented vessel. The data were filtered in this way for every stratum. Once balanced subsets were assembled for each vessel type, the FPC was estimated using the Kappenman estimator. This whole procedure was done 50 times, producing as many estimates of FPC. The mean of these estimates was taken as the final estimate of FPC. (Note that the estimator itself ignored stratitfication.) Table 28 gives FPC values estimated with the Kappenman estimator. Those species for which estimates were made were represented by 60 to 100 nonzero tows for each vessel or vessel type. Fewer nonzero observations leads to instability in the Kappenman estimator. FPCs were not estimated for yellowfin sole, starry flounder (Platichthys *stellatus),* giant grenadiers, shortspine thomyhead, dusky rockfish (Sebustes ciliatus), harlequin rockfish *(Sebastes* uartegatus), or shortraker rockfish due to inadequate numbers of nonzero tows.

Table 28.--Third round estimates of FPCs for 1984. The Kappenman estimator was applied to data from the entire survey. It was assumed that there was no fishing power difference between nylon and polyethylene Noreastern trawls and no fishing power difference between the two U.S. vessels. Catches made by the *Daikichi Maru No. 37* were adjusted to those made by the U.S. vessels.

	Estimated Fishing Power Corrections multiply against catches by:	
Species	**U.S. standard vessel**	***Daikichi Maru No. 37***
skates, sp.*	--	--
arrowtooth flounder	1	1
Pacific halibut	1	1.27
flathead sole	1	1.37
Dover sole	1	1.02
rex sole	1	0.81
rock sole	1	1.38
sablefish	1	0.50
giant grenadier*	--	--
popeye grenadier*	--	--
Pacific cod	1	1
walleye pollock	1	1.02
shortspine thornyhead*	--	--
rougheye rockfish	1	1
Pacific ocean perch	1	1
dusky rockfish*	--	--
northern rockfish	1	1
shortraker rockfish*	--	--

* No FPC was estimated because there were too few nonzero catches.

1987-First Analysis

The goals, assumptions, and guiding strategies of the first analysis of the 1987 survey were the same as those in the first analysis of the 1984 survey. The focus was, again, on estimating actual abundance: hence, the most efficient trawl strategy was followed. Since the 1987 survey was not an exact replica of its predecessor, implementation of those strategies took a slightly different approach. The primary difference was that the comparison study provided independent data for estimating FPCs. Also, only the polyethylene version of the Noreastern trawl was employed by the U.S. boats.

From the comparison tows, mean CPUEs were computed for each vessel, compared, and combined in an FPC estimator. Arithmetic means were calculated for each' vessel/area combination. These means were then summed over the strata of the study for each vessel. Table 29 compares these summed means for species that were commonly encountered. The comparison was done by taking the highest summed mean and using it as the denominator in a ratio of summed means. These ratios were aids in deciding whether or not to apply an FPC. Each decision was subjective; for most species, it was based on the magnitude of these ratios.

Appendix C shows the strategies used for estimating and applying FPCs. Though we started out by assuming that there was a non-negligible fishing power difference between the two U.S. vessels, we abandoned that assumption for every species except Pacific halibut and shortraker rockfish. Table 30 gives the estimates for the various species. No variance was estimated for the estimates of FPC, so no notion of its variability could be incorporated in the estimator of the stratified mean CPUE.

Table 29.--Ratios of summed mean CPUEs to compare for vessel effects. Means were computed within each vessel/area cell, summed across areas but within vessels, and then placed in ratios where the denominator was the largest of the three summed means.

	Comparison Ratios		
Species	*Lets Go*	*Nore-Dick*	*Taisei Maru No. 35*
skates, sp.	1.00	0.89	0.52
arrowtooth flounder	1.00	0.96	0.65
Pacific halibut	0.41	1.00	0.67
flathead sole	1.00	0.92	0.46
Dover sole	1.00	0.88	0.13
rex sole	1.00	0.95	0.38
rock sole	0.46	1.00	0.15
walleye pollock	0.87	1.00	0.43
Pacific cod	1.00	0.77	0.59
shortspine thornyhead	0.83	1.00	0.36
Pacific ocean perch	1.00	0.94	0.38
rougheye rockfish	0.83	1.00	0.62
northern rockfish	1.00	0.36	0.72
shortraker rockfish	0.55	0.87	1.00

1987 - Second Analysis: Adjusting to the Standard Trawl

The goals, concerns, and strategies embodied in the second analysis of the 1984 survey also informed this analysis. As before, we assumed that the difference between U.S. vessels was negligible. Because we wanted to assess change in abundance rather than abundance itself, we used FPCs to adjust to the standard vessel/net combination regardless of whether or not the standard had higher or lower fishing efficiency. Data from the comparison study were analyzed in a way that accounted for area/depth effects: this analysis will be discussed later.

In this analysis the strategies for estimating and applying FPCs were the same as those in the first analysis except for Pacific halibut and shortraker rockfish. For these two species the comparison study data were pooled for *the Lets Go* and *the Nore-Dick*, a new mean CPUE estimated for the U.S. standard vessel, and a new FPC ratio calculated. These new quantities are included in the final column of Table 30. For all species, catches made by the *Taisei Maru* No. 35 were adjusted to the fishing efficiency of the U.S. standard. This changed the direction of adjustment from that of the first analysis for only one species, shortraker rockfish.

1987 - Third Analysis: The Kappenman Fishing Power Correction Estimator

As in the third analysis of the 1984 triennial, the goals, assumptions, and strategy of this round were the same as those of the second. The difference is in the FPC estimator and the data mapped through it.

The ratio of arithmetic means-was abandoned as an estimator of FPC in favor of the Kappenman estimator. FPCs were estimated directly from survey data rather. than from the side-by-side tow study. Again, this was because there were too few nonzero tows in that study to permit use of the Kappenman estimator. Balanced representation of *Taisei Maru* No. 35 data and U.S. standard data was ensured with the same resampling scheme described previously. This was necessary because of larger sample sizes for the Japanese vessel in those strata that it cosampled with a U.S. vessel (Table 12).

FPC estimates generated with the Kappenman estimator are given in Table 31. FPCs were not estimated for yellowfin sole, starry flounder. grenadiers, shortspine thomyhead, harlequin rockfish. or shortraker rockfish due to inadequate numbers of nonzero tows.'FPC were computed for Dover sole, rougheye rockfish, and dusky rockfish but not applied because low numbers of nonzero tows gave these estimates questionable certainty. The rest of the estimates were based on 60 to 100 nonzero observations for each vessel type or vessel, *(the* U.S. standard or *the Taisei Maru No. 35).*

Second Analysis of the Fishing Power Experiment

In this analysis we used ANOVAs to test the hypotheses that there were no vessel effects, no effects due to depth stratification within the comparison study, and no interaction effects between vessel and depth. We limited the analysis to those species that were well represented by nonzero tows: we considered a preponderance of zero catches to imply that a particular species was simply not present in the study area and thus it was not appropriate for us to draw inference regarding it. Some species were well represented in only one stratum of the comparison study area and only a one-way ANOVA could be performed.

Species that were well represented in two or more depths were pollock, Pacific cod, rock sole, arrowtooth flounder, Dover sole, Pacific halibut,. rex sole, flathead sole, rougheye rockfish, Pacific ocean perch, and dusky rockfish. The two-way ANOVAs followed an additive, mixed model (Joseph and Calkins 1969, Hoff 1989). The CPUE data were transformed with the natural log, resulting in the following model:

$$\log_e(\text{CPUE} + 1) = V_i + A_j + (V \, X \, A)_{ij} + e_{ijk}$$

where V_i is the vessel effect, (a fixed effect),

A_j is the stratum effect, (a random effect),

$(V \, X \, A)_{ij}$ is the interaction effect between vessels and strata, and

e_{ijk} is a random error term.

The log transform was deemed appropriate because it seemed most likely that differences in fishing power would show as differences in catch rates since CPUE is. in fact, the rate of catch per unit of effort. Additive effects in the transformed data would imply multiplicative effects in the untransformed data, which is precisely what a rate change is. The log transform also had the effect of producing more equal within-cell variances,

This model was used three different ways. The first was with Japanese data excluded, causing there to be only two levels of the vessel effect. Rejecting the hypothesis that there is no vessel effect in this case would suggest that it was invalid to assume the fishing power difference between the two US. vessels was negligible. The second application was with all three of the vessels for three levels of the vessel effect. The third application was with data from the U.S. vessels pooled, resulting, again, in only two levels of the vessel effect.

Table 30.--First and second-round estimates of FPCs for the 1987 triennial bottom trawl survey of the Gulf of Alaska. Data were collected in the fishing power experiment. First-round estimates were derived according to strategies and with estimators described in Appendix C.

	First-round FPCs (catch multipliers)				Second-round FPCs
Species	*Lets Go*	*Nore-Dick*	*Taisei Maru No. 35*	Strategy	(multiply against survey catches by the *Taisei Maru No. 35*)
skates sp.	1.00	1.00	1.82	1	1.82
arrowtooth flounder	1.00	1.00	1.50	1	1.50
Pacific halibut	2.43	1.00	1.47	2	0.86
flathead sole	1.00	1.00	2.08	1	2.08
Dover sole	1.00	1.00	7.06	1	7.06
rex sole	1.00	1.00	2.58	1	2.58
rock sole	1.00	1.00	4.96	1	4.96
walleye pollock	1.00	1.00	2.20	1	2.20
Pacific cod	1.00	1.00	1.52	1	1.52
shortspine thornyhead	1.00	1.00	2.54	1	2.54
Pacific ocean perch	1.00	1.00	2.55	1	2.55
rougheye rockfish	1.00	1.00	1.48	1	1.48
northern rockfish	1.00	1.00	1.38	3	1.38
shortraker rockfish	1.82	1.14	1.00	4	0.42
yellowfin sole	1.00	1.00	2.64	5	2.64
English sole	1.00	1.00	2.64	5	2.64
butter sole	1.00	1.00	2.64	5	2.64
Alaska plaice	1.00	1.00	2.64	5	2.64
starry flounder	1.00	1.00	1.50	6	1.50
harlequin rockfish	1.00	1.00	2.55	7	2.55
sharpchin rockfish	1.00	1.00	2.55	7	2.55
dusky rockfish	1.00	1.00	2.55	7	2.55
giant grenadier	1.00	1.00	1.69	8	1.69
popeye grenadier	1.00	1.00	1.69	8	1.69

Table 31.--Third-round estimates of FPCs for 1987. The Kappenman estimator was applied to data from the entire survey. It was assumed that there was no fishing power difference between the two U.S. vessels. Catches made by the *Taisei Maru No. 35* were adjusted to those made by the U.S. vessels.

	Estimated Fishing Power Corrections multiply against catches by:	
Species	**U.S. standard vessel**	***Taisei Maru No. 35***
skates sp.*	--	--
arrowtooth flounder	1	1.12
Pacific halibut	1	0.87
flathead sole	1	2.63
Dover sole**	1	2.68
rex sole	1	1.52
rock sole	1	2.54
yellowfin sole*	--	--
English sole*	--	--
butter sole*	--	--
Alaska plaice*	--	--
starry flounder*	--	--
sablefish	1	1.73
Pacific cod	1	1.27
walleye pollock	1	1.71
giant grenadier*	--	--
popeye grenadier*	--	--
shortspine thornyhead*	--	--
rougheye rockfish**	1	2.27
Pacific ocean perch	1	1
northern rockfish	1	1.03
shortraker rockfish*	--	--
harlequin rockfish*	--	--
sharpchin rockfish*	--	--
dusky rockfish**	1	1.91

* No FPC was estimated because there were too few nonzero catches.

** An FPC was estimated but not applied. Numbers of nonzero catches were low enough to cause this estimate to have questionable certainty.

We performed one-way ANOVAs for species represented in only one depth with the following model:

$$\ln(\mathrm{CPUE} + 1) = V_i + e_{ik},$$

where V_i **is the vessel effect,**

and e_{ik} **is a random error term.**

These species were northern rockfish, shortraker rockfish, shortspine thomyhead, sablefish, starry flounder, yellowfin sole, and butter sole *(Isopsetta* isolepis). This model was used three different ways, just as in the two-way analyses: with two levels of vessel effect, U.S. data only: with each of the three vessels representing a different level of the vessel effect: and pooling the U.S. data for only two levels of the vessel effect.

There were a number of species which had too few nonzero tows to support these analyses. They were English *sole, Alaska* plaice *(Pleuronectes quadritubercufatus),* harlequin rockfish, sharpchin rockfrsh (Sebastes *zacentrus),* popeye grenadier *(Coryphaenoides cinereus),* giant grenadier, and starry flounder.

In the following discussion of the ANOVA results we give a number of tables in which we have listed a p-value for the significance of the F-test appropriate for each effect. A p-value is itself a statistic that estimates the probability of seeing a given value of the F-statistic. Throughout, the discussion we define statistical significance to be the conventional alpha = 0.05, which corresponds to a p-value of 0.05.

This analysis was performed to assess the validity of assumptions of negligibility made in the second and third rounds of analysis. Though we estimated various F-statistics and associated p-values, we did not base our assumptions of negligibility on the results of the hypothesis tests. Such assumptions are about the cost of adjusting for effects that are either assumed or known to exist while the hypotheses tested here are merely concerned with the presence or absence of effects, They shed light only on the first Part of the negligibility assumptions-- that an effect exists or not. Of course, if a test fails to reject the hypothesis that there is no difference between vessels, it supports the assumption of a negligible fishing power difference: either there is no difference to correct or there was a difference but the test failed to detect it because its power was low, the sample size was too low, or the variance was large enough to obscure it. If a true difference was not detected for reasons of sample size or variance, then it was also quite likely that the correction factor would be burdened with a high variance and thus too costly to use.

By failing to reject the hypothesis that there is no difference in log-transformed CPUEs due to vessel effect, the results in Table 32 support the assumption that there was a negligible fishing power difference between the two U.S. vessels for all species except arrowtooth flounder, flathead sole, and Pacific ocean perch. Those species had statistically significant differences in mean CPUE due to vessel effects. Hypothesis test results in Table *33* show significance for vessel effects for those three species again, as well as for walleye pollock. rock sole, and Dover sole. For our purposes, the most important result is Table 34. the case where U.S. data were pooled into the standard category and that vessel type and the *Taisei Maru No. 35* were the only two levels of vessel effect. It describes statistically significant vessel effects for walleye pollock, arrowtooth flounder, rock sole, Dover sole, flathead sole and Pacific ocean perch. These results make it more difficult to defend the assumption that fishing power differences between the U.S. standard vessel and the *Taisei Maru* No. 37 were not negligible for Pacific cod, Pacific halibut, rougheye rockfish. and dusky rockfish. Nonsignificance of vessel effects for these species is not consistent. with the magnitude of the FPCs estimated for them in Table 22. It is consistent with the questionable certainty hypothesized for the Kappenman FPC estimates for rougheye and dusky rockfish. The depth effect was statistically significant for all species in each of the ways the ANOVA model was applied for every species except Pacific halibut and dusky rockfish. We cannot explain the lack of significance for the depth effect in these two species other than low power of the test due to small sample size.

Column one of Table 35 shows statistical significance for a vessel effect when the US. vessels were considered to be different and Japanese data were excluded from the analysis. Only starry flounder showed significance at the conventional level, supporting the assumption of negligible fishing power differences between U.S. vessels for the other species. Column two of that table shows significance for the case when all three vessels were considered different. The vessel effect was statistically significant for shortspine thomyhead as well as for starry flounder. Column three shows results for the case where U.S. data were pooled into the standard category and that vessel type and the *Taisei Maru* No. 35 were the only two levels of vessel effect. Only shortspine thornyhead showed a statistically significant vessel effect.

The interaction term between vessel and depth effects in Tables 33 and 34 was significant only for arrowtooth flounder. This implies that relative fishing power differences between the U.S. standard vessel and the *Taisei Maru* No. 35 vary as some function of depth. Herding effects may be a function of fish size (Engas and Godo 1989). Larger fish may be more easily caught because their superior swimming ability allows more effective flight from the bridles and doors which places the fish directly in the path of the net. Arrowtooth flounder have been seen to increase in length with depth (Wilderbuer et al. 1985). Thus, the larger Japanese trawl may have gained in relative efficiency at deeper

Table 32.--Results of two-way ANOVAs on data from the 1987 fishing power experiment. Data from the *Taisei Maru No.* 35 were excluded from this analysis. The relative fishing power difference between the *Nore-Dick* and the *Lets Go* was assumed to be non-negligible. p-values are themselves statistics that estimate the probability of seeing a value of the F-statistic less than or equal to that derived from these data: it can be thought of as an estimate of the level of significance of the observed test statistic.

	Significance of ANOVA effects (p-values associated with F-tests)			
SPECIES	VESSEL	DEPTH	VESSEL X DEPTH	Levels of the depth effect
arrowtooth flounder	0.02	0.00	0.48	4
Pacific halibut	0.38	0.65	0.26	2
flathead sole	0.00	0.00	0.56	3
Dover sole	0.24	0.00	0.16	2
rock sole	0.58	0.04	0.21	2
Pacific cod	0.12	0.00	0.82	4
walleye pollock	0.67	0.00	0.71	3
rougheye rockfish	0.91	0.01	0.08	2
Pacific ocean perch	0.03	0.00	0.09	2
dusky rockfish	0.84	0.17	0.14	3

Table 33.--Results of two-way ANOVAs on data from the 1987 fishing power experiment. Data from the *Taisei Maru No.* 35 were included from this analysis. The relative fishing power difference between *the Nore-Dick* and the *Lets Go* was assumed to be non-negligible. p-values are themselves statistics that estimate the probability of seeing a value of the F-statistic less than or equal to that derived from these data; it can be thought of as an estimate of the level of significance of the observed test statistic.

	Significance of ANOVA effects (p-values associated with F-tests)			
SPECIES	VESSEL	DEPTH	VESSEL X DEPTH	Levels of the depth effect
arrowtooth flounder	0.00	0.00	0.03	4
Pacific halibut	0.54	0.27	0.36	2
flathead sole	0.00	0.00	0.89	3
Dover sole	0.01	0.00	0.22	2
rock sole	0.00	0.00	0.27	2
Pacific cod	0.25	0.00	0.89	4
walleye pollock	0.03	0.00	0.74	3
rougheye rockfish	0.96	0.00	0.09	2
Pacific ocean perch	0.02	0.00	0.20	2
dusky rockfish	0.64	0.00	0.08	3

Table 34.--Results of two-way ANOVAs on data from the 1987 fishing power experiment. Data from the *Taisei Maru* No. 35 were excluded from this analysis. The relative fishing power difference between the *Nore-Dick* and the *Lets Go* was assumed to be negligible and their data were pooled. p-values are themselves statistics that estimate the probability of seeing a value of the F-statistic less than or equal to that derived from these data: it can be thought of as an estimate of the level of' significance of the observed test statistic.

	Significance of ANOVA effects (p-values associated with F-tests)			
SPECIES	VESSEL	DEPTH	VESSEL X DEPTH	Levels of the depth effect
arrowtooth flounder	0.00	0.00	0.01	4
Pacific halibut	0.55	0.20	0.45	2
flathead sole	0.00	0.00	0.97	3
Dover sole	0.00	0.00	0.33	2
rock sole	0.00	0.00	0.38	2
Pacific cod	0.93	0.00	0.75	4
walleye pollock	0.01	0.00	0.47	3
rougheye rockfish	0.79	0.00	0.26	2
Pacific ocean perch	0.00	0.00	0.86	2
dusky rockfish	0.35	0.00	0.13	3

Table 35.--Results of one-way ANOVAs on data from the 1987 fishing power experiment. Column one shows results of tests for a vessel effect between the two U.S. boats. Column two shows results of tests for vessel effects when all three vessels are considered different. Column three shows results of tests for a vessel effect when data for all three vessels are used but the U.S. data were pooled to represent a standard U.S. vessel. p-values are themselves statistics that estimate the probability of seeing a value of the F-statistic less than or equal to that derived from these data; it can be thought of as an estimate of the level of significance of the observed test statistic.

	Significance of vessel effects (p-values associated with F-tests)		
Species	U.S. vessels only	All three vessels	U.S. standard vessel and *Taisei Maru No. 35*
yellowfin sole	0.30	0.43	0.70
starry flounder	0.04	0.01	0.19
butter sole	0.21	0.08	0.09
sablefish	0.58	0.86	0.93
shortspine thornyhead	0.69	0.00	0.00
northern rockfish	0.06	0.07	0.44
shortraker rockfish	0.70	0.51	0.27

depths: This hypothesis is not supported by the FPC estimates of Table 36 which show that the *Taisei Maru* No. 35 had a reduction of efficiency with increased depth. However, we cannot accept or reject this hypothesis because towing parameters such as speed and scope ratio also changed with depth and thus were confounded with any possible depth effect (Tables 14 - 17).

These analyses of variance cannot be taken as definitive tests. They are possibly low in power due to low sample sizes. More importantly, all three applications of the model were performed on the same data and thus were not independent. We found this acceptable since we were really only interested in the last application, where the U.S. data were pooled and there were only two levels of the vessel effect. This is because we had made the assumption of negligibility based on the cost of correcting a difference rather than on the existence of a difference.

Table 36 gives alternate estimates of FPCs derived from the data collected in the fishing power experiment. Rather than pooling all data, we only used data from depth strata that were well represented by nonzero tows. We also only estimated FPCs for species that had statistically significant vessel effects. With the exception of arrowtooth flounder, we did pool data from different depths for those species that were represented in more than one depth. This was justified by the nonsignificance of the vessel X area interaction effect. In estimating these FPCs, we assumed that the fishing power difference between the two U.S. vessels was negligible, regardless of the statistical significance of the above F-test. Thus these estimates are ratios of the mean CPUE for pooled U.S. data and the mean CPUE of the *Taisei Maru* No. 35. Because the interaction term was significant for arrowtooth flounder, we estimated an FPC for each depth in which this species was encountered. These FPC

Table 36.--Fishing Power Corrections (FPC) estimated from 1987 fishing power experiment data, following the conclusions of ANOVAs on that data. The estimator is the ratio of arithmetic means. Data for each species have been pooled across those strata in which it was found, with the exception of arrowtooth flounder. For that species, separate FPCs have been estimated for each stratum of the comparison study.

	Estimated Fishing Power Corrections multiply against catches by:	
Species	U.S. standard vessel	*Taisei Maru No. 37*
flathead sole	1	1.85
Dover sole	1	7.05
rock sole	1	3.99
walleye pollock	1	2.83
Pacific ocean perch	1	2.45
shortspine thornyhead	1	2.37
arrowtooth flounder:		
Depth Stratum I	1	1.47
Depth Stratum II	1	1.22
Depth Stratum III	1	2.01
Depth Stratum IV	1	3.86

estimates are consistent in direction with the Kappenman estimates made from survey data, (Table 31), though they were not similar in magnitude.

DISCUSSION

The 1984 and 1987 triennial bottom trawl surveys of the Gulf of Alaska comprise an exercise in applying standardized trawl procedures to an extremely large area and refining those applications. The sheer size of the Gulf constrains a survey that is both comprehensive and synoptic to be executed by more than one vessel. The success of the first two surveys of this area was related to in a large part to the cooperative efforts of the Fisheries Agency of Japan. However, unavoidable deviations from standardized methods resulted from the participation of the large Japanese trawlers. The majority of the analyses presented here have dealt with these deviations.

Data Review

Primary Features

The most powerful feature of these two data sets is their comprehensive coverage of the Gulf of Alaska. Because of this, geographic shifts in distribution of centers of abundance can be discerned from changes in abundance itself. This is possible because the stratification scheme seems to identify truly unique regions and does a good job of minimizing within-stratum variation and maximizing among-strata variation. Adequate sample sizes in most strata permit real confidence in separating change in abundance from random variation and sampling error.

Observed CPUEs provide a good index of abundance. This sample unit is well matched to the technology and methodology available for use in a trawl survey. All of its parameters except the probability of capture are directly measurable or estimable. This has permitted very welldefined standardized sampling procedures to be developed, which in turn permitted the collection of data in these two surveys that are very comparable. Also, because definitions of standards are so clear, documentation of deviations from them are also clear for these two data sets, allowing some chance of correcting for those deviations.

Warnings

These data consist of CPUE observations in which it is assumed that effort is a known constant rather than a random variable, and has no error. At present. it is not clear how to account for error in effort, nor are we able to easily incorporate error in that variable into the CPUE. For these two surveys, sources of error in effort could have entered in several ways. For every tow, we depended on the judgment of the skippers for what scope to use. This may have more effect on fishing efficiency than actual effort, but we don't really know right now. For many tows, we also depended on the skippers to judge when the net was in fishing configuration so that we could start timing the tow. This was often not measurable: that judgment could not be checked. Such tows may have had shorter or longer fishing times than we thought. Estimating path width was another source of error in the measure of effort. For many tows, path width was not observed and had to be estimated. Those estimates were made with error (Rose and Walters 1990). Error also could have entered the measure of effort due to inaccuracies in start and end positions that are built into the Loran technology. These errors are likely to be of greater magnitude for tows that took place near a Loran sending station.

For many species the sampling gear was not ideal. In particular, the standard trawl was not suitable for harder grounds. Consequently. we expected the relative fishing power of the Japanese nets to be higher for species that live on rough bottoms since both those nets used tire gear rather than bobbin roller gear. barge catches of rockfish in tows on rough grounds were often excluded from the estimation of mean CPUE because the net was badly torn during the tow and the observation defined as invalid. Unfortunately, catch data were rarely recorded for such tows: the effect of their exclusion is not estimable though probably of large influence due to their CPUE distributions being so often heavily skewed to the right.

Between allocation constraints, the difficulty of sampling continental slope strata with a trawl, and the high variance of CPUE data for most rockfish species. we were unable to adequately sample strata preferred by rockfish. Their high variance distributions demand large allocations of sampling effort. To sample the slope strata appropriately would have weakened the survey with respect to roundfish and flatfish to an unacceptable level. After the 1984 survey, we reduced sampling levels in the slope strata, despite the commercial value of rockfish stocks that inhabit those strata. Table 3 shows that sampling density in slope strata was equal or greater than that of other strata in 1984. Table 11 shows that station density in slope strata, though reduced in 1987, was still comparable to many other strata. Given the high variance of CPUEs for these species, we will probably never be able to sample their strata adequately within the context of a multispecies survey. Data from these two surveys do not allow definitive conclusions to be drawn with regard to changes in abundance for rockfish species.

The probability of capture, as we have defined it, was not known for any of the species. Fish behavior with respect to the net was not known. How each species avoided the gear or was herded by it no doubt influenced the probability of capture. When working with length and age data from these surveys it would be wise to keep in mind that probability of capture may be a function of size (Engas and Coda 1989).

Area effects, time effects, and vessel effects are confounded in both surveys. Tables 3 and 11 describe a great many strata for which there was little overlap among the vessels. This is particularly true for the deeper strata. Consequently, FPCs estimated from the whole of the data (Tables 28 and 31) may be influenced by an area effect. Because in both years the Japanese vessels sampled from east to west in the second half of their voyages, double counting may have occurred for any species that might migrate during the survey period. Likewise. growth studies will have imposed on them either a de facto interaction term between time and region or large numbers of empty cells.

FPCs were estimated from the same data to which they were applied. This may artificially remove sources of variation that more properly should remain in the data since time and area differences may be confounded with fishing power differences. The significance of the area effect seen in the two-way ANOVAs affirms that FPCs estimated from the survey data, where area and vessel effects are confounded, should be treated with caution.

Fishing Power Corrections and Comparability of Survey Results

Tables 7 - 10 show that trawling speed and distance fished were very similar for all three boats in 1984. This suggests fairly close adherence to standardized methodology. Areas swept are different, of course, since the tow path of the Daikichi *Maru No. 37 was* 1.5 to 2 times greater than the tow path of the standard net. If the effective fishing area is really between the doors rather than between the wing tips, then area swept differences could be even greater. We do not know this; if it is true, then we might perceive it in the data as a fishing power difference. Also, herding and avoidance behavior was likely to have been quite different for the net of the Daikichi *Maru No. 37* due to its size, the door and dandyline configuration. and the presence of tire gear.

Tables 25, 26. and 27 describe estimates of FPCs that seem unrealistically large. A nylon/polyethylene fishing power correction of 1666.67 for Atka mackerel (Pleurogrommus monopteryglus) is the most extreme case. A number of estimates in these tables were greater than 2.3. Estimates produced by the Kappenman estimator were less extreme for all species. Table 27 has as its most extreme values 0.5 and 1.38. The robustness of the Kappenman estimator and the use of the whole of the survey data caused this moderation of the estimates.

The most stunning difference between FPC estimates produced by the ratio of means and estimates produced the Kappenman estimator was that the estimates changed direction. Under the ratio of means the Daikichi Mar-u No. 37 and its net appeared to have a higher fishing power than the U.S. standard for all the common species except rock sole, butter sole, walleye pollock, dusky rockfish, and harlequin rockfish. The relatively higher efficiency of this vessel for almost all the flatfishes was surprising since it used tire gear on the footrope.

Under the Kappenman estimator, the Daikichi Maru No. 37 appeared to have relatively lower fishing power, or equal, for every species with data suitable to allow estimation. The lower fishing power of the *Daikichi Maru* No. **37** for rockfish species also surprised us since we thought it would have higher efficiency on bottoms favored by rockfish. However, rockfish have the greatest skewness in CPUE frequency distributions of all the species encountered by these surveys. This means the CPUE observations were dominated by very low numbers with a few rare but huge catches. Differences in these extremes produce the differences in arithmetic means of CPUE that might indicate that the distributions are different. However, the symmetric distributions of the Kappenman estimation process reduced the effect of rare extreme observations to such a degree that the estimator itself is a function of the scale parameters of two nearly identical distributions.

This is as it should be. Because the tows were made blindly, that is, without responding to fish sign on the sonar, the probability of getting one of the rare, extreme catches was nearly equal among boats. Even if the Japanese vessel was a little more likely to make such a catch because it could fish on rougher bottom, it is still a relatively rare event. Thus the large tows should not be a driving force in the FPC estimation. We did not want to base our FPC estimates on rare events and the high variance that goes with them.

Tables 20 - 23 show that trawling speed was quite different for all three vessels in 1987. The Lets Go came closest to standardized tow procedures, though it tended to trawl about 0.4 km/hr too fast. The Nore-Dick deviated a little farther from standard speed, trawling for the most part about 1.2 km/h.r too slow. The *Taisei Maru No. 35 was* at greatest variance from standards, towing about 2.7 km/hr too fast for the vast majority of its tows. (The difference in trawling speed between the *Nore-Dick* and the *Taisei Maru* No. 35 was generally about 3.8 km/hr.) Differences in trawling speed translated directly into differences in distances fished. Markedly different distances fished magnified the difference in area swept that the much wider net of the *Taisei Maru* No. 35 imposed.

Though we cannot say just how, fish behavior, particularly gear avoidance, herding, and interactions with the footrope and headrope, were probably quite different between the vessel/net system of the Taisei *Maru No. 35* and that of the U.S. standard. The effect of the high trawl speed and the effect of the difference in gear configuration on probability of capture are totally confounded. The performance parameters and the analyses of variance of the comparison study data strongly support the assumption that the fishing power difference between the *Taisei Maru* No. 35 and the U.S. standard was not negligible.

Given the failure of the Nore-Dick and the *Taisei Maru* No. 35 to follow standard trawl procedures, the large FPC estimates of the first two rounds of analysis, Table 29, were not as surprising as those of 1984. Table 11 shows that the *Taisei Maru* No. 35 trawled even faster in the comparison study than it did throughout the survey. FPCs estimated from the comparison study data were probably slight inflations of whatever effect the high trawl speed produced in the survey catch data.

When the Kappenman estimator was applied to the survey data, &direction of difference did not change, though the magnitude of the differences did change. The exception to this was Pacific halibut: under the Kappenman estimator the Japanese catches of halibut needed to be adjusted downward to the U.S. standard vessel/net system where they had needed to be adjusted upwards before. This makes some sense in that the fast-moving Japanese net may have been more effective in catching a strong swimmer such as the Pacific halibut.

Again, we were surprised that the U.S. standard vessel/net outperformed the Taisei Maru No. 35 for rockfish species (Table 31). But, as before, we cannot really conclude too much from the notable FPC estimates for rougheye rockfish and dusky rockfrsh since they suffered poor representation by nonzero tows. Restricting the Kappenman estimation process to data that were cosampled by a U.S. vessel and the *Taisei Maru* No. 35 and resampling from data collected by the over-represented vessel eliminated many of the slope strata from contributing data to the FPC estimate. Again, we simply cannot conclude from these data whether or not fishing power differences for most rockfish species were negligible.

Table 12 shows that the *Taisei Maru* No. 35 was the only vessel to sample strata deeper than 300 m. This is particularly unfortunate since this vessel also deviated so far from standards. Changes in indices of abundance for these strata are confounded with fishing power differences due to the different net and due to the higher trawling speed.

The Kappenman estimator was not applied to data from the comparison study because the sample sizes were too small. Otherwise this would have been the preferred data set because it had full cells and vessel effects were not confounded with area effects. Additionally, it was an independent study.

Implicit in a comparison of mean CPUEs from the 1984 and 1987 surveys is the assumption that a standard vessel/net system is common to both. Though standardized gear was common to both and though standardized procedures were intended to be common to both, no vessel participated in both surveys. Comparing vessel performance parameters in the 1984 survey to those of the 1987 survey (Tables 7 - 10 and Tables 20 - 23) indicates that this assumption is tenuous. To compare indices of abundance between these surveys almost certainly confounds change in abundance with change in fishing power. However, if assumptions of negligibility made within each one of these years are valid, then it may also be valid to assume the fishing power difference between the U.S. standard in 1984 and the U.S. standard in 1987 is negligible.

The two Japanese vessels could have been considered candidates for the standard but they were not adopted as such because 1987 was the last year of involvement in cooperative bottom trawl surveys with the AFSC in the Gulf of Alaska by the Fisheries Agency of Japan. Another argument against using these vessels to establish the standard system is that their nets were not alike. Also the tow performance of the *Daikichi Maru* No. 37 was more different from the performance of the *Taisei Maru* No. 35 than were the tow performances of the U.S. standard vessel between the two surveys. Looking at Tables 27 and 31, it is clear that much larger FPC estimates were generated for the *Taisei Maru* No. 35.

Though differences between the two Japanese nets are confounded with differences between trawling procedures, we are led to speculate that something about the faster trawling speed of the Taisei Maru No. 35 reduced its effectiveness in catching most of the species commonly encountered by these surveys. The Taisei Maru No. 35 specialized in rockfish trawling when fishing commercially, often targeting on Pacific ocean perch, rougheye rockfish. or shortraker, rockfish. The accustomed strategy of the Fishing Master aboard the vessel was to hunt for schools or promising habitat with the sonar while flying the trawl off-bottom. When a school or site was located, the trawl was quickly dropped down onto it. A fast towing speed was a critical element in this strategy. During the survey the Fishing Master was highly resistant to slowing his vessel down to the standard speed of 5.56 km/hr (3 knots) The chief scientist aboard the vessel was in constant conflict with the Fishing Master over this, to no avail as Table 20 shows. It may be that a fast towing speed increases the catch when targeting on schools of rockfish that have been located by echo sounder because it allows quicker response by the vessel to fish sign. However. when fishing blindly for multiple species, as in these surveys, it may be that such fast trawling speed causes the net to simply pass over many individuals. It may be that a smaller fraction of the encountered fish are strong enough swimmers to respond to the doors, dandylines, mudcloud, or wings and be herded into the net.

The estimates of FPCs in Tables 28 and 31 were derived from survey data and then applied to that same data. Thus estimates of FPC and mean CPUE were not independent, which in turn invalidates commonly accepted methods of estimating the variance of a function of random variables. The 1987 comparison study was an attempt to avoid this. Though not large enough to provide adequate certainty in its estimates of FPC, it is encouraging that the directions of differences indicated by the comparison study agree, for the most part, with directions of difference indicated by the Kappenman estimates made from the survey data.

Despite such imperfections, comparable estimates of abundance indices can be rendered from these two surveys. The survey design and the underlying methodology of taking the sample remained consistent. Departures from standards in 1987 on the parts of *the Nore-Dick* and the Lets Co are very unlikely to obscure changes in abundance. So long as the data have been calibrated to the U.S. standard vessel/trawl systems, changes in abundance will be quantifiable from the data of these two surveys.

Considerations for Future Surveys

Invalid Tows and High Catches

The phenomenon of very high catches in tows that were invalid due to damaged gear is common for species that live in rough terrain, particularly major rockfish species. This presents an interesting question: What is the effect on the estimate of the mean CPUE of including or excluding these tows? Unfortunately, few or no data exist to investigate this question. Since invalid tows have traditionally not been mapped into the estimate of mean CPUE. it has been common practice to simply not process their catches for data. They are invalid tows only in that we do not know what the effort was for them and do not know how to incorporate them into the estimate of the index of abundance. They are still concrete observations. They may prove critical to figuring out how to cope with the highly skewed frequency distributions that are the hallmark of CPUE data. We may learn how to use such tows as minimum CPUE observations and in that way build them into the estimate of mean

CPUE. Perhaps such observations can be weighted according to the degree of damage to the gear. In any case, in future surveys. catches in 'invalid' tows should be worked up completely .

Survey Design and Execution

The most obvious way to improve triennial trawl surveys of the Gulf of Alaska is to build a common factor into them, namely, a vessel and captain that participates in survey after survey. This will anchor the notion of a standard vessel/net system in something a little more concrete and measurable than the abstractions of definitions and standardized procedures. The Gulf of Alaska is too large to survey adequately with only one vessel within the time of one season. A multivessel survey is still the only way to ensure adequate sample size in each stratum and still sample all strata. This makes having a repeat vessel that much more important as it would provide the standard by which to assess the adherence of other vessels to standardized procedures or specifications.

The alternative to a standard vessel is to gain such control over the sampling gear and the execution of a tow to a degree sufficient to assure that there are no systematic deviations from standards. There must be rigorous control of the speed of the net over the bottom. We need precise assessment of the distance fished in a tow and precise measurement of the width of the net. From this, we can more accurately and precisely estimate the area swept. We must assess the effect on estimation of mean CPUE of effort being a random variable rather than a known constant. We may need to control the net in some way that causes it to have a constant area swept regardless of depth or width of the vessel. Scope ratios must be strictly defined. No gear other than the-polyethylene Noreastern should ever be used, nor other than the doors and dandylines described earlier. If a vessel or a gear is to be used in a survey but does not or cannot conform to standards, then it should not contribute to data for estimating indices of abundance. Rather, it should be assigned the tasks of collecting age and growth data as well as collecting special specimens and data for studies such as food habit investigations. Such a vessel or gear could legitimately operate in a nonrandom fashion since the sample unit would no longer be the standardized catch. It could target on species and areas for which biological data are in greatest demand.

Fishing power differences appear to us to be much easier to control in the field than to correct once they have insinuated themselves into the data. The data must be collected in a way that is as platform-independent as possible. Fishing power differences will always exist, assuming them to be negligible will not make systematic error in data disappear. Future surveys must be designed with this in mind.

If fishing power differences were controlled to the point of elimination, then the most efficient use of vessel time would be to have different vessels work in entirely different regions of the Gulf. With no vessel effect there would be no confounding of area effect with fishing power differences. We did, in fact, act on this strategy when we designed the 1984 survey which resulted in little overlap between the Morning *Star* and the *Ocean Spray*. However, we recommend against following such a strategy again. The definition of negligibility employed in these analyses was not an assumption of no fishing power differences. It was an assumption about the costs of correcting for fishing power differences that were assumed to exist, a very different proposition. Based on vessel performance (Tables 7 - 10, 14 - 17, and 20 - 23) it would a mistake to assume there were no actual fishing power differences.

This being so, it is important that all strata be sampled at least twice by every vessel participating in each future triennial survey. Whatever the sampling allocation is for each stratum, it should be divided evenly among the vessels. Furthermore, all vessels should work in the same stratum at the same or nearly the same time. While this will not reduce confounding of time and area effects, it will prevent those effects from being confounded with the vessel effect.

The Role of Fishing Power Corrections

Until more thorough investigations show otherwise. the appropriately conservative strategy is to estimate FPCs but not apply them. There are two reasons for this. The most important is that sufficient data for an FPC estimate, which is independent of the survey data, is far too costly to collect. If the Kappenman estimator remains the estimator of choice, an independent study of sufficient sample size is quite likely to be larger than either the 1984 or the 1987 survey.

It is also more conservative to assume negligibility of fishing power differences and challenge that assumption than to do the reverse. This strategy comes from the assumption that the cost of bringing the variance of an FPC estimate into the estimate of mean CPUE is generally higher than the cost of the bias being corrected. We believe that it is better to be slightly wrong due to bias and not risk being extremely wrong due to variance of the FPC estimate.

Though we recommend that they not actually be applied to data, FPC estimates may be used. along with vessel and gear performance evaluations, to assess the rigorousness with which vessels followed standardized procedures or conformed to specifications. As data from sequential surveys accrues, this measure may become important in trying to determine how much weight to give an estimated index of abundance for a particular year when charting long-term trends.

Even if we develop an estimator to correct bias which is low enough in variance, we still cannot apply it until there is a vessel that is common to several surveys in a sequence. Until such a de facto standard vessel has contributed to two or more surveys we will have no way of knowing which vessel/net systems among those participating in a survey is ‘more standard’ than the others.

Critical Ancillary Work

If a low variance estimator of the probability of capture becomes available, and if the data it requires are affordable, all of the FPC considerations become moot. Even the need for a repeat vessel would disappear. Work to identify such an estimator and to develop the appropriate technology should be strongly supported.

Regardless of the estimator used to estimate FPCs, it is critical that the variance of the FPC estimate be incorporated in the estimate of the index of abundance. When an FPC is applied, the estimated mean CPUE is no longer just a function of the data It becomes a function of the data and an estimate of a random variable, which itself is a function of the data. The resultant variance of the estimate of the index of abundance cannot help but be inflated by this. Currently our variance estimates of mean CPUE do not account for this inflation and are thus false. An estimator that does account for this increased uncertainty needs to be developed as soon as possible.

A clear problem is that of sample size. In this paper, we have written of ‘adequate sample size’ without really defining “adequate.” Given the high variances of CPUE data, we have been operating under the assumption that the levels of sampling in 1984 and 1987 were adequate but barely so, and that larger sample sizes could be justified. Since vessel time is costly,\ it is important to determine if this assumption is valid. We need to know both ideal and minimum sample sizes, stratum by stratum, over the whole of the survey. Then in the face of vessel-time constraints, we would know whether to reduce sample density or eliminate regions of the survey area. We suggest, as a starting place, simulation studies to relate sample size to coefficients of variation, super variance. and the ability to detect changes in the index of abundance among years. We also need to investigate the role of sample size in FPC estimation and assuming negligibility of fishing power differences.

An important step forward would be the quantification of the notion of negligibility as it is defined here. It may be possible to construct cost functions that provide a means to optimize the costs and benefits of controlling each. We would balance the cost of error due to bias, the cost of error due to uncertainty, the initial costs of controlling bias, and the costs of collecting data to estimate bias. From such functions, we could derive decision rules to more rigorously determine whether to control bias, correct bias, put up with bias, or some combination of these responses. Such work, of course, must be done in the context of estimating indices of abundance: estimation of an FPC is of itself not important. Costs and benefits must be defined in terms of reducing or increasing error in the estimate of mean CPUE and reducing or increasing the ability to detect change in those indices.

It remains to be seen whether or not it is wise to correct for fishing power differences at all. In this work, we assumed that it was not wise for all but the extreme cases of the Japanese vessels. The opposite assumption is invoked in the estimation of abundance indices from other AFSC surveys (Wilson and Armistead 1991, Bakkala et al. 1992). As usual, it is a question of cost-s. The initial costs of controlling differences through standardization are quite high. If, however, correcting a bias renders an index of abundance incomparable to another due to obscuringly large variance, that cost may be well worth it.

CITATIONS

Alverson. D. L., and W. T. Pereyra. 1969. Demersal fish explorations in the northeast Pacific Ocean--An evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Board Can. 26:1985-2001.

Bakkala, R. G., W. A. Karp, G. F. Walters, T. Sasaki, M. T. Wilson, T. M. Sample. A. M. Shimada; D. Adams, and C. E. Armistead. 1992. Distribution, abundance, and biological characteristics of groundfish in the eastern Bering Sea based on results of U.S. Japan bottom trawl and hydroacoustic surveys during June - September 1988. US. Dep. Commer., NOAA Tech. Memo. NMFS FINWC-213, 372 p.

Cochran. W. G. 1977. Sampling Techniques, Third Edition. 428 p. John Wiley and Sons, New York.

Engas A.. and O. R. Godo. 1989. The effect of different sweep lengths on the length composition of bottom-sampling trawl catches. J. Cons. int. Explor. Mer 45:263-268.

Feldman, G. C.. and C. S. Rose. 1981. Trawl survey of groundfish resources in the Gulf of Alaska, summer 1978. U.S. Dep. Commer.. NOAA Tech. Memo. NMFS FINWC-13. 44 P.

Gunderson, D. R., and T. M. Sample. 1980. Distribution and abundance of rockfish off Washington, Oregon, and California during 1977. Mar. Fish. Rev. 42(3-4):2-16.

Hoff, R. Z. 1989. Spatial distributions and abundance trends for two species of flatfish in the eastern Bering Sea. M.S. thesis, University of Washington, Seattle. 154 p.

Hughes, S. E. 1976. System for sampling large trawl catches of research vessels. J. Fish. Res. Board Can. 33:833-839.

Joseph, J., and T. P. Calkins. 1969. Population dynamics of the skipjack tuna (Katsuwonus pelamis) of the eastern Pacific Ocean. Inter-American Tropical Tuna Commission Bulletin 13:26-34.

Kappenman;R. F. 1992. Estimation of the fishing power correction factor. AFSC Processed Rep. 92-18, 10 p. Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA. 7606 Sand Point Way NE, Bldg. 4. Bin C 15700. Seattle. WA, 98115-0070

Munro. P. T. 1989. Estimating sport catch in Puget Sound using aerial survey and creel census techniques. M.S. thesis, University of Washington, Seattle. 74 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 p.

Robson. D. S. 1960. An unbiased sampling estimation procedure for creel census of fishermen. Biometrics 16:261-277.

Robson. D. S. 1961. On the statistical theory of a roving creel’census of fishermen. Biometrics 17:414-437.

Ronholt. L. L.. H. H. Shippen. and E. S. Brown. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass, 1948-1976; (a historical review), Volumes 14. NWAFC Processed Rep., 955 p. Alaska Fisheries Science Center, National Marine Fisheries Service, NOM, 7600 Sand Point Way NE, Bldg. 4. Bin C 15700. Seattle, WA 98115-0070

Rose, C. S., and G. E. Walters. 1990. Trawl width variation during bottom trawl surveys: Causes and consequences, p. 57-67. _In_ Loh-Lee Low [ed.], Proceedings of the Symposium on Application of Stock Assessment Techniques to Gadids. Int. North Pac. Fish. Comm. Bull. 50.

Sasaki, T.. D. Rodman, M. Onoda, and J. Rosapepe. 1982. Preliminary report on Japan-U.S. joint longline survey for sablefish and Pacific cod by Anyo Maru No. 22 in the Aleutian Region and the Gulf of Alaska in the summer of 1981. 88 p. Far Seas Fishery Research Laboratory. Shimizu, 424 Japan.

Stark, J.. K. Mito. E. Brown, and T. Yoshimura. 1988. Report to industry: Results of the 1987 U.S. - Japan Cooperative Bottom Trawl Survey of the central and western Gulf of Alaska. NWAFC Processed Rep. 88-15, 215 p. Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, Bldg. 4, Bin C 15700, Seattle, WA, 98115-0070

Wakabyashi. K. 1984. Preliminary report on the Japan-U.S. cooperative demersal trawl survey in the Gulf of Alaska by Daikichi Maru No. 37 in 1984. [Document submitted to the International North Pacific Fisheries Commission.) 6 p. Fisheries Agency of Japan, Tokyo, Japan 100.

Wakabyashi. K.. R. G. Bakkala, and M. S. Alton. 1985. Methods of the U.S. Japan demersal trawl surveys, p. 7-29. In R. G. Bakkala and K. Wakabayashi [ed;]. Results of cooperative U.S.Japan groundfish investigations in the Bering Sea during May-August 1979. Int. North Pac. Fish. Comm. Bull. 44.

Wathne. F. 1977. Performance of trawls used in resource assessment. Mar. Fish. Rev. 39(6): 16-23.

Wilderbuer. T. K. 1988. Fishing power standardization in multi-vessel, multi-gear, resource assessment surveys. M.S. thesis, University of Washington, Seattle. 171 p.

Wilderbuer. T. K.. K. Wakabyashi, L. L. Ronholt, and H. Yamaguchi. 1985. Survey report: Cooperative U.S. Japan Aleutian Islands groundfish trawl survey - 1980. U.S. Dep. Commer., NOAA Tech. Memo. NMFS FINWC-93. 356 p.

Wilson, M. T.. and C. E. Armistead. 1991. 1989 bottom trawl survey of the eastern Bering Sea continental shelf. U.S. Dep. Cornmer., NOAA Tech. Memo. NMFS FINWC-212, 212 p.

Zenger. H. H., and K. Wakabyashi. 1985. Groundfish survey Central and Western Gulf of Alaska. NOAA, NWAFC. Fishing Log, 165 p.

APPENDIX A

SAMPLING GEAR SPECIFICATIONS

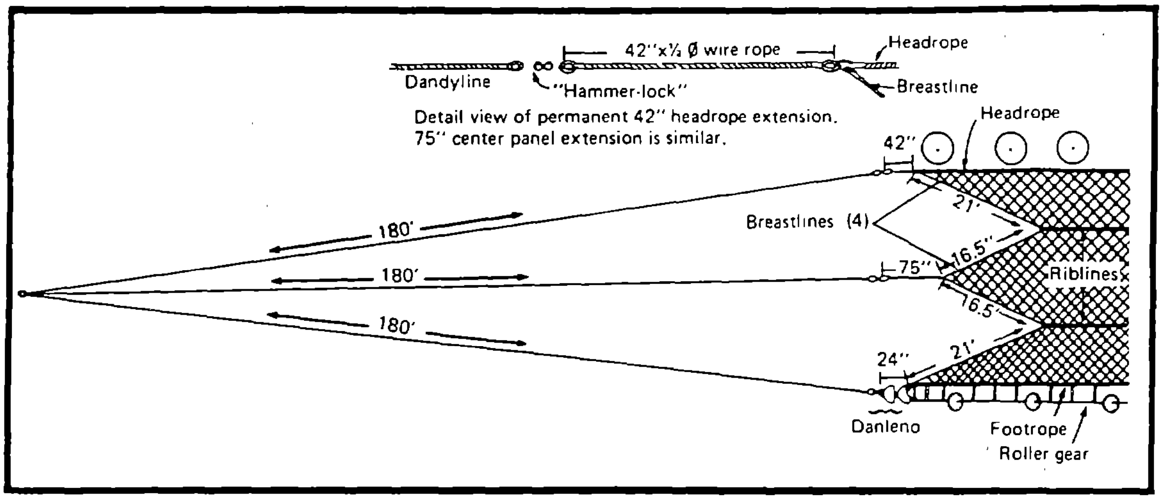
Table A- 1 .--Differences between nylon and polyethylene Noreastern trawls:

Trawl Characteristic	Polyethylene Noreastern	Nylon Noreastern
netting:	polyethylene (dyed orange)	nylon (dyed green)
headrope:	89 ft. 1 in.	90 ft.
footrope:	120 ft. 7 in. (3/8 in. diameter), uses a Bolsh line of 3/8 in. long link chain secured to the footrope every sixth link using a benzel of nylon twine.	105 ft. (3/8 in. diameter), Bolsh line absent.
roller gear:	79 ft. 6 in., 3/4 in. diameter, 6 X 19 galvanized wire rope, 14-18 in. wing bobbins. Attached to the Bolsh line using 3/8 in. shackles.	102 ft., 3/4 in., 6 X 19 galvanized wire rope, 18-18 in. wing bobbins, lashed directly to the footrope.
lower wing:	Flying wing. Bottom wing tip is cut shorter than side and top wings. Footrope length that is usually constructed of web (i.e. nylon trawl) is replaced with 6 X 19 1/2 in. cable strung with 4 in. rubber discs.	No flying wing. Netting is attached to footrope from wingtip to wingtip.
gussets:	absent	present
riblines:	Duralon 2 in 1 sampson ribline 3/4 in. diameter hung 98% of the stretched measurement of the gored seam.	Polydacron 3 strand 7/8 in.diameter hung 98% of the stretched seam length.
breastlines:	3/8 in. galvanized wire rope wrapped with 3/8 in polypropylene. Top corner 19 ft. 6 in., bottom corner 8 ft. 4 in., top side panel 19 ft. 6 in., bottom side pannel 30 ft. 6 in.	3/8 in. galvanized wire rope wrapped with 7/8 in. polypropylene. Top corner 21 ft., bottom corner 21 ft., top side panel 16 ft. 5 in., bottom side panel 16 ft. 5 in.

Table A-2.--Features common to both polyethylene and nylon Noreastern trawl.

Feature	Description
floatation:	Cycolac trawl floats, 12 in. diameter, 21 pieces. Bouyancy 22.4 pounds each and rated for 800 m (400 fm) depth.
codend liner:	Nylon, no. 18, 1 1/2 in. stretched mesh, 315 meshes circumference and 300 meshes deep, laced to inner bag at 97 meshes from end of the cod end. When stretched the liner protrudeds 2-3 ft. beyond the codend.
restrictors:	Polypropylene rope, 1 in. diameter, 14 ft. circumference, secured loosely to codend at each ribline, 4 ft. apart, five pieces.
splitting gear:	1/2 in. diameter galvanized wire rope, 21 ft. long. The wire is passed through five galvanized steel rings which are secured to the codend with 1/2 in. diameter braided nylon "spiders".
side seams:	Panels are joined together gathering 3 meshes (4 knots) from each panel. Panels which are secured to framing lines have a selvaged edge created by gathering 3 meshes.
rigging:	3 dandylines each side, 5/8 in. diameter galvanized wire rope, 30 fathoms long.
doors:	6 X 9 ft., steel V-doors, approximately 2,000 pounds each.

NYLON NOREASTERN



POLYETHYLENE NOREASTERN

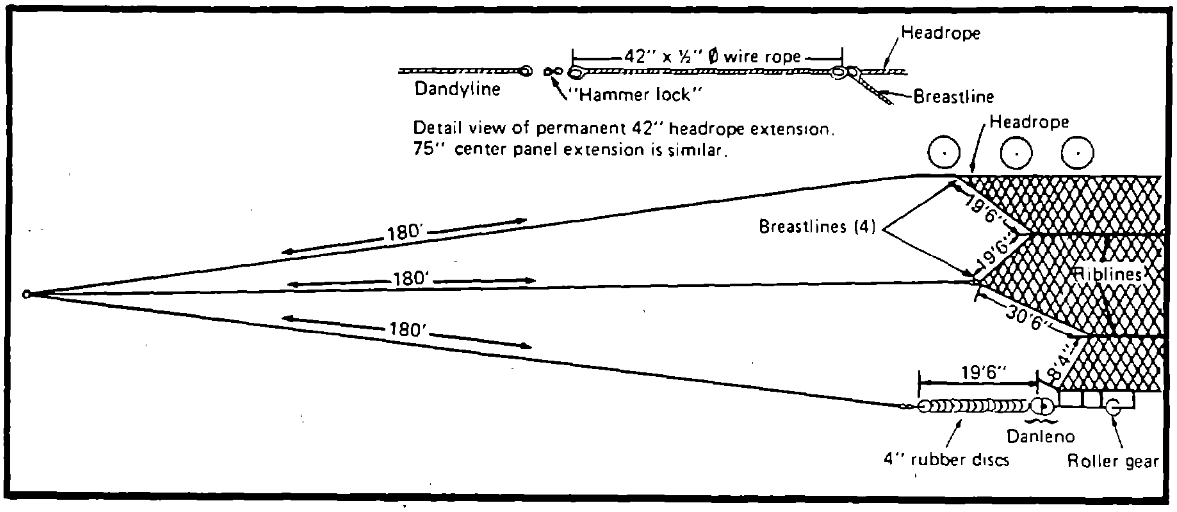
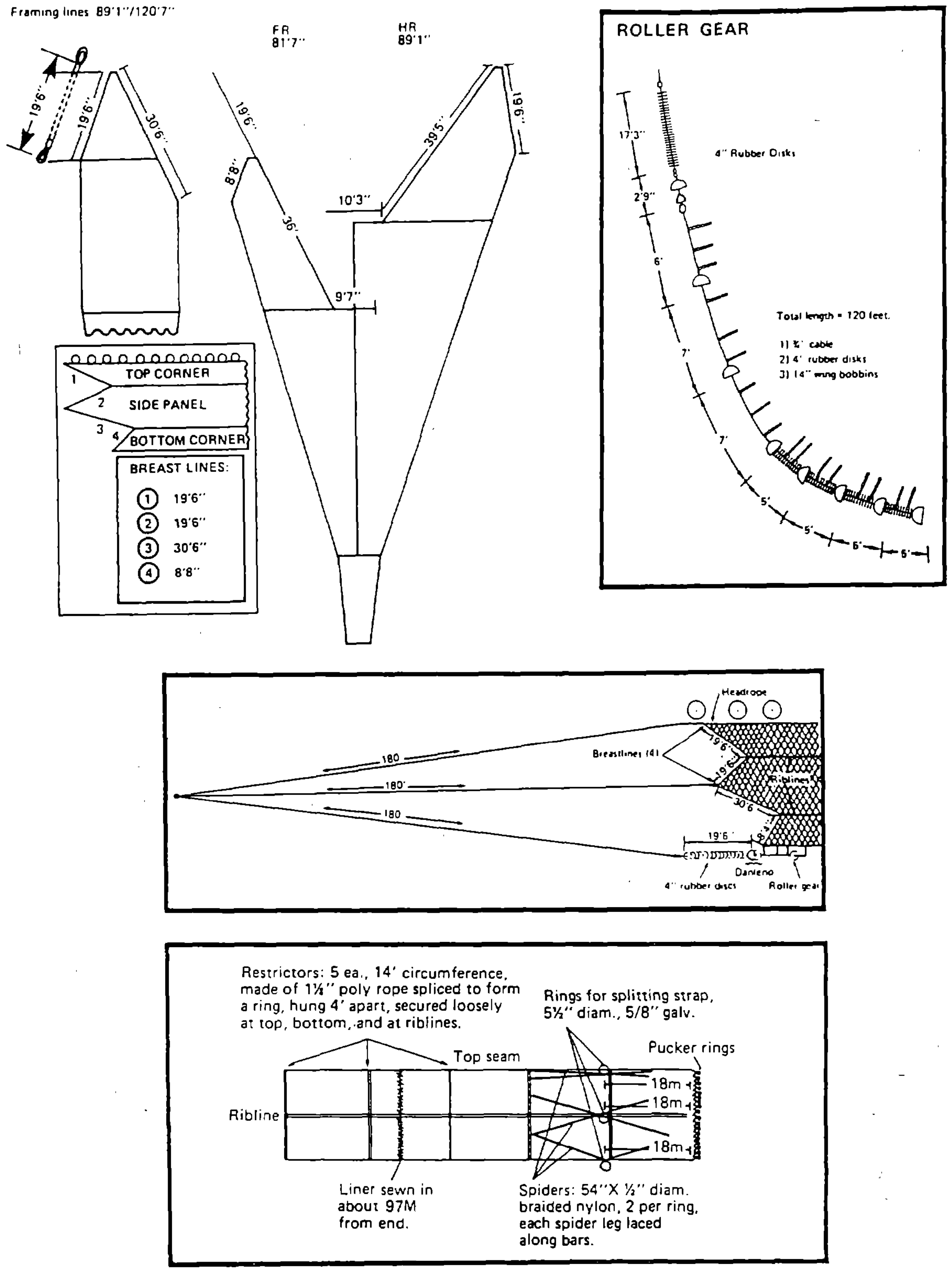


Figure A-l .--Diagram contrasting the polyethylene Noreastern trawl and the nylon Noreastern trawl.

POLY–NOREASTERN



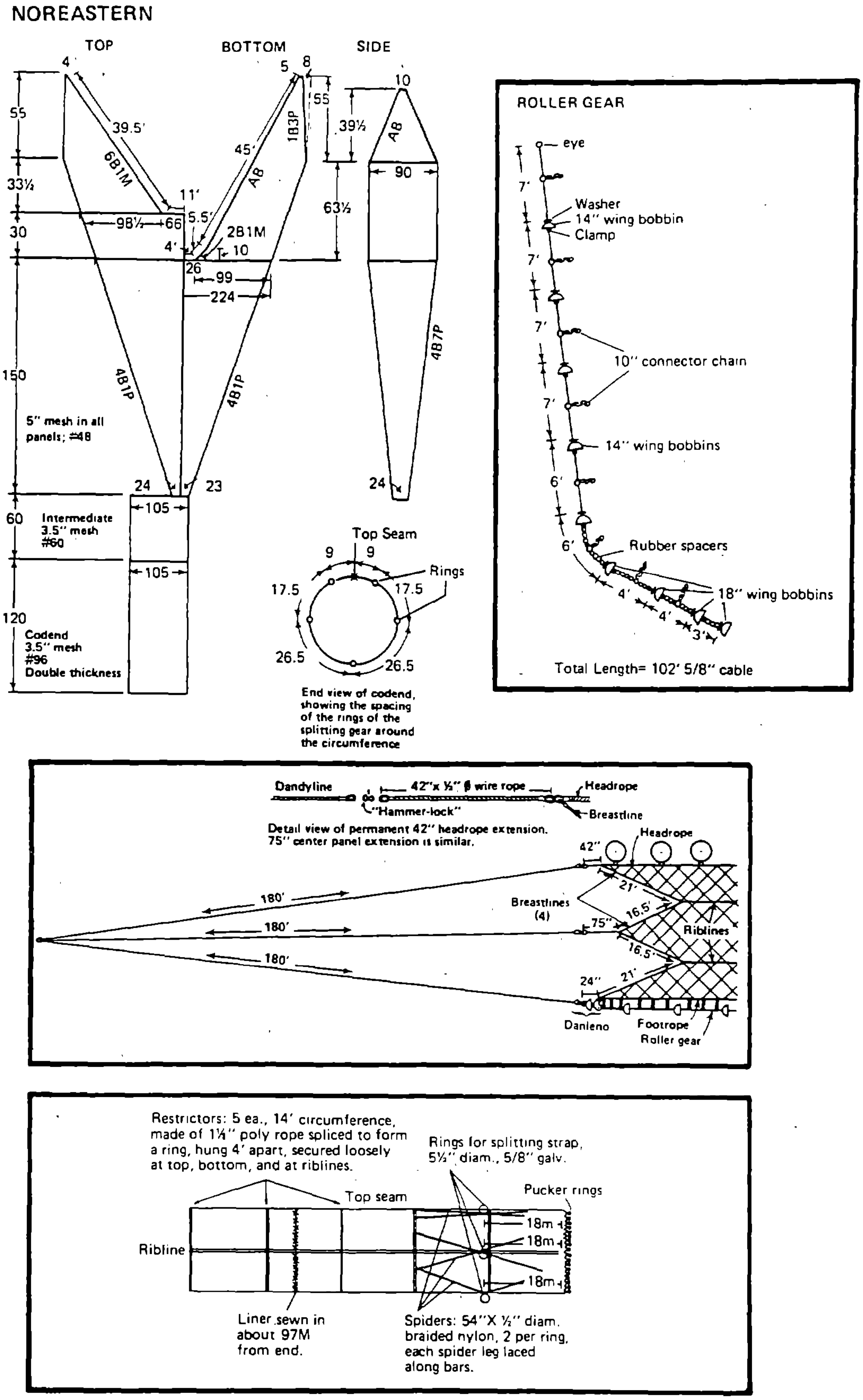
Restrictors: 5 ea., 14' circumference, made of 1½" poly rope spliced to form a ring, hung 4' apart, secured loosely at top, bottom, and at riblines.

Rings for splitting strap, 5½" diam., 5/8" galv.

Liner sewn in about 97M from end.

Spiders: 54"X ½" diam. braided nylon, 2 per ring, each spider leg laced along bars.

Figure A-2.--Diagram of the polyethylene Noreastern trawl used in the 1984 and 1987 triennial demersal trawl surveys of the Gulf of Alaska.



End view of codend, showing the spacing of the rings of the splitting gear around the circumference

Detail view of permanent 42" headrope extension. 75" center panel extension is similar.

Restrictors: 5 ea., 14' circumference, made of 1¼" poly rope spliced to form a ring, hung 4' apart, secured loosely at top, bottom, and at riblines.

Rings for splitting strap, 5½" diam., 5/8" galv.

Liner sewn in about 97M from end.

Spiders: 54"X ½" diam. braided nylon, 2 per ring, each spider leg laced along bars.

Figure A-3.--Diagram of the nylon Noreastern trawl used in the 1984 triennial demersal trawl survey of the Gulf of Alaska.

Table A-3.--Features of the trawl and rigging used by the *Daikichi Maru* No. 37 in the 1984 triennial demersal trawl survey of the Gulf of Alaska.

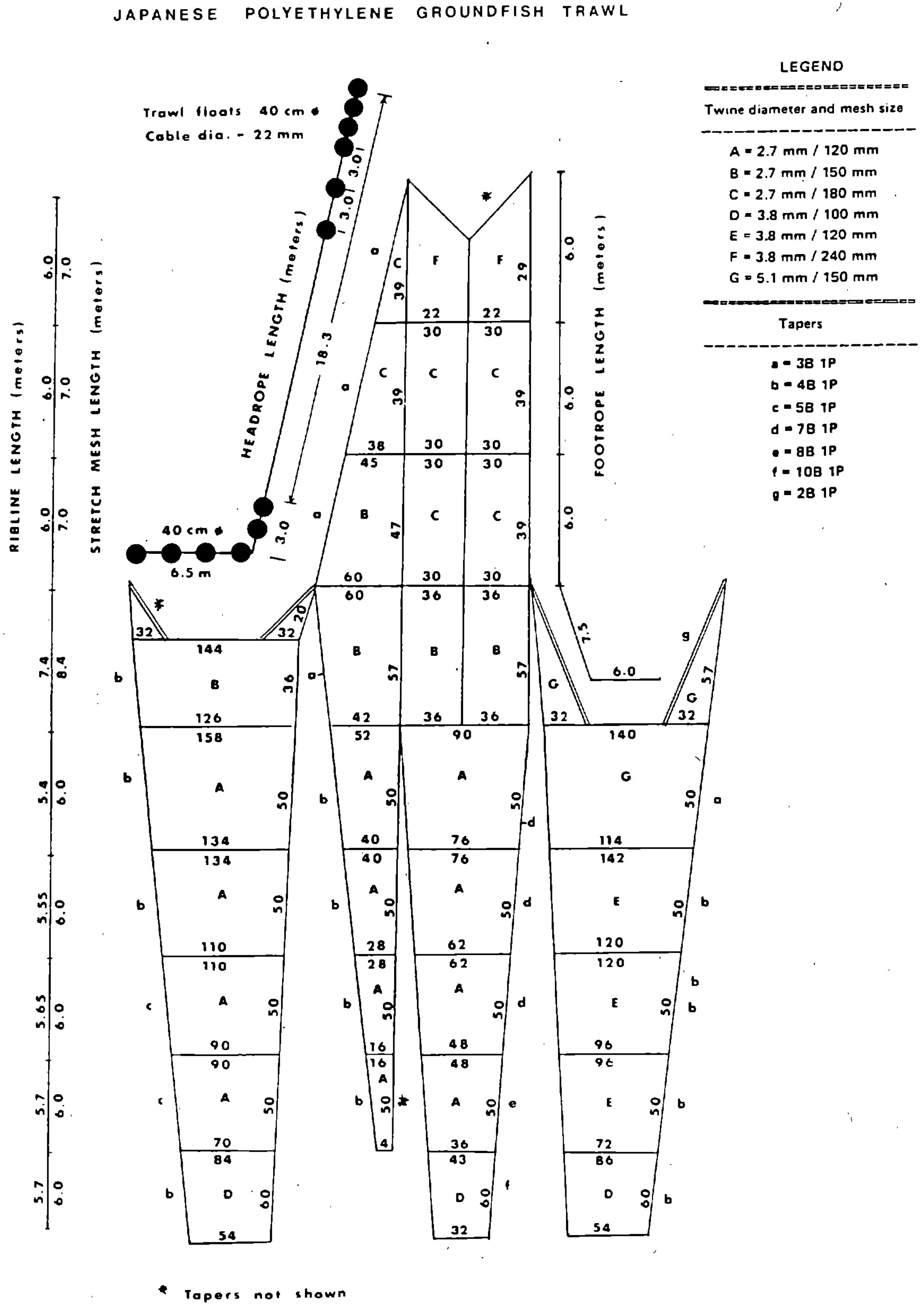


Figure A-4.--Diagram of the polyethylene trawl and headrope used by the *Daikichi Maru* No. 37 in the 1984 triennial demersal trawl survey of the Gulf of Alaska.

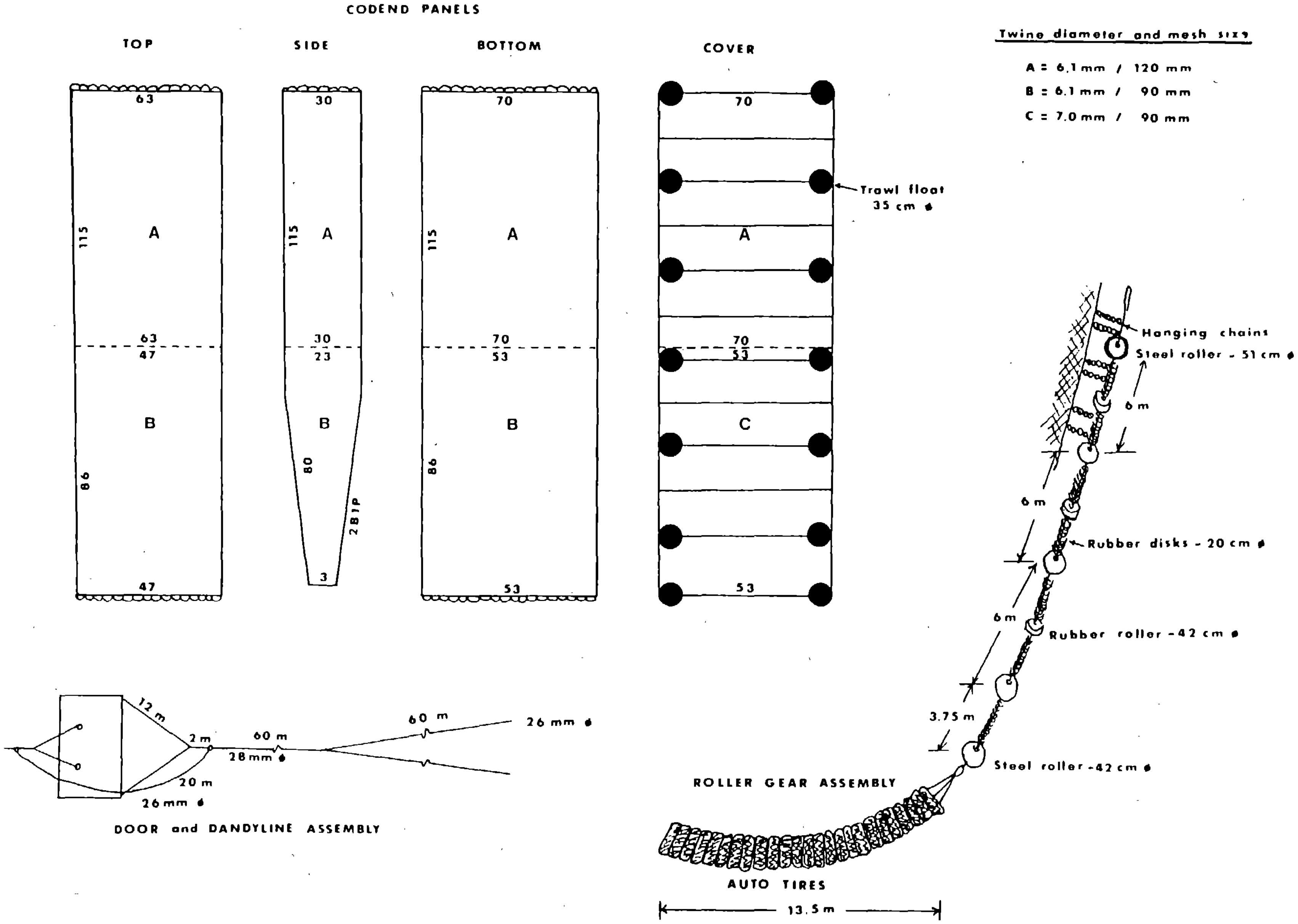


Figure A-5.--Diagram of the footrope. roller gear, codend, codend cover, and doors and dandyline assembly used by the *Daikichi Maru* No, 37 in the 1984 demersal trawl survey of the Gulf of Alaska.

Table A-4.--Features of the trawl and rigging used by the Taisel *Maru No. 35 in the* 1987 triennial demersal trawl survey of the Gulf of Alaska.

Feature	Description
Netting:	polyethylene
Headrope:	55.6 m
Footrope:	65.0 m
Overall net length:	89.8 m
Codend:	triple layer, 100 mm meshes in each layer
Roller gear:	
Bobbins:	530 mm diameter
Tires:	600 mm diameter
Dandylines:	156 m
Doors:	2.55 m by 3.85 m. approximately 3,200 kg

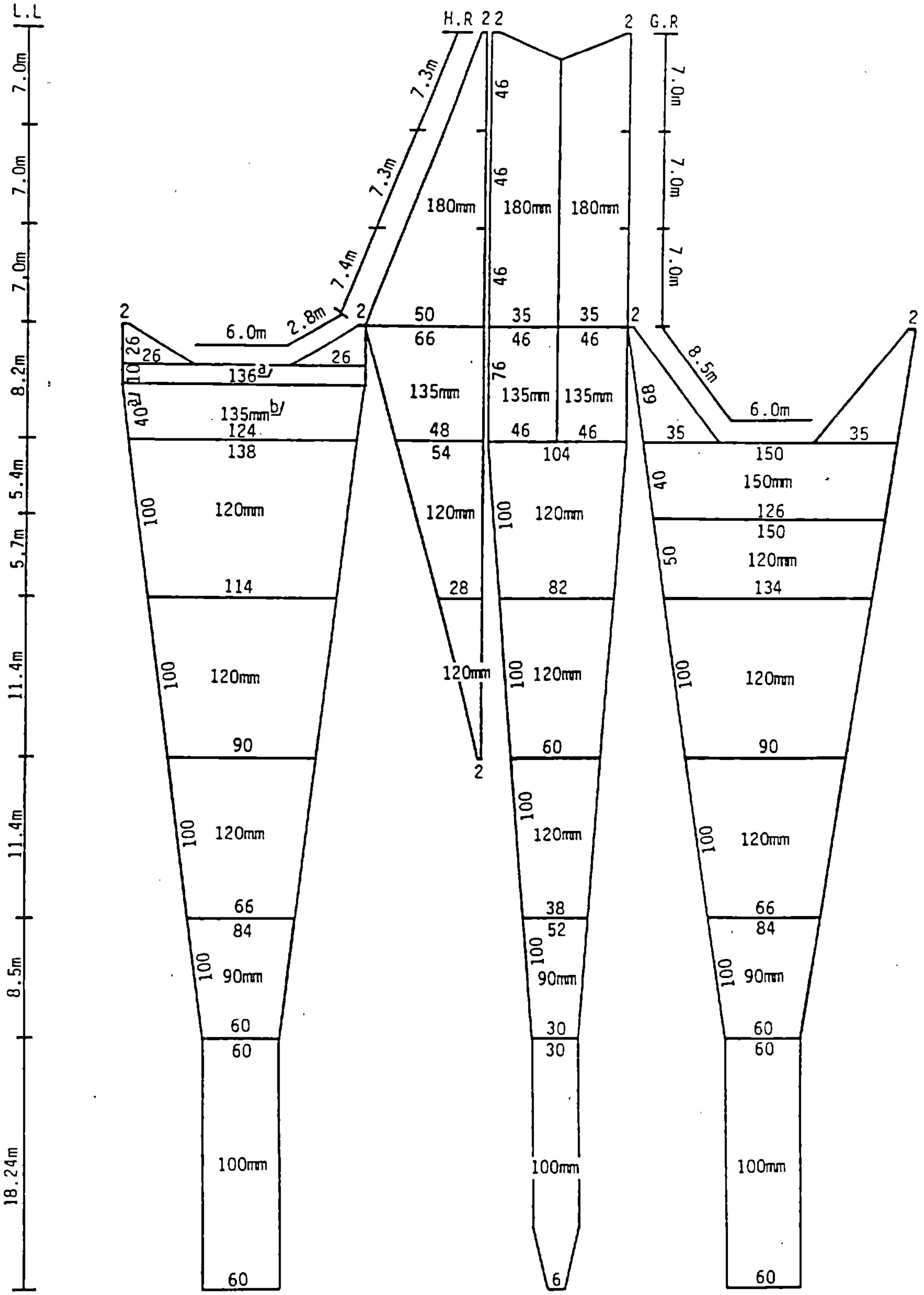


Figure A-6.--Diagram of the trawl used by the *Taisei Maru No.* 35 in the 1987 demersal trawl survey of the Gulf of Alaska.

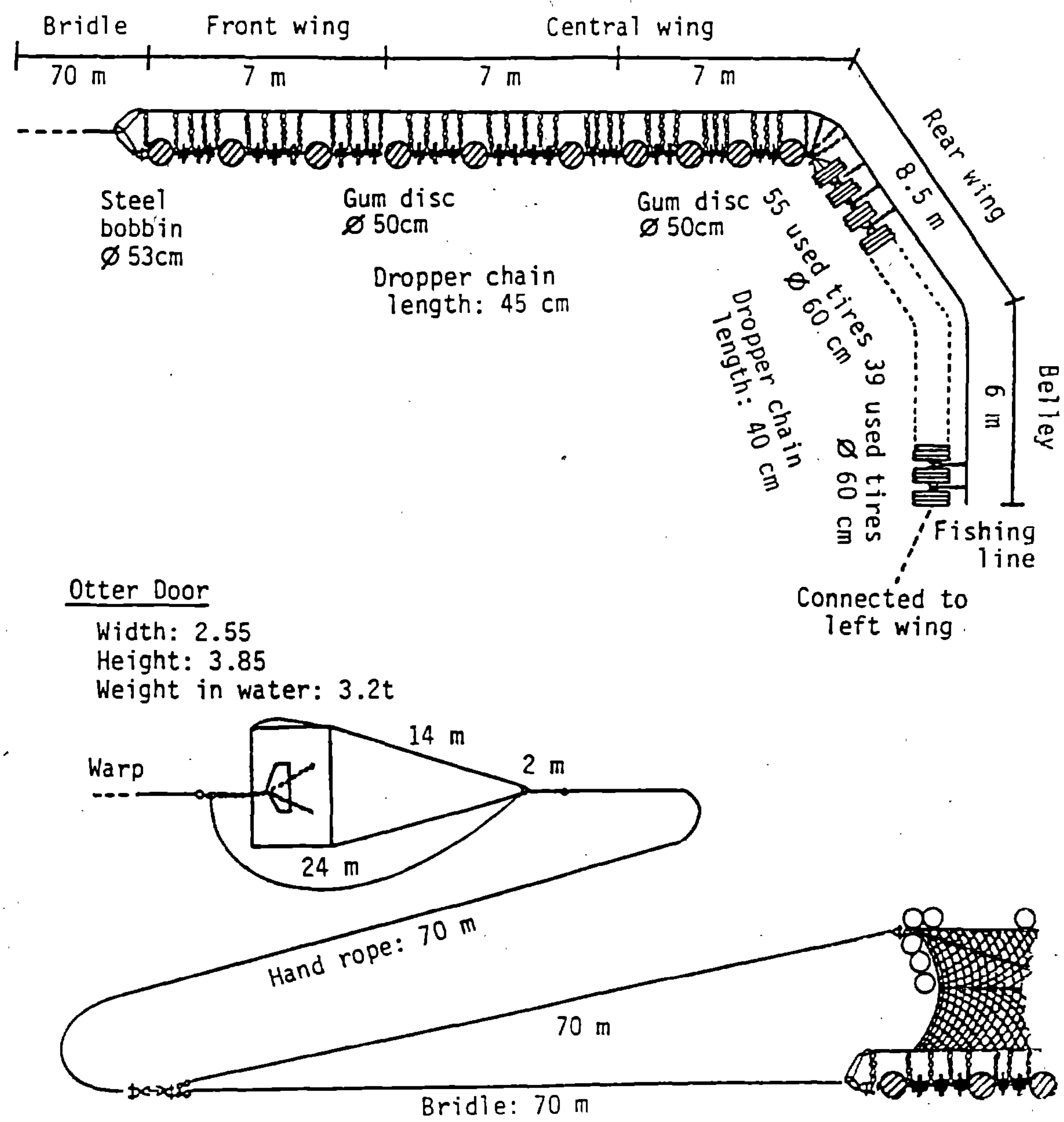


Figure A-7.--Diagram of the footrope, roller gear, and doors and dandyline assembly used by the *Taisei Maru* No. 35 in the 1987 demersal trawl survey of the Gulf of Alaska.

APPENDIX B

ESTIMATES FOR THE SCATTERPLOT COMPARISON OF NYLON AND POLYETHYLENE NOREASTERN TRAWLS

Means, medians, and coefficients of variation for selected species

Table B-l.--Numbers of nonzero tows, medians, means, and coefficients of variation of CPUE for arrowtooth flounder estimated from tows made by the FV Morning Star using nylon and polyethylene trawls. CPUE is in kilograms per square kilometer. CV is 100% times the sample standard deviation divided by the sample mean.

	Nylon Net				Polyethylene Net			
Stratum	Non-zero tows	Median	Mean	CV	Non-zero tows	Median	Mean	CV
10	4	302.88	298.16	81.28	4	133.07	802.52	199.88
11	10	128.79	947.46	137.57	6	4.76	233.9	175.53
12	5	58.86	898.99	220.01	5	7	606.84	264.57
13	8	77.7	849.5	222.11	5	14.38	229.36	204.74
20	2	38.68	38.68	135.45	2	1586.12	1586.12	39.84
110	6	1840.92	2080.98	97.3	7	1367.73	1944.97	93.71
111	11	1067.4	1689.76	107.97	9	3446.27	4303.75	127.82
112	3	3378.15	4146.34	82.73	3	1725.51	2658.47	68.9
120	14	2990.37	3556.55	67.34	15	2827.51	4600.17	110.44
122	5	3585.24	17440.14	121.59	5	1080.72	1720.11	115.53
134	6	7667.61	14862.25	142.1	7	1388.87	5377.8	137.89
140					1	5044.28	5044.28	
210	3	376.2	276.14	78.02	6	840.44	826.62	78.75
221	4	5518.91	4857.98	51.63	4	2047.27	1739.24	71.59
231	9	1242.59	2342.16	131.15	2	9346.68	9346.68	136.01
240					1	918.1	918.1	
310	5	278.25	256.01	52.98	1	59.66	59.66	141.42
320	2	1571.29	1571.29	134.81	4	298.52	284.55	39.68
330	3	4007.24	3923.02	80.41	6	461.34	2646.42	204.29
410	0	0	0		1	0	8.11	223.61
420	0	0	0		2	126.21	126.21	126
430	2	0	120.97	183.32	1	148.6	148.6	141.42
510	0	0	0		0	0	0	
520	1	160.8	160.8		0	0	0	
530					1	0	97.44	173.21

Table B-2.--Numbers of nonzero tows, medians, means, and coefficients of variation of CPUE for Pacific halibut estimated from tows made by the FV Morning Star using nylon and polyethylene trawls. CPUE is in kilograms per square kilometer. CV is 100% times the sample standard deviation divided by the sample mean.

	Nylon Net				Polyethylene Net			
Stratum	Non-zero tows	Median	Mean	CV	Non-zero tows	Median	Mean	CV
10	5	815.94	1138.89	60.16	7	326.22	560.83	110.74
11	10	665.72	780.23	101.76	10	481.89	553.05	105.85
12	6	1080.11	1038.89	53.02	8	1429.56	1691.69	80.1
13	7	64.89	326.2	182.56	8	552.23	751.5	94.28
20	2	431.02	431.02	112.54	2	290.82	290.82	75.37
110	7	1390.39	1863.57	78.63	8	546.25	867.36	96.53
111	9	482.02	796.65	115.06	6	129.55	765.03	143.18
112	3	810.54	811.14	70.24	3	193.57	266.93	93.95
120	12	397.5	538.84	98.23	14	667.77	931.79	108.67
122	4	954.72	2494.39	115.77	4	1461.71	2131.69	103.47
134	6	3640.38	4305.28	98.59	7	1512.21	4563.42	163.33
140					1	786.46	786.46	
210	0	0	0		1	0	36.61	264.58
221	3	584.42	669.36	101.31	3	196.11	295.94	120.04
231	5	23.01	832.99	137.48	1	864	864	141.42
240					0	0	0	
310	0	0	0		0	0	0	
320	0	0	0		0	0	0	
330	1	0	113.65	200	0	0	0	
410	0	0	0		0	0	0	
420	0	0	0		0	0	0	
430	0	0	0		0	0	0	
510	0	0	0		0	0	0	
520	0	0	0		0	0	0	
530					0	0	0	

Table B-S.--Numbers of nonzero tows, medians, means, and coefficients of variation of CPUE for rock sole estimated from tows made by the FV Morning Star using nylon and polyethylene trawls, CPUE is in kilograms per square kilometer. CV is 100% times the sample standard deviation divided by the sample mean.

	Nylon Net				Polyethylene Net			
Stratum	Non-zero tows	Median	Mean	CV	Non-zero tows	Median	Mean	CV
10	5	997.74	1155.49	33.79	6	1020.23	1020.56	97.78
11	11	1534.55	1315.03	44.59	11	1181.17	1643.68	92.81
12	6	644.14	770.76	65.92	8	1094.37	1623.07	94.65
13	9	906.45	1505.45	119.28	8	943.8	840.6	70.93
20	2	1220.3	1220.3	80	2	1583.58	1583.58	133.28
110	6	24.12	179.33	159.66	8	128.27	204.81	127.22
111	9	317.01	718.55	120.49	6	401.01	429.08	105.27
112	2	82.09	166.46	132.81	2	10.04	10.56	102.57
120	10	54.37	271.31	154.46	9	9.91	203.94	200.57
122	2	0	60.59	211.36	2	0	37.96	201.44
134	2	0	96.66	217.13	2	0	22.46	237.21
140					0	0	0	
210	1	0	12.54	173.21	2	0	177.51	209.96
221	0	0	0		0	0	0	
231	0	0	0		0	0	0	
240					0	0	0	
310	2	0	9.04	220.31	0	0	0	
320	0	0	0		0	0	0	
330	0	0	0		0	0	0	
410	0	0	0		0	0	0	
420	0	0	0		0	0	0	
430	0	0	0		0	0	0	
510	0	0	0		0	0	0	
520	0	0	0		0	0	0	
530					0	0	0	

Table B-4.--Numbers of nonzero tows. medians, means, and coefficients of variation of CPUE for walleye pollock estimated from *tows* made by *the* FV *Morning Star* using nylon and polyethylene trawls. CPUE is in kilograms per square kilometer. CV is 100% times the sample standard deviation divided by the sample mean.

	Nylon Net				Polyethylene Net			
Stratum	Non-zero tows	Median	Mean	CV	Non-zero tows	Median	Mean	CV
10	4	201.67	4119.95	183.13	3	0	202.75	245.6
11	6	1.62	225.6	301.27	5	0	2201.09	224.57
12	5	4604.61	7058.14	129.89	4	334.83	1007.37	192.88
13	7	33.99	263.63	220.91	3	0	23.68	180.15
20	0	0	0		2	2117.9	2117.9	140.43
110	4	0.96	2143.94	231.84	5	2.45	456.7	226.24
111	9	176.66	8734.23	145.91	5	29.72	39172.61	195.9
112	3	1349.86	3827.2	138.88	3	591.46	4967.41	156.87
120	12	10.66	5449.6	357.85	12	9.46	10325.76	314.42
122	0	0	0		0	0	0	
134	2	0	40.63	234.06	4	9.84	175.08	222.55
140					1	15.16	15.16	
210	3	10242.04	16466.17	101.04	7	1902.44	4727.28	125.17
221	4	32.74	49.96	95.41	2	4.73	14.59	159.7
231	5	30.12	797.31	189.16	1	11.34	11.34	141.42
240					0	0	0	
310	1	0	37.15	244.95	0	0	0	
320	1	361.78	361.78	141.42	2	7.74	43.67	177.16
330	3	71.2	69.37	107.07	2	0	142.22	176.46
410	0	0	0		1	0	8.43	223.61
420	1	0	1.72	173.21	0	0	0	
430	1	0	11.47	244.95	1	140.83	140.83	141.42
510	0	0	0		0	0	0	
520	0	0	0		0	0	0	
530					0	0	0	

Table B-5.--Numbers of nonzero tows, medians, means, and coefficients of variation of CPUE for Pacific cod estimated from tows made by the FV Morning Star using nylon and polyethylene trawls. CPUE is in kilograms per square kilometer. CV is 100% times the sample standard deviation divided by the sample mean.

	Nylon Net				Polyethylene Net			
Stratum	Non-zero tows	Median	Mean	CV	Non-zero tows	Median	Mean	CV
10	4	1195.68	15416.96	197.97	6	811.43	920.18	101.02
11	9	391.58	867.03	134.91	10	514.38	832.57	128.67
12	6	1921.03	1789.97	62.53	6	956.67	2140.85	151.4
13	7	118.88	706.46	142.56	6	235.95	1513.55	153.83
20	1	18.93	18.93	141.42	2	1328.21	1328.21	33.68
110	6	984.23	1603.44	93.97	8	423.07	1093.05	114.03
111	13	1046.73	2449.66	176.45	8	3125.37	2901.52	81.38
112	3	1302.79	44728.11	168.62	3	1085.16	1270.13	30.92
120	12	602.05	867.14	125.45	11	1074.33	1531.89	102.02
122	4	491.88	1808.21	128.9	4	956.02	1539.7	118
134	4	570.93	1081.15	138.49	7	1626.82	12593.56	232.53
140					1	212.28	212.28	
210	3	263.34	236.35	59.14	7	495.33	819.53	82.38
221	4	2544.89	2864.27	58.9	4	544.11	455.54	52.48
231	9	521.06	818.1	94.85	2	333.76	333.76	9.24
240					1	2025.49	2025.49	
310	0	0	0		0	0	0	
320	0	0	0		1	0	13.27	200
330	2	66.04	172.94	153.37	0	0	0	
410	0	0	0		0	0	0	
420	0	0	0		0	0	0	
430	1	0	6.65	244.95	0	0	0	
510	0	0	0		0	0	0	
520	0	0	0		0	0	0	
530					0	0	0	

Table B-6.--Numbers of nonzero tows, medians, means, and coefficients of variation of CPUE for Pacific ocean perch estimated from tows made by the FV Morning Star using nylon and polypropylene trawls. CPUE is in kilograms per square kilometer. CV is 100% times the sample standard deviation divided by the sample mean.

	Nylon Net				Polypropylene Net			
Stratum	Non-zero tows	Median	Mean	CV	Non-zero tows	Median	Mean	CV
10	0	0	0		1	0	15.16	264.58
11	0	0	0		2	0	8.18	225.01
12	0	0	0		0	0	0	
13	0	0	0		0	0	0	
20	0	0	0		0	0	0	
110	1	0	1.49	264.58	2	0	2.56	185.26
111	6	0	43.24	221.23	5	0.97	273.83	208.22
112	1	0	818.16	173.21	0	0	0	
120	1	0	11.25	374.17	3	0	19.35	291.45
122	2	0	20.91	179.38	3	5.09	7.88	111.78
134	3	5.63	485.68	238.5	4	217.69	4377.1	249.28
140					0	0	0	
210	3	1652.35	3376.24	101.67	7	657.73	2860.35	160.76
221	4	1380.19	2138.23	120	4	173.13	548.82	146.09
231	7	60.9	1094.93	215.1	2	3763.06	3763.06	100.71
240					1	5915.56	5915.56	
310	1	0	2.37	244.95	1	10.85	10.85	141.42
320	2	29.35	29.35	94.62	0	0	0	
330	4	448.66	533.08	96.91	2	0	38.46	156.69
410	0	0	0		2	0	21.02	196.78
420	0	0	0		0	0	0	
430	1	0	11.64	244.95	0	0	0	
510	0	0	0		0	0	0	
520	0	0	0		0	0	0	
530					0	0	0	

APPENDIX C

STRATEGIES AND FORMULAE FOR FIRST ESTIMATES OF FISHING POWER CORRECTIONS IN 1987

Data from the comparison study were used to calibrate two of three vessels to the third vessel, the boat with the greatest fishing power. In these estimations, data from all depths and areas of the study were pooled for each vessel. The vessel with the highest fishing power was not the same for every species. For some species there was no apparent difference between the two U.S. vessels. For other species, one of the boats was so poorly represented by nonzero tows that its data was not used in the estimate. A few species were so poorly represented by nonzero tows among all boats that FPC estimates from other species or species groups were used instead. These considerations led to a variety of strategies for estimating FPCs, using several versions of the estimators, all slight variants on the basic ratio of means. The "Most Efficient Trawl" principle was always followed in determining how to apply the estimates to catch data. The strategies are described here. The actual estimates of the fishing power corrections and the strategy for application are given in Table 30.

Throughout this appendix three different estimates of mean CPUE are combined in various ways. Rather than describe them repeatedly in each strategy, they are given here:

Mean CPUE for the *Lets Go* was estimated with:

$$\overline{CPUE}_{LG} = \frac{1}{n_{LG}}\sum_{i=1}^{n_{LG}} CPUE_{LG,i} \ .$$

Mean CPUE for the *Nore-Dick* was estimated with:

$$\overline{CPUE}_{ND} = \frac{1}{n_{ND}}\sum_{i=1}^{n_{ND}} CPUE_{ND,i} \ .$$

Mean CPUE for the *Taisei Maru* No. 35 was estimated with:

$$\overline{CPUE}_T = \frac{1}{n_T}\sum_{i=1}^{n_T} CPUE_{Ti} .$$

One last quantity was used in several of the following strategies, a combined mean of CPUEs for the two U.S. vessels to represent the "standard' U.S. vessel/net combination. The mean CPUE for this standard vessel was estimated as the unweighted average of the mean CPUEs for each of the two U.S. boats:

$$\overline{CPUE}_{ST} = \frac{1}{2} (\overline{CPUE}_{LG} + \overline{CPUE}_{ND}) .$$

Strategy 1

In this strategy the fishing power difference between *the Lets Go* and *the Nore-Dick* was considered negligible. Their estimated mean CPUEs were combined in an unweighted average to represent a U.S. standard vessel. The U.S. vessel appeared to have a higher fishing power than the *Taisei Maru* No.. 35. Catches made by the *Taisei Maru No. 35 as part* of the survey were multiplied by an estimate of the fishing power difference to adjust them to those of the U.S. standard vessel.

The estimator was

$$FPC^* = \frac{\overline{CPUE}_{ST}}{\overline{CPUE}_T} .$$

Strategy 2

The fishing power difference between the Lets Co and the *Nore-Dick* was considered non-negligible. The *Nore-Dick* appeared to have the highest fishing efficiency. Separate FPCs were computed for the *Lets Go* and *Taisei Maru* No. 35. Catches by each of those vessels were multiplied against their FPC estimates to adjust them to catches made by the *Nore-*Dick.

The FPC estimator for the *Lets Go-was*

$$FPC^{*}_{ND/LG} = \frac{\overline{CPUE}_{ND}}{\overline{CPUE}_{LG}} .$$

The FPC estimator for the *Taisei Maru* No. 35 was

$$FPC^{*}_{ND/T} = \frac{\overline{CPUE}_{ND}}{\overline{CPUE}_{T}} .$$

Strategy 3

The difference in fishing power for northern rockfish between the *Lets Go* and the *Nore-Dick* seemed large. However, we were forced to consider it negligible due to poor representation by nonzero tows in catches by the Nore-Dick. For the same reason only catches by the *Lets Go* were used to represent the standard vessel. The fishing power difference between the *Taisei Maru* No. 35 and the standard vessel was not considered negligible. It was corrected in the survey data by multiplying catches made by the *Taisei Maru No,* 35 with an FPC estimated by the following:

$$FPC^{*}_{LG/T} = \frac{\overline{CPUE}_{LG}}{\overline{CPUE}_{T}} .$$

Strategy 4

The fishing power difference between the *Lets Go* and; the *Nore-Dick* was considered non-negligible. The fishing power differences between the *Taisei Maru* No. 35 and each of the other two vessels were also considered non-negligible. The most efficient vessel was the *Taisei Maru No.* 35. Survey catches made by the *Lets Go* were multiplied against an FPC estimated by:

$$FPC^{*}_{T|LG} = \frac{\overline{CPUE}_{T}}{\overline{CPUE}_{LG}} .$$

Survey catches made by the *Nore-Dick* were multiplied against an FPC estimated by:

$$FPC^{*}_{T|ND} = \frac{\overline{CPUE}_{T}}{\overline{CPUE}_{ND}} .$$

Strategy 6

For each species of smaller flatfish which was poorly represented by nonzero tows in the comparison study an FPC was estimated as a combination of mean CPUEs for other similar species, flathead sole, Dover sole, rex sole, and rock sole. Fishing power differences between the two U.S. boats were assumed negligible and a CPUE was estimated for a standard U.S. vessel/net combination. This standard vessel was seen to be the more efficient. Survey. catches made by *the Taisei* Maru No. 35 were multiplied against an FPC estimated by:

$$FPC^{*} = \frac{\overline{CPUE}_{ST,flathead} + \overline{CPUE}_{ST,dover} + \overline{CPUE}_{ST,rex} + \overline{CPUE}_{ST,rock}}{\overline{CPUE}_{T,flathead} + \overline{CPUE}_{T,dover} + \overline{CPUE}_{T,rex} + \overline{CPUE}_{T,rock}} .$$

Strategy 6

Starry flounder, a somewhat larger flatfish, was poorly represented in the comparison study data. The estimated FPC generated for arrowtooth flounder using Strategy 1 was applied to survey catches of this species *made* by the *Taisei Maru No. 35*. This was done because this species was so poorly represented by nonzero tows in the comparison study.

Strategy 7

The FPC for Pacific ocean perch estimated from the comparison study data. using Strategy 1, was also used to correct survey catches made by the Taisei *Maru No. 35* of harlequin, sharpchin. and dusky rockfish. This was done because these species were so poorly represented by nonzero tows in the comparison study and were thought to be sufficiently similar to Pacific ocean perch.

Strategy 8

The FPCs to adjust survey catches of giant grenadier and popeye grenadier by the Taisei Maru No. 35 were estimated as combinations of CPUEs for Pacific cod and walleye pollock. The estimator was:

$$FPC^{*} = \frac{\overline{CPUE}_{ST,cod} + \overline{CPUE}_{ST,pollock}}{\overline{CPUE}_{T,cod} + \overline{CPUE}_{T,pollock}} .$$

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AFSC-

49 STARK, J. W., and D. M. CLAUSEN. 1995. Data Report: 1990 Gulf of Alaska bottom trawl survey, 221 p. NTIS No. PB95-194825.

48 NARITA, R., M. GUTTORMSEN, J. GHARRETT, G. TROMBLE, and J. BERGER. 1994. Summary of observer sampling of domestic groundfish fisheries in the northeast Pacific Ocean and eastern Bering Sea, 1991, 540 p. NTIS No. PB95-190963

47 DORN, M. W., E. P. NUNNALLEE, C. D. WILSON, and M. E. WILKINS. 1994. Status of the coastal Pacific whiting resource in 1993, 101 p. NTIS No. PB95-176467.

46 SINCLAIR, E. H. (editor). 1994. Fur seal investigations, 1993, 93 p. NTIS No. PB95-178943.

45 SINCLAIR, E. H. (editor). 1994. Fur seal investigations, 1992, 190 p. NTIS No. PB95-173472.

44 KINOSHITA, R. K., and J. M. TERRY. 1994. Oregon, Washington, and Alaska exports of edible fishery products, 1993, 52 p. NTIS No. PB95-165924.

43 FERRERO, R. C., and L. W. FRITZ. 1994. Comparisons of walleye pollock, Theragra chalcogramma, harvest to Steller sea lion, Eumetopias jubatus, abundance in the Bering Sea and Gulf of Alaska, 25 p. NTIS No. PB95-155602.

42 ZIMMERMANN, M. , M. E. WILKINS, R. R. LAUTH, and K. L. WEINBERG. 1994. The 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition, 110 p. plus Appendices. NTIS No. PB95-154159.

41 ZIMMERMANN, M., P. GODDARD, T. M. SAMPLE. 1994. Resullts of the 1991 U.S.-U.S.S.R. cooperative bottom trawl survey of the eastern and western Bering Sea continental shelf, 178 p. NTIS No. PB95-111589.

40 SIGLER, M. F., and H. H. ZENGER, Jr. 1994. Relative abundance of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1989, 79 p. NTIS No. PB94-204963.

39 ZENGER, H. H., Jr., M. F. SIGLER, and E. R. VAROSI. 1994. Assessment of Gulf of Alaska sablefish and other groundfish species based on the 1988 National Marine Fisheries Service longline survey, 79 p. NTIS No. PB94-204872.

38 LOWRY, L. F., K. J. FROST, R. DAVIS, R. S. SUYDAM, and D. P. DEMASTER. Movements and behavior of satellite-tagged spotted seals (Phoca largha) in the Bering and Chukchi Seas, 71 p. NTIS No. PB94-180684.

37 BUCKLEY, T. W., and P. A. LIVINGSTON. 1994. A bioenergetics model of walleye pollock (Theragra chalcogramma) in the eastern Bering Sea: Structure and documentation, 55 p. NTIS No. PB94-181831.

36 YANG, M-S., and P. A. LIVINGSTON. 1994. Variations in mean stomach content weights of walleye pollock, Theragra chalcogramma, in the eastern Bering Sea, 32 p. NTIS No. PB94-178084.

35 PARKS, N. B., and F. R. SHAW. 1994. Relative abundance and size composition of sablefish (Anoplopoma fimbria) in the coastal waters of California and Southern Oregon, 1984-1991. NTIS number pending.