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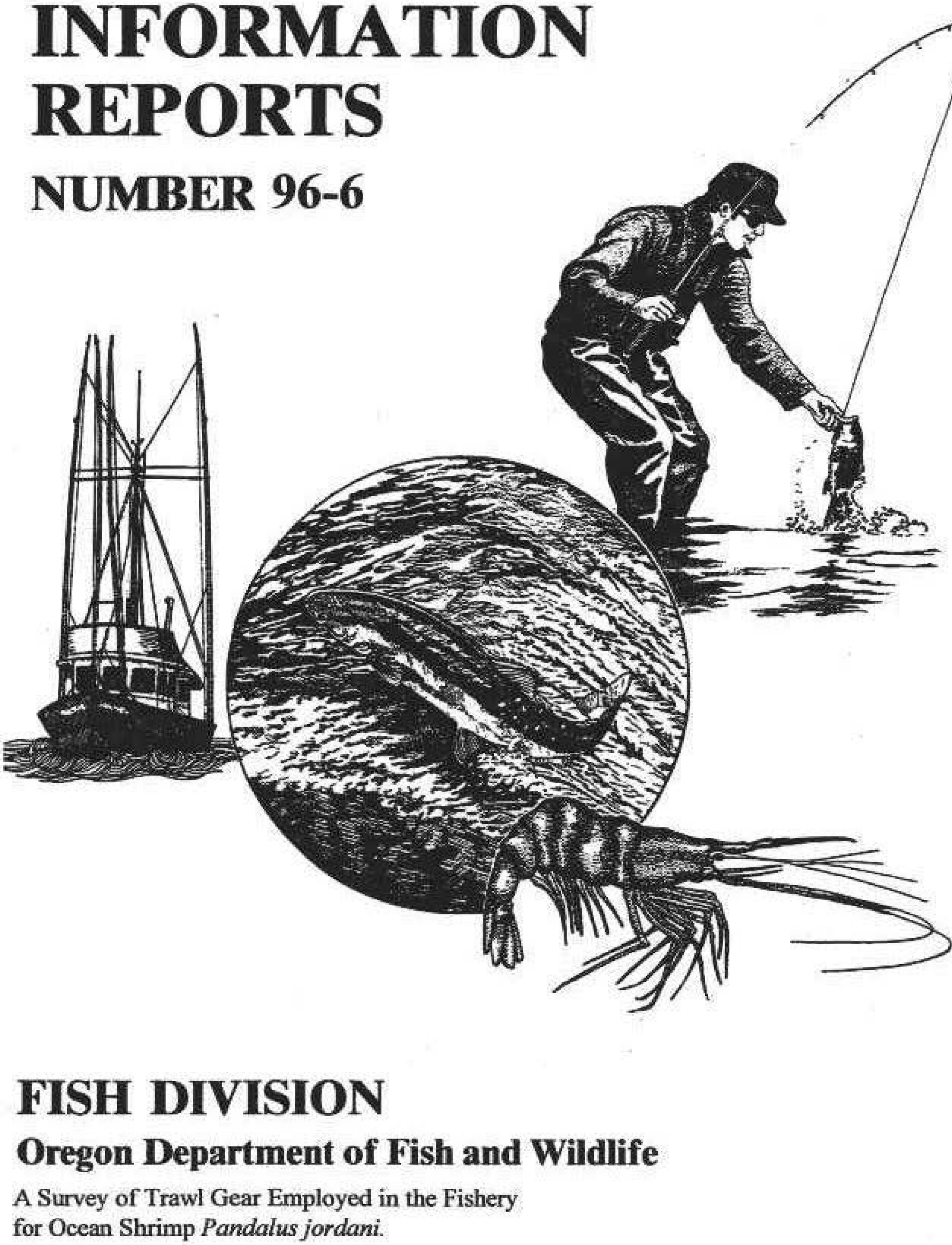

FISH DIVISION

Oregon Department of Fish and Wildlife

A Survey of Trawl Gear Employed in the Fishery
for Ocean Shrimp *Pandalus jordani*.

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INTRODUCTION

The northeast Pacific trawl fishery for ocean shrimp *Pandalus jordani* is managed using mutually consistent state regulations in Washington, Oregon and California, rather than a federal fisheries management plan and rules. The principal management regulation is an aggregate size limit (Hannah and Richmond 1993). This regulation requires landings of ocean shrimp to average 353 shrimp per kg (160 shrimp per lb). The regulation is intended to limit exploitation rates of age one shrimp and to help maintain the economic value of the catch (Pacific Fishery Management Council 1981). As of 1991, when the most recent portion of this study was begun, the states of Washington and California also required that shrimp trawls have a minimum codend mesh size of 34.9 mm (1-3/8 inches) stretch measure, between the knots. Oregon has had no minimum codend mesh size regulation since 1969 (Zirges and Robinson 1980). The other principal management regulation restricting trawl fishing for ocean shrimp is a coastwide closed season from November through March each year, designed to protect egg-bearing female shrimp from harvest (PFMC 1981).

Prior study of the fishing gear used in the ocean shrimp fishery has focused on determining an appropriate minimum codend mesh size to allow for escapement of age one shrimp (Lo 1978). The work was somewhat successful in showing how age one escapement varies with mesh size, at least under low volume catch conditions, and can be used to predict the effect that a change in mesh size might have on catch rates. However, to evaluate the impact that a coastwide minimum codend mesh size regulation might have on Oregon shrimp fishermen, it's also necessary to know something about the statistical distribution of codend mesh sizes presently in use by the fleet. Gathering this type of information for the Oregon shrimp fleet was one of the principal objectives of this study.

Zirges and Robinson (1980) and Hannah and Jones (1991) have reviewed the various changes in shrimp fishing gear which have taken place since the inception of this fishery. One of the major structural changes in shrimp fishing, which took place in the mid-1970's, was the switch from predominantly single-rigged vessels fishing two-seam trawls, to predominantly double-rigged vessels fishing four-seam, high-rise trawls. These gear changes have created problems in interpreting trends in catch and catch-per-unit-effort (CPUE) data for this fishery (Hannah and Jones 1991, Hannah 1993). It has been argued that the correction factor which was developed for converting double-rig effort into single-rig equivalent hours may substantially account for the gear improvements which took place (Hannah 1993). However, the near total lack of information on the fishing gear in use by particular vessels before, during and after the gear changes took place makes the testing of this assertion impossible. A second objective of this study was to generate information on the fishing gear presently in use by the ocean shrimp fleet so that trends in catch and CPUE data can be more accurately assessed in the future.

METHODS

Trawl Gear Survey

To describe the varied trawl gear in use in the ocean shrimp fishery during the early 1990's, we used a combination of direct measurements and interviews of vessel operators. We surveyed Oregon shrimp vessels three times; once over the years 1991-1992, and then again during fall 1993 and fall 1994. Vessels from north, central and south coast ports were all surveyed in order to evaluate regional differences. To keep the surveys brief and to gather a variety of information, the content of the surveys varied some between years. Some questions were included in more than one survey to measure short term changes. We combined our results with Oregon Department of Fish and Wildlife mesh size data collected during 1981 and with the summary information provided for the ocean shrimp fishery by Zirges and Robinson (1980).

The method used to select vessels for the surveys varied some between years. In 1981, 1991 and 1992, we contacted vessel operators opportunistically, surveying vessels as we encountered them at the docks. We standardized the selection method for the next two surveys by using a list of all vessels landing shrimp in Oregon during August of that year as our sample. We contacted as many owners or operators as possible from this list. The August vessel list was used because many vessels switch into the shrimp fishery for the beginning of the April-October season, but leave the fishery after a month or two. We were interested in the gear characteristics of the vessels that fish full-time so we purposely selected a month later in the season. We didn't choose the September or October period because some full-time vessels stop fishing during the last two months of the season.

We summarized mesh size data by coastal region and net section, in the recent surveys and in 1981. We used an I.C.E.S. (International Council for the Exploration of the Sea) mesh gauge in the 1990's because of its precision, providing a consistent stretch pressure of ten pounds for each measurement. We took mesh measurements from one net on each vessel. The most accessible net was selected on double-rigged vessels. Meshes were measured along the long axis of the net. We compared our findings on average mesh size to those collected during 1981 using t-tests. It is the only other comparable mesh size data of the ocean shrimp fleet. The 1981 survey included 36 vessels, divided similarly between regions. Metal wedge gauges were used, which measured in increments of 1/8 inch.

Shrimp trawl meshes were measured from the codend, intermediate and body sections when possible (Figure 1), however some nets did not have an identifiable intermediate section. Accordingly, only body and codend measurements were taken from these nets. We measured codend mesh following the general protocol used during 1981. This method consisted of measuring at least eight meshes within each longitudinal third of the codend. In 1991, we chose locations to measure at 20, 50

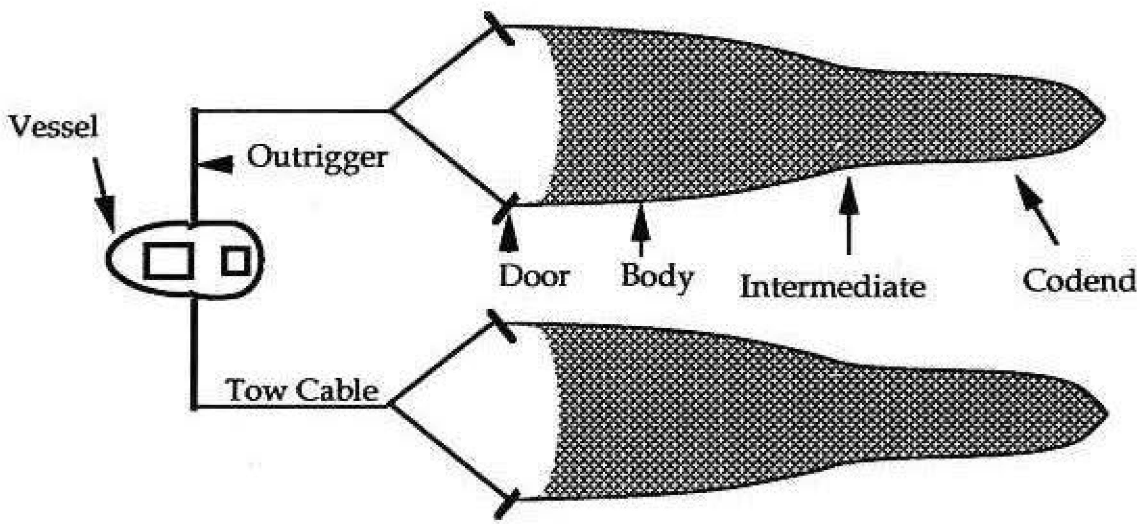

Figure 1. Schematic of a double-rigged shrimp vessel with net body, intermediate and codend sections indicated.

and 100 meshes forward of the terminal pursing rings, measuring ten meshes in each region. We averaged all measurements to determine a mean mesh size for the entire codend. For the intermediate section, we measured ten meshes at any accessible point at least several feet forward of the codend. For the body of the net, we also measured ten meshes approximately four feet behind the trawl headrope.

We evaluated other vessel and trawl gear characteristics by surveying vessel owners or operators. We gathered information on rigging type, vessel length, engine horsepower, electronics, trawl characteristics and dimensions, and other selected deck gear.

Fish Excluder Survey

Another aspect of shrimp fishing gear we evaluated in 1993 and 1994 was the use of fish excluder devices. A variety of soft-paneled excluders (Figure 2), were introduced into the west coast ocean shrimp fishery during the early 1990's. These devices consist of a mesh panel of large trawl web installed just forward of the codend, reclining at about a 45° angle. Working properly, shrimp pass through the panel while most fish are guided by the panel out an escape port at the top of the net (Figure 2). The devices are also designed to be quickly enabled or disabled (Hannah et al. 1996). Vessel operators were asked if they had ever used a fish excluder device. If yes, they were asked to estimate the percentage of time spent fishing with the device enabled in 1994. The nominal mesh size of the panel used was also noted.

RESULTS AND DISCUSSION

Trawl Mesh Size

We measured mesh size on 42 vessels during 1991 and 1992, and found that mean codend mesh size varied by coastal region (Table 1, Figure 3). Codend mesh size in the north and central regions was somewhat smaller than codend mesh in the south. A comparison with data collected in 1981 showed that mean codend mesh size from the southern region has not changed significantly since 1981 (Table 1, Table 2). However, for the northern and central ports, mean codend mesh size has decreased since 1981 (t-test, $P<0.06$). The central region showed the smallest mean codend mesh size and had changed the most since 1981.

The states of Washington and California had minimum mesh size regulations of 34.9mm until 1994, when Washington dropped its minimum requirement. Our mesh size data from both 1991-1992 and 1981 suggest that the codend mesh regulations have not been routinely enforced. Almost all of the nets we measured were well below the legal minimum (Figure 4, Figure 5), even though many of the

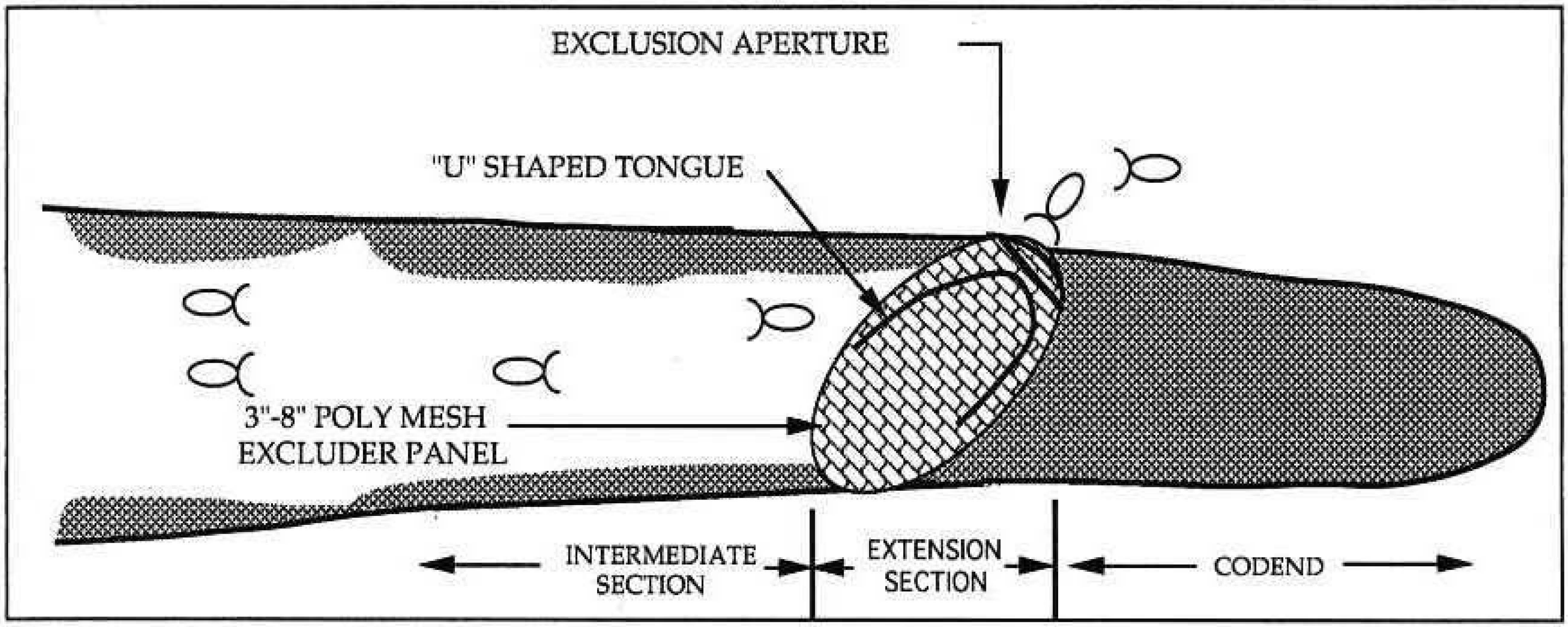

Figure 2. Diagram of an enabled soft mesh panel fish excluder installed in a ocean shrimp trawl. The device is mounted in an extension section, placed between the intermediate of the trawl and the codend. The device is disabled by unlacing the "U" shaped tongue and lacing the exclusion aperture closed.

Table 1. Mesh size statistics of Oregon ocean shrimp trawl vessels during 1991 and 1992, by section of the net and coastal region of the vessels home port.

Gear, coastal region	mean (mm)	standard error	range (mm)	n
codend				
north	27.7	1.331	23.0 - 31.2	14
central	27.2	1.900	26.2 - 30.6	16
south	31.7	3.450	27.1 - 38.4	12
intermediate				
north	35.8	2.030	31.2 - 37.8	14
central	34.8	1.970	32.5 - 37.7	16
south	32.4	2.510	29.9 - 35.9	4
body				
north	34.9	2.510	31.2 - 38.1	13
central	36.3	4.270	31.6 - 47.3	16
south	35.5	1.610	32.6 - 37.9	12

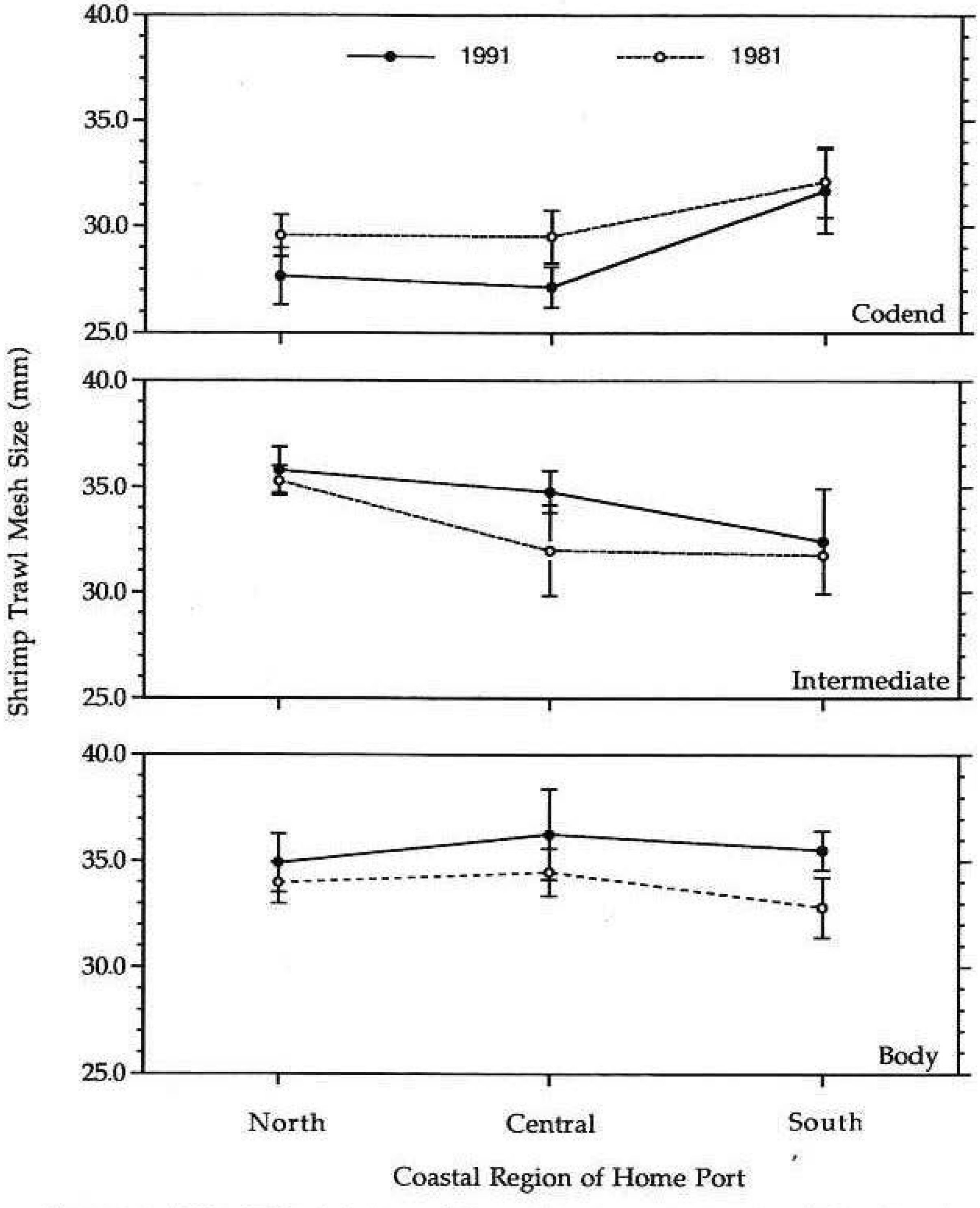

Figure 3. Mean codend, intermediate and body mesh size (mm) from trawls on Oregon ocean shrimp vessels by coastal region for 1991 and 1981. Error bars show the standard error of the mean.

Table 2. Mesh size statistics of Oregon ocean shrimp trawl vessels during 1981, by section of the net and coastal region of the vessels home port.

Gear, coastal region	mean (mm)	standard error	range (mm)	n
codend				
north	29.6	0.978	28.6 - 31.8	10
central	29.5	1.233	25.4 - 34.9	14
south	32.1	1.655	28.6 - 38.1	9
intermediate				
north	35.3	0.705	34.9 - 38.1	9
central	32.0	2.153	25.4 - 38.1	14
south	31.8	0.000	—	10
body				
north	34.0	0.970	31.8 - 34.9	10
central	34.5	1.125	31.8 - 38.1	14
south	32.8	1.427	31.8 - 38.1	12

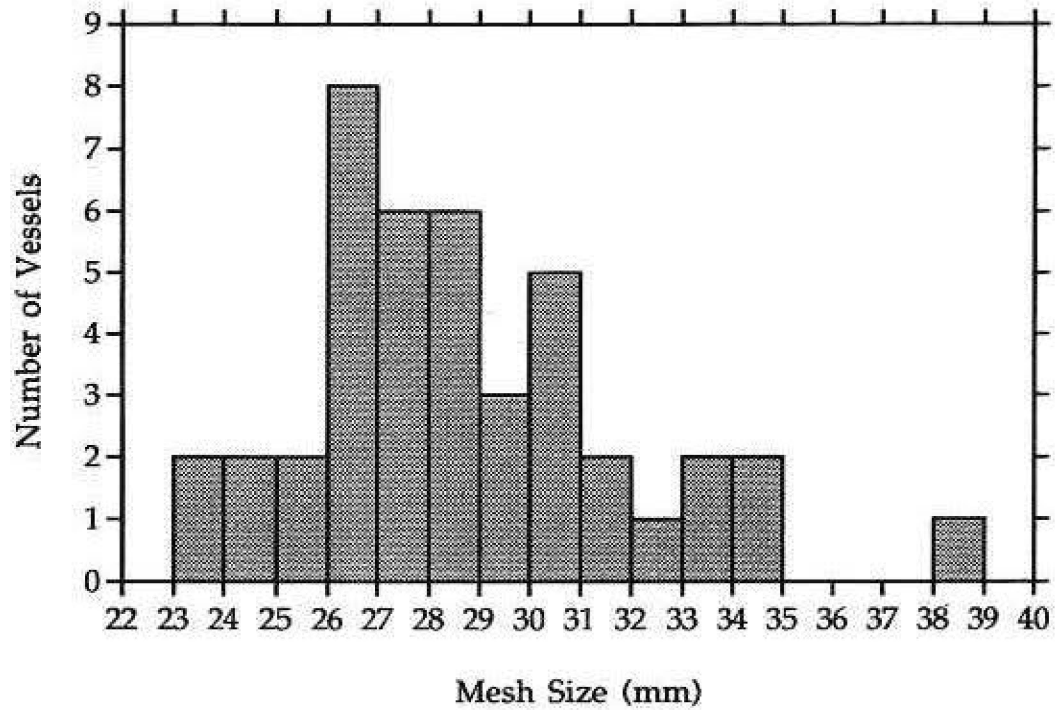

Figure 4. The frequency distribution of mean codend mesh sizes (mm) on Oregon shrimp vessels surveyed during 1991-1992.

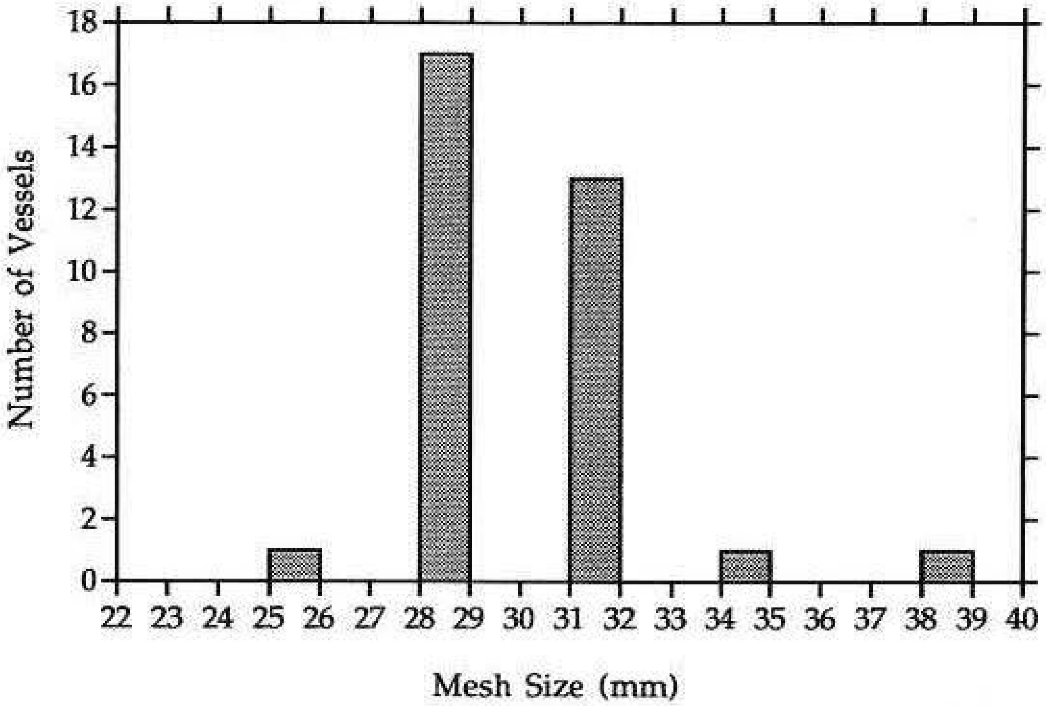

Figure 5. The frequency distribution of mean codend mesh sizes (mm) on Oregon shrimp vessels surveyed during 1981.

vessels we surveyed regularly fished off Washington and landed into Washington ports. In the absence of a functional mesh size regulation, central and north coast shrimpers have apparently chosen small mesh in order to increase retention of relatively small, but legal, shrimp which are common in the more northern fishing areas. Ocean shrimp are generally larger at age in the southern region (Hannah and Jones 1991). Accordingly, the incentive for vessels to use smaller mesh codends may be less in the south, possibly explaining the lack of change in mesh size in the southern region since 1981. In 1981, south coast shrimpers indicated that they preferred a mesh size that conformed with California's legal requirement to allow flexibility to fish in both states' waters.

In contrast to codend mesh, which has become smaller in some areas, average mesh size in the intermediate and body sections of shrimp trawls has increased in some areas since 1981 (Figure 3). For the intermediate sections this difference was statistically significant only in the central region (t-test, $p<0.03$). Mean mesh size in the body of the nets was larger in the southern region in 1991 than in 1981 (t-test, $p<0.01$). These differences may be due to the types of netting used by net shops in different regions, or to the styles of nets used by shrimpers. Using larger mesh in these sections also decreases water resistance (Fridman, A.L. 1973), potentially increasing fuel economy.

Vessel Type

We found that double-rig vessels far outnumbered single-riggers (Figure 6), comprising 88.6% of the vessels surveyed in 1993. The double-rig percentages are higher than the 64-79% range reported from 1985 through 1989 (Jones and Hannah 1992), which included all vessels landing during a particular year. This finding suggests that the full-time shrimp fleet includes a greater proportion of double-rig vessels than a simple listing of all vessels making landings in the fishery each year.

Vessel Length and Horsepower (HP)

Vessel total length data were summarized by double- and single-rig categories for 1991-1992 and 1993 (Table 3). In 1993, our largest length sample, single-rig vessels averaged 17.2 m and double-riggers averaged 20.9 m. The two gear types had significantly different total lengths (t-test, $p<.01$), with double-rig vessels averaging about 3.7m longer than single-rig vessels. Zirges and Robinson (1980) described a typical shrimp vessel in the mid-1960's as a single-rig vessel approximately 15-21m long. By 1978, the typical vessel was a double-rigger about 24 m long. In 1993, we found that a typical shrimp vessel was double-rigged, approximately 20.9 m long. The apparent decline in length indicated from 1978 to 1993 probably resulted from our efforts to document vessel lengths of the full-time fleet only. The August landing list which we used as a sample of the shrimp fleet did not include some large vessels which had fished for shrimp earlier in the season. Another possible

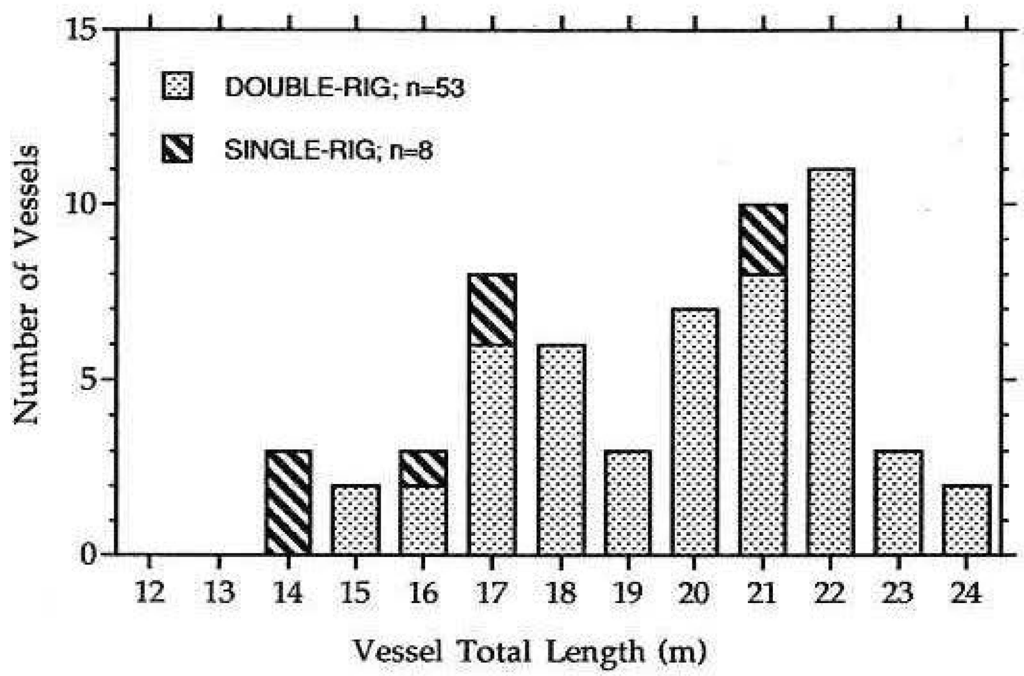

Figure 6. The number of single-rig and double-rig Oregon ocean shrimp vessels, by total length (m), surveyed during 1993.

Table 3. Statistical summaries of vessel length (m) and engine horsepower of Oregon ocean shrimp trawl vessels, from 1981 and 1991 to 1993.

	1981*		
	horsepower		
Vessel type	n	mean	st. dev.
single-rig	79	275.0	145.3
double-rig	159	343.2	92.0

	1991-1992					
	length (m)			horsepower		
	n	mean	st. dev.	n	mean	st. dev.
single-rig	5	17.1	2.6	4	277.5	68.5
double-rig	36	21.5	3.4	34	367.2	108.1

	1993					
	length (m)			horsepower		
	n	mean	st. dev.	n	mean	st. dev.
single-rig	8	17.2	3.0	7	264.3	80.2
double-rig	53	20.9	2.9	56	360.2	105.9

*HP compiled from ODFW vessel registration records for all vessels landing shrimp into Oregon ports during 1981.

explanation is that some of the larger vessels which had fished groundfish and shrimp in the late 1970's had become full-time groundfish vessels with the onset of the Pacific hake fishery in the early 1990's.

In 1993, mean single-rig HP was sharply lower than double-riggers (Table 3, t-test $p<0.03$), which averaged 264 HP and 360 HP respectively. For comparison, we compiled a list of declared HP ratings fom ODFW vessel registration records for all shrimp vessels landing shrimp into Oregon ports in 1981. The HP of single- and double-rig vessels was significantly different ($p<0.01$) during 1981, and appears to have remained stable for both gears through 1993.

Electronics

Zirges and Robinson (1980) stated that economic incentives in place around 1978 had led to investments in electronics technology, although no specifics were provided. LOng RAnge Navigation (LORAN) was readily available at that time and its capabilities were improving with the switch from LORAN A to LORAN C imminent. Chromoscopes (color depth sounders) and video plotters were becoming available but were considered costly. Not surprisingly, LORAN C systems were present on all of the 42 vessels surveyed in 1991-1992. Geographic Positioning Systems (GPS) were far less prevalent, present on only four (9.5%) of these vessels. GPS potentially allows skippers to more finely tune their tow paths, thus increasing their fishing efficiency over what LORAN can offer. LORAN systems have generally been less accurate but offered slightly better repeatability than GPS, especially nearshore (Anonymous 1994). The advent of Differential GPS (DGPS), scheduled to be operable soon, has the potential to outperform both LORAN and GPS for both accuracy and repeatability. The percentage of vessels with chromoscopes and plotters was 90.5% and 95.2% respectively.

Trawl Footropes

Zirges and Robinson (1980) reported that footrope length of double-rig shrimp vessels in their study ranged from 24.3-30.5m per side in 1978. The mean double-rig footrope lengths we observed in 1991-1992 and in 1993 fell in the lower end of this range (Table 4), suggesting that footrope lengths may have changed little since 1978. Mean footrope lengths of individual nets in 1991-1992 and 1993 were not significantly different on single- and double-rig vessels (t-tests; $p<0.15$ and $p<0.55$). Comparative information for single-rig shrimp vessels from the mid 1970's is unavailable.

Oregon shrimpers use a variety of footrope designs. Most vessels we surveyed used an arrangement of chain; primarily "tickler" or "ladder" chains. However, we found that about 16% of the vessels used some combination of "roller", "disc" and/or "bobbin" gear ("roller gear") in 1993. Most of these vessels were from

Table 4. Statistical summaries of footrope length (m) and door area (m^2) on Oregon ocean shrimp trawlers surveyed during the early 1990's.

Gear	Year, vessel specification, statistic					
	1991-1992					
	footrope length (m)			wood doors (m^2)		
	n	mean	st. dev.	n	mean	st. dev.
single-rig (total length)	5	28.2	2.823	2	2.5	0.424
double-rig (length/side)	36	25.2	4.100	36	5.4	1.447

	1993		
	footrope length (m)		
	n	mean	st. dev.
single-rig (total length)	8	25.4	4.429
double-rig (length/side)	59	24.5	3.741

southern ports. The use of roller gear had increased by 1994, to about 23%. Again, they were concentrated to the south, but the number of vessels using this gear had increased to the north (Table 5). Stated reasons for using this gear included increased shrimp catch, decreased bycatch and the ability to fish tougher ground. Several fishermen said that they were planning a switch from tickler gear to some version of roller gear. We found the configurations of this type of gear were highly variable among those who used it, indicating that much experimentation was occurring. The apparent increase in use we found from 1993 to 1994, also suggests that use of roller gear is increasing.

Doors

Most shrimp vessels fished wooden trawl doors in 1991-1992. Three of the 42 vessels evaluated (all single-rig) used steel "V" doors, but the remainder used rectangular wooden doors. Mean wooden door surface area was sharply lower for single-riggers than for double-riggers (Table 4).

Net Style

We inquired about net style on 42 vessels during 1991-1992, including nets on 37 double-riggers and 5 single-riggers. All of these vessels used high-rise four seam trawls, however the various styles encountered included most of the four seam trawls described by Watson et al. (1984).

The type of twine used in the different trawls and trawl sections was also quite variable. In each of the 42 nets evaluated, the body and intermediate were constructed of the same material; 47.6% of these sections were made of polypropylene, 47.6% of nylon and 2.0% of cotton. All of the nets with a nylon body and intermediate also had a nylon codend. Of those nets with polypropylene forward sections, 85% had nylon codends and the remainder were polypropylene. Only two vessels used cotton netting, and it was used in the entire net.

Deck Gear

Sixty-nine percent of the 42 vessels surveyed in 1991-1992 used "smelt belts" as part of their on-deck shrimp handling gear (Figure 7). The primary use of these belts on all of the vessels was to separate fish bycatch from shrimp. During years when small shrimp have been abundant, we have received complaints that some shrimpers were using these belts to separate small shrimp from the catch, thus improving the average count of the load. We have conducted some experiments with "smelt belts" that suggest some degree of sorting is possible (ODFW unpublished). Eleven of the operators questioned said that they had tried some method of sorting small shrimp from the catch in order to improve count. Ten of these eleven operators had used a

Table 5. Use of "roller gear" including rollers, bobbins or discs on the footropes of Oregon ocean shrimp trawl vessels, surveyed during 1993 and 1994.

Year, n, percent	Coastal region			
	south	central	north	total
1993				
n	9	1	1	70
% of total	12.9	1.4	1.4	
1994				
n	10	0	5	57
% of total	17.5	0.0	8.8	

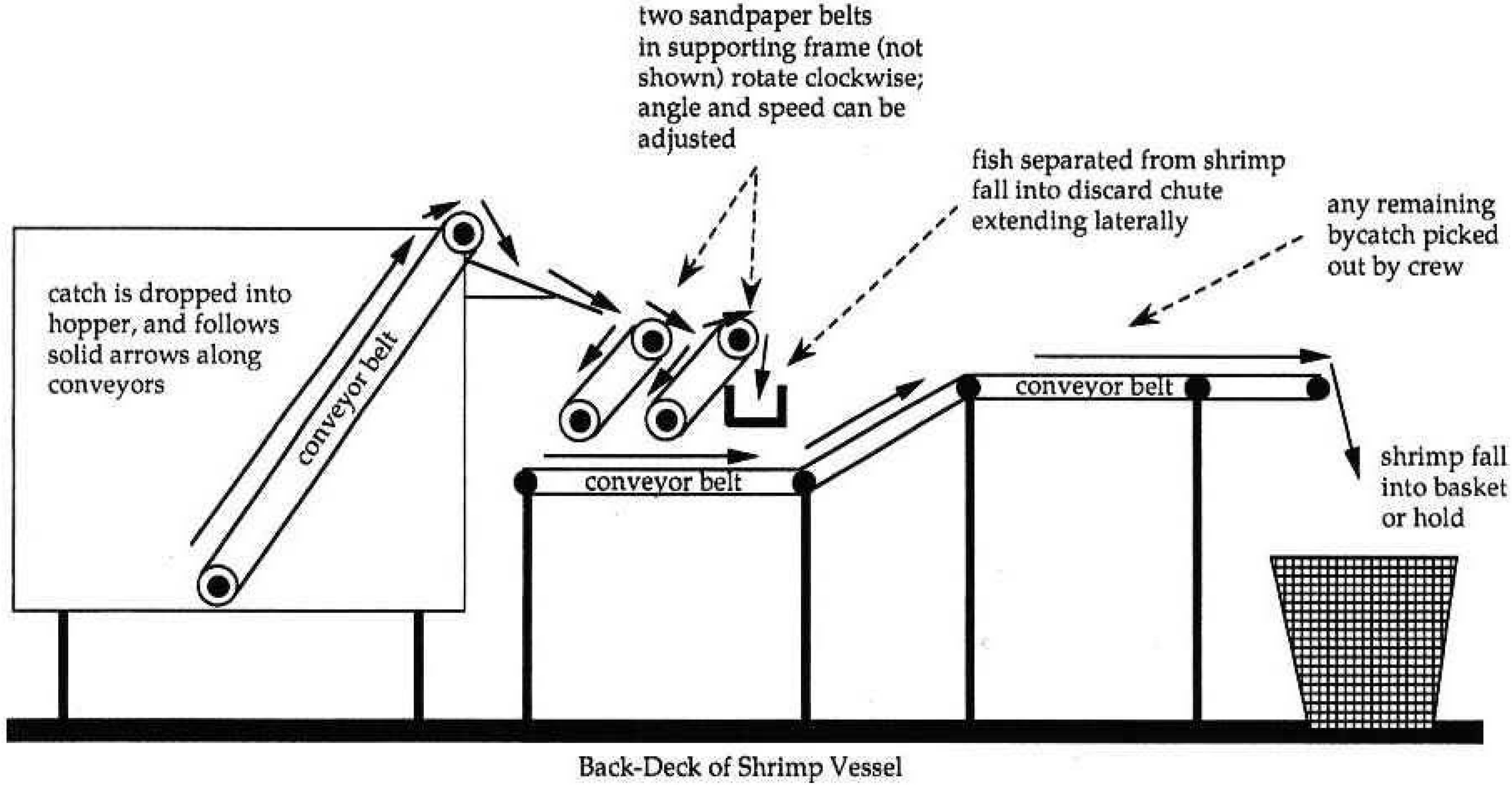

Figure 7. Diagram of back-deck shrimp handling equipment, including the "smelt belt" (rotating belts and discard chute). As the catch falls onto the first belt, smaller fish tend to stick to the belt while shrimp slide down onto the conveyor below. The process is repeated on the second belt, with anything sticking to the belt entering the discard chute. Small shrimp and molting shrimp tend to stick to the sandpaper belts more readily than larger shrimp, sometimes ending up in the discard chute.

"smelt-belt" as the means of sorting. One operator had sorted by hand on a sorting table. Opinions varied widely concerning the effectiveness of sorting shrimp with a "smelt-belt". Two operators described the process as highly effective. The others estimated improvements in count per pound of the load ranging from 0-15 shrimp per pound (0-33/kg).

During the mid 1980's, ODFW conducted a study testing a variety of scales to determine which scales were most appropriate for determining count per pound at-sea (Saelens and Hannah 1988). As a result of this work, a magnetically balanced triple-beam balance is the scale that ODFW recommends to shrimpers. The "Garibaldi scale" (a type of liberty balance) also performs reasonably well. In 1991-1992, 34 of the vessels surveyed had some type of scale on board for determining count at-sea. The remaining 8 vessels used the "can" method, a method which assumes that a known volume of shrimp (usually a coffee can full) weighs a known fraction of a pound. All shrimp from a full can are counted and the results are used to calculate the number of shrimp per pound. Of the 34 vessels with scales, 4.8% used a triple-beam balance, 42.9% used a "Garibaldi scale", and 52.4% used a variety of spring scales such as a postal scale.

Fish Excluders

Use of fish excluders was evaluated during 1993 and 1994 in order to track the voluntary use of these devices. In 1992, only one vessel was known to be using an excluder. About 7% of the vessels used some type of device in 1993 (Figure 8). Percent use in 1994 had grown to 33% of the vessels surveyed, however most fishermen still used the device only part time. Two thirds of the vessels which used an excluder actually used it less than 25% of the time (Figure 9). The mesh size used in the excluder panels varied from 5" to 8" in 1993. During 1994, excluder panel mesh size varied from 3" to 8", as fishermen continued to experiment with the device.

Summary

The data presented here suggest that the fishing gear used in the ocean shrimp trawl fishery is quite dynamic. While some characteristics of the fleet, such as average double-rigged vessel size, have changed little since the late 1970's, a number of gear characteristics have changed markedly and probably will continue to change. In some areas, codend mesh size has decreased. The data also suggest that minimum codend mesh regulations have not been routinely enforced in California and Washington. Almost all of the nets we measured were below the legal minimum size required by these states at the time of the surveys, even though many of the vessels surveyed commonly land shrimp in these states. Electronic equipment used by the shrimp fleet continued to improve and the use of more sophisticated electronics was noted. We found that the use of roller ground-gear and the use of

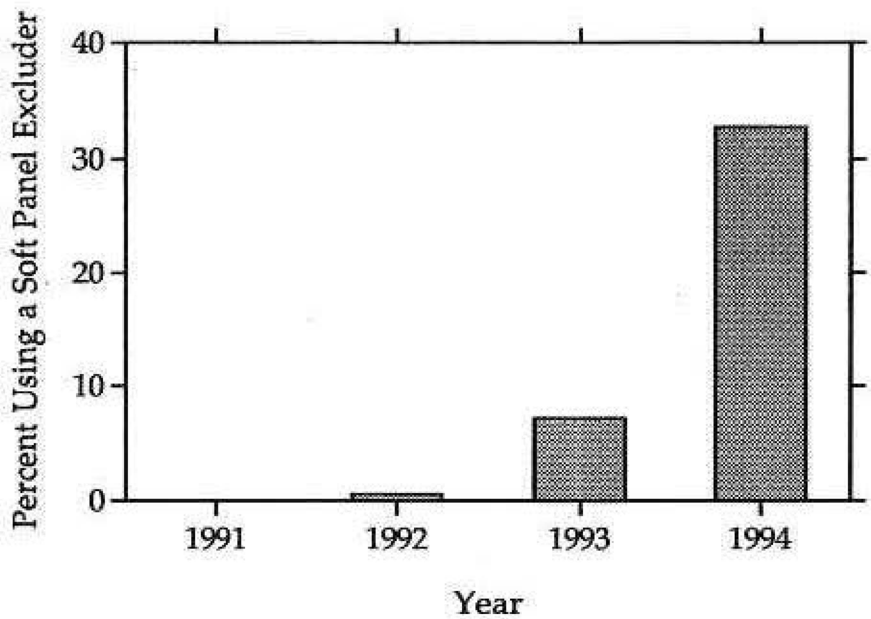

Figure 8. The estimated percentage of the Oregon ocean shrimp fleet that used soft panel excluders during at least some part of the 1991-1994 shrimp seasons.

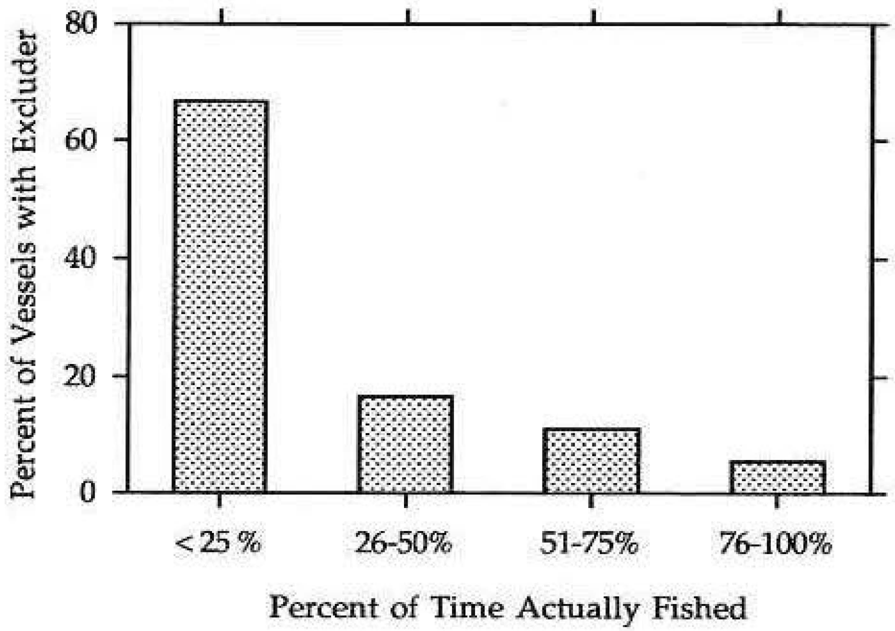

Figure 9. The estimated percentage of time that shrimpers using a soft panel excluder fished with the device enabled during 1994.

fish excluder devices were recent innovations. Future surveys will be needed to determine if these recent gear changes will become permanent components of the fishing gear used by the Oregon shrimp trawl fleet.

Acknowledgements

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