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ABUNDANCE OF BOTTOM FISH OFF ORANGE COUNTY

Variability is a perplexing aspect of monitoring programs, especially those concerned with fish. During the past few years. Project biologists have been attempting to determine the cause and scale of temporal and spatial variations in marine populations in hopes of understanding natural processes that affect common coastal organisms.

This year, we undertook an analysis of data on fishes captured during 8 years of trawl surveys on the coastal shelf off northern Orange County. The objective was to determine the magnitude of variations in the catches over the years and to ascertain whether or not catches have changed in accordance with changes in such basic oceanographic conditions as temperature, transparency, or currents. We hoped that such a study might lead to the development of better criteria for monitoring.

Data on over 113,000 fishes, sharks, and rays and on an equally large number of shrimp, crabs, echinoderms, and other invertebrates have been collected between 1969 and 1977 during the Orange County Sanitation Districts' quarterly trawl monitoring program. During this period, fish abundance in the survey area has varied about four-fold. A large part of this variation was a reflection of occasional (but not annual) major increases in the abundance of very young fish (a few months old). These and other periods of "recruitment" generally occurred during the onset of increasing turbidity and just following periods when water temperatures were the coolest of the year. An apparent decrease in the catches of some species after 1974 was partly a reflection of a change in the location and depth distribution of sampling stations in that year.

Some of these data were examined prior to this study. In 1976, we reported that the number of fish taken annually had varied 10-fold between 1969 and early 1976, that the number of species per survey had been remarkably stable, and that catch per year had gradually increased between 1972 and 1975 (Alien and Voglin 1976). Since that report, fish catches throughout the area have decreased considerably; at the same time, there has been a rather prolonged episode of clear, warm water in the area (July 1976 through February 1977).

The quarterly trawl program was initiated in August 1969 by Marine Biological Consultants, Inc. (MBC), of Costa Mesa under contract to the Orange County Sanitation Districts. Six stations were sampled that month. Beginning in November, a fixed grid of eight stations was sampled quarterly, with one haul per station, through May 1974. In 1974, the Santa Ana

Regional Water Quality Control Board ordered a change in location of several stations and deletion of the deepest. Since that time, quarterly trawling has continued at these seven fixed stations; an occasional trawl in deeper water has been made when ship time was available. All stations used over the 8-year period are shown in Figure 1.

Important changes taking place during the survey period included (1) a switch in vessels (FURY II to VAN TUNA) in August 1970, and (2) diversion of effluent (at the time, 130 million gallons per day (mgd)) from a 1-mile outfall at a depth of 18 meters to a 5-mile outfall at a depth of 58 meters in April 1971. Since November 1971, biologists from this Project have participated in all but one survey.

Marinovich otter trawls with a 7.6-meter (25-foot) head-rope length were used in all surveys. Detailed characteristics of this gear were reported by Mearns and Stubbs (1974). On most occasions, the net was towed with a pair of 14-meter (46-foot) bridles. Measurements at sea confirmed that the nets were opening 4.9 to 5.2 meters (16 to 17 feet) during towing.

Trawls were taken along isobaths and generally down swells. Boat speed during trawling was 7.4 km/hr (4.0 knots), somewhat faster than the recommended 4.6 km/hr (2.5 knots; Mearns and Alien 1976). Trawls were 10 minutes in duration measured from the time the cable was fully deployed to the time retrieval was initiated. In actual practice, this meant that the trawl was on the bottom some-what longer (up to 15 minutes). Scope ratios used on the Van Tuna were very high, ranging between 8 to 1 at 18 meters and 3.3 to 1 at 90 meters.

Upon retrieval of the net, all animals were sorted, and larger organisms were identified and counted. Beginning in 1969, fishes were examined for external diseases, and the range of sizes of individuals taken was recorded by species. From 1971 on, all fishes were measured to the nearest centimeter, standard length (SL), and beginning in 1975, fishes and invertebrates were weighed in lots by species.

MBC published quarterly and annual reports of the total catches through May 1974; from September 1974 on. Orange County Sanitation Districts personnel have prepared these reports. Data taken on fishes since 1969 have been coded, keypunched, and summarized in tabular form by computer by the Project. In this review of the data, I considered each survey as a unit of effort for examining long-term trends and each sample within a survey a unit of effort for examining variation within that survey.

Over 113,000 fishes, representing 112 species and 37 families of sharks, rays, and bony fishes, were collected in the 244 samples taken between August 1969 and May 1977. The total catch and frequency of occurrence of the species making up 95 percent of the catch from the 32 trawl surveys are given in Table 1. The four most abundant species were the speckled and Pacific sanddabs (*Citharichthys stigmaeus* and *C. sordidus*, respectfully), the yellowchin sculpin (*Icelinus quadriseriatus*), and the Dover sole (*Microstomus pacificus*). These fishes, as well as several others that were less abundant—the stripetail rockfish (*Sebastes saxicola*), bigmouth sole

(*Hippoglosina stomato*.), English sole (*Parophrys vetulus*), hornyhead turbot (*Pleuronichthys verticalis*), pink seaperch (*Zalembius rosaceus*), and California tonguefish (*Symphurus atricauda*)—-were present in the catch in all surveys. Carlisle (1969) also reported the capture of about 113,000 fish of 104 species from 705 bottom trawls taken over a 6-year period in Santa Monica Bay; comparison of the results of the two surveys indicates that, in general, the same species are most common and most abundant in both areas.

As indicated in Figure 2, average catch per unit effort varied considerably during the 8-year period. The largest annual catches were taken in 1971 and 1975; catches were low in 1970 and 1976-77. Overall, catches averaged 469 fish/haul (ranging from 224 to 793 fish/haul) and 15.9 species/haul (ranging from 8.6 to 20.8); Shannon-Weaver diversity indices for the catches averaged 1.62 (ranging from 1.06 to 1.91). The catch per survey ranged from 1,570 to 6,344 fish (average 3,560) and from 23 to 65 species (average 45.1).

I used the coefficient of variation (CV) to compare the magnitudes of variation of different catch variables. As shown in Table 2, Shannon-Weaver diversity, with a CV of 12.1 percent, was the least variable parameter, followed by number of species per haul (CV = 17.5 percent), and average total catch per haul (CV = 30.7 percent). These "between survey" variations were considerably lower than "within survey" variations caused by differences among individual samples: Coefficients of variation within surveys averaged 25.1 percent for diversity (the range was 7 to 45 percent), 26.3 percent for number of species per haul (range: 12 to 44 percent), and 62 percent for total catch per haul (range: 28 to 174 percent). Thus, as a unit of effort, the survey was considerably less variable than the single haul.

Large fluctuations in the catch of very young fish (<55 mm, SL) was one factor contributing to long-term variations in total catch. For many species, fish 5 cm or less in size are only a few months old, and fluctuations in their abundance in survey catches probably reflect their success in recruiting into and surviving in the survey area. The coefficient of variation for average survey catches of these small fish was high (73 percent; Table 2); occasionally, catches of these "young of the year" accounted for one-half of the total catch in a survey (the average catch per survey was 20 percent, and values ranged from 7.2 to 55.4 percent). Sixty-two percent of the 112 species taken in the 32 surveys were at one time or another represented in the catches by their young. However, as shown in the last column of Table 1, 26 common and abundant species were not equally represented by their young. Young of the speckled and Pacific sanddabs, yellow-chin sculpin, pink seaperch, stripetail rockfish and plainfin midshipman (*Porichthys notatus*) were present in 70 percent or more of the surveys. Common and abundant species such as white croaker (*Genyonemus lineatus*), calico rockfish (*Sebastes dalli*), English sole, northern anchovy (*Engraulis mordax*), and shiner perch (*Cymatogaster aggregata*) were only occasionally represented by their young (6.3 to 34 percent of the surveys), suggesting that the primary rearing or brooding areas for these species are outside this survey area (i.e., inshore or offshore or in nearby bays and estuaries). In other words, most of the catch of these species consisted of somewhat older migrants from other areas.

As summarized in Figure 3, young fish appeared in abundance in the survey area on only a few occasions during the 8-year period. Largest catches occurred during the spring and early summer of 1975 when over 4,500 young (50 percent of the total catch) of over 20 species were caught. The next largest periods of "recruitment" detected occurred in the early surveys in 1971, 1977, and 1973. In fact, even-numbered years surveyed (i.e., 1972, 1974, and 1976) produced rather poor catches of young fish.

There are several possible explanations for these apparent differences in recruitment each year. First, it is likely that recruitment of the young nearshore fish occurs over a relatively short period of time (within a period of a month or two) and that natural mortality is high during and following this period. Thus, surveys spaced at 3-month intervals may not always reveal the peak recruitment for the year; monthly trawls during the period when recruitment seems highest (February through July) could give better results. Second, year-to-year differences in oceanographic conditions (i.e., temperature, food availability, currents) may lead to increased or decreased success of fish reproduction and recruitment and survival of juveniles.

To explore this second hypothesis, I reviewed data on surface water transparency (Secchi disk readings) and surface and bottom water temperature collected during each trawl survey during the past 5 years (other routine measurements indicative of food and productivity—i.e., plankton volumes, nutrient measurements, chlorophyll—were either not made or not readily available for analysis). A brief examination of the data suggested that the largest catches occurred in cold water of low transparency. More detailed physical data was required to confirm this association, but none was available from the Orange County monitoring programs. I therefore used inshore and offshore temperature and Secchi disk data from 19 stations in Santa Monica Bay sampled weekly for nearly 20 years by the staff of the Hyperion Treatment Plant. Monthly mean sea surface temperatures and transparency readings for the period January 1969 through April 1977 were calculated and plotted (Figure 3). Regression analysis of transparency data collected during the same weeks by both Orange County Sanitation Districts and Hyperion revealed a moderately good correlation ($r = 0.51$, $0.1 < p < 0.05$); the correlation improved substantially ($r = 0.7$, $p < .01$) when Hyperion values were interpolated to obtain estimates of the transparency two days prior to each of the quarterly Orange County trawls. This indicated that the Hyperion records were representative of conditions in San Pedro Bay.

There are several trends in the physical data (Figure 3). During the past 8 years, there has been a trend of increasing temperature, with notably warmer winter temperatures occurring since 1972. In addition, only the years 1973 and 1975 had seasonal temperature trends that are somewhat similar; otherwise, every year appeared to have its own pattern of warming and cooling. The transparency data showed more marked variations. The period between early 1969 and early 1972 was marked by relatively turbid water and only occasional periods of clear water (Secchi disk depth readings averaged about 9 meters); the spring of 1971 was particularly turbid (6 meters visibility), but clearing increased gradually into the winter of 1971-72. After this time, there were three episodes of very turbid summer water (visibility 4 to 5 meters) followed by rapid autumn and winter clearing (visibility to 15 meters)—these occurred at approximately 2-year intervals (1972, 1974, and 1976). Each episode of very transparent water lasted approximately 6 months and was followed by a rapid decline in transparency (winter/spring 1973, 1975, and 1977). During four of the summers (1969, 1970, 1972, and 1974), warming was accompanied by increased turbidity; but during 1971, 1973, and 1976, summer warming was accompanied by clearing water.

Comparison of physical data and trawl data indicates that increasing catches of young fish were associated with episodes of cool or cooling water and decreasing clarity while low catches were generally associated with clear periods (see bars on Figure 3). One exception to this pattern was the turbid-water spring of 1976, which also followed one of the warmest winters of the survey period.

There are several possible explanations for higher catches of young fishes during or just following periods of turbidity. The fish may be better able to see and avoid the trawl gear in clear water than in turbid water. Alternatively, the turbid water may simply be an indicator of high plankton activity (which includes larval fish and their food), and thus may be marking those periods when young fish successfully arrive on the coastal shelf and when enough food exists to support their survival and growth during their first few months of life.

This work is an initial attempt to understand the causes of fluctuation in coastal fish and invertebrate populations. It also represents an example of the use of long-term biological monitoring data to increase under- standing of local ecology and to find ways to improve monitoring to answer important environmental questions. The present analysis indicates that this particular survey area is occasionally an important rearing area for many coastal fishes and that this process is to some extent controlled by occasionally favorable and unfavorable oceanographic conditions. It also suggests the kinds of measurements that are necessary to determine causes of change in coastal marine populations.

The results of this study, as well as additional analyses of these data, are being summarized for publication by the Project and in the scientific literature. I thank Greg Pamson, Michael Heinz (both of the County Sanitation Districts of Orange County) and Joe Nagano (Hyperion Treatment Plant) for their contribution and cooperation. Jim Allen, Jack Word, Bob Voglin, Brad Myers, and Michael Moore of the Project and Dr. Charles Greene (presently with the California Water Resources Control Board) contributed to the collection and analysis of these data.

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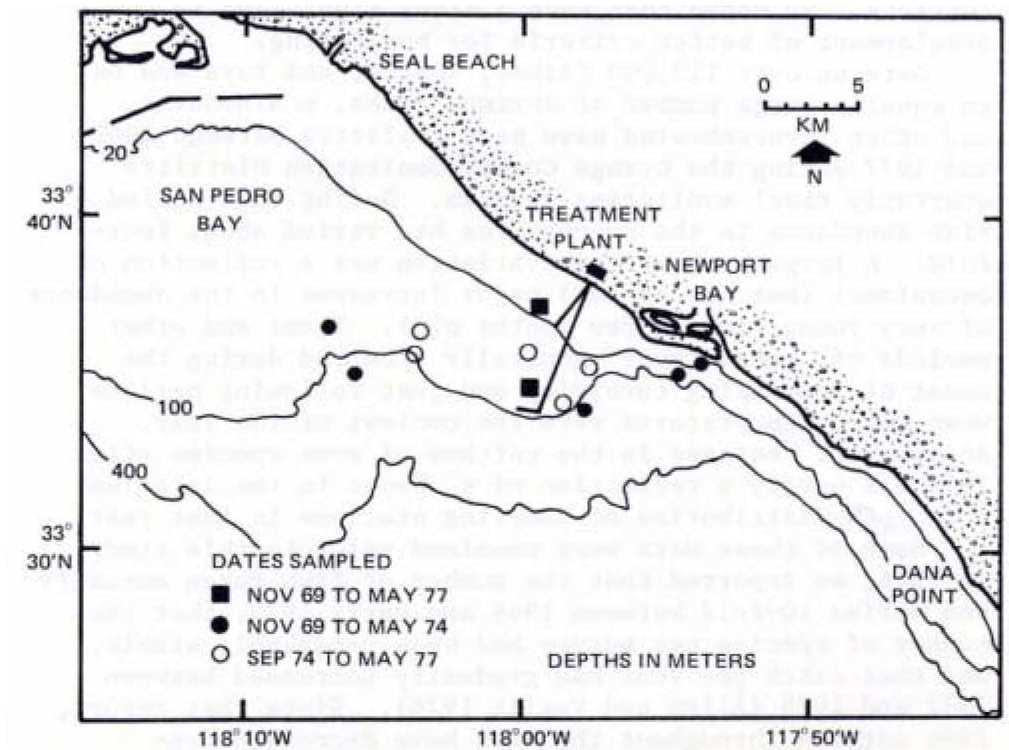

Figure 1. Trawl survey stations off Orange County outfall.

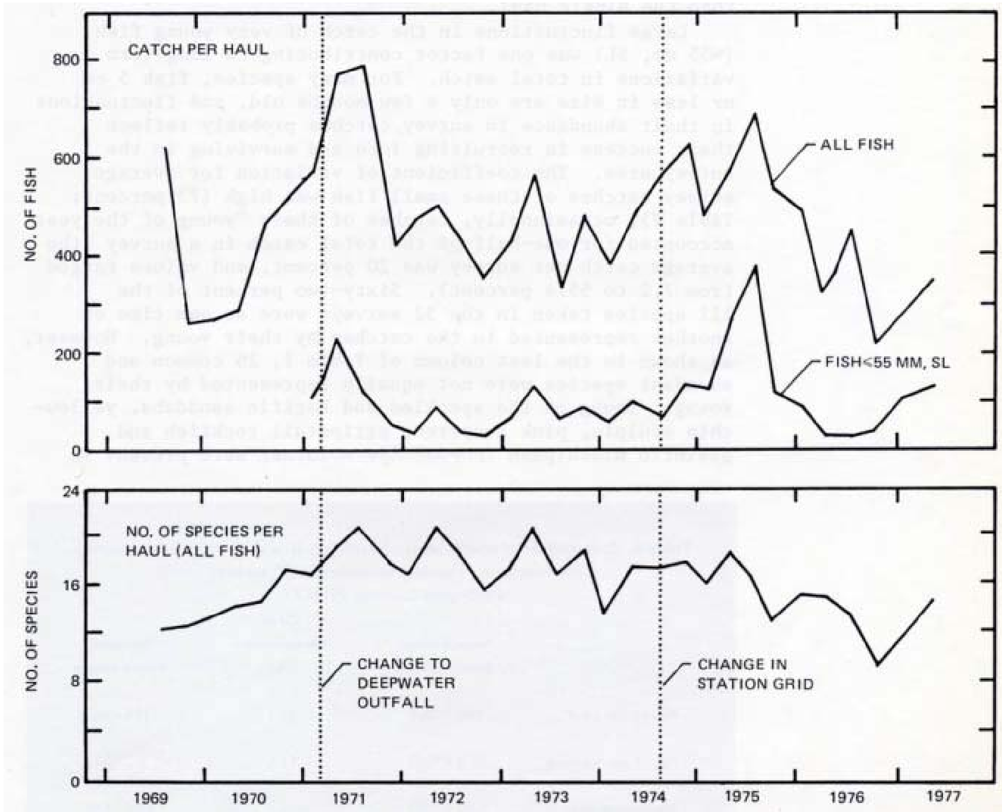

Figure 2. Mean catch and number of species per 10-minute haul for fish collected during 32 quarterly trawl surveys of Orange County, August 1969 through May 1977. Mean catch per haul of small fish showed major peaks in 1971 and 1975. Variety of fish caught was highest during the period 1971-74. Note that change in station grid included deletion of deeper stations.

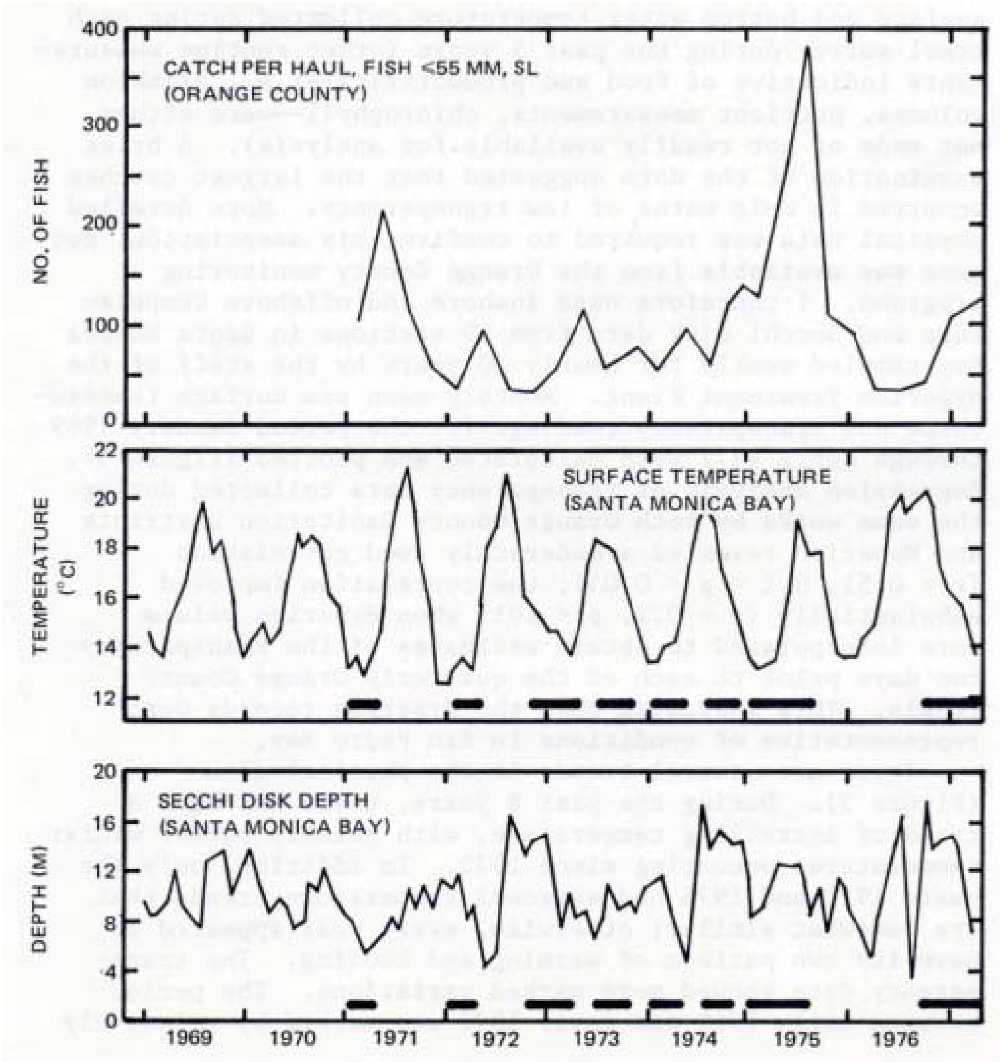

Figure 3. Average catch of small fish per trawl off Orange County, and monthly average sea surface temperatures and Secchi disk readings from 19 stations sampled weekly in Santa Monica Bay. Bars at bottom of lower graphs indicate episodes of increasing catches of young fish. Increases generally followed cooling and accompanied periods of decreasing or low transparency.

Table 1. Total catches and frequency of occurrence of 26 fish species that accounted for 95% of the catch in 32 quarterly trawl surveys off Orange County, 1969-1977. Frequency of occurrence of young fish (<55 mm, SL) is also given.

Common Name	Scientific Name	Number of Individuals	% of Total Catch	Frequency of Occurrence in Surveys (%) Adults and Young	Young Only
Speckled sanddab	*Citharichthys stigmaeus*	19,083	16.8	100	100
Pacific sanddab	*Citharichthys sordidus*	15,418	13.5	100	97
Yellowchin sculpin	*Icelinus quadriseriatus*	12,232	10.7	100	97
Dover sole	*Microstomus pacificus*	7,361	6.5*	100	63
Stripetail rockfish	*Sebastes saxicola*	6,852	6.0	81	72
White croaker	*Genyonemus lineatus*	6,090	5.3	97	34
California tonguefish	*Symphurus atricauda*	5,503	4.8	100	41
Plainfin midshipman	*Porichthys notatus*	4,354	3.8	97	69
Calico rockfish	*Sebastes dalli*	4,028	3.5	91	19
Halfbanded rockfish	*Sebastes semicinctus*	4,009	3.5	88	41
Pink seaperch	*Zalembius rosaceus*	3,322	2.9	100	78
Slender sole	*Lyopsetta exilis*	2,606	2.2	63*	50
English sole	*Parophrys vetulus*	2,086	1.8	100	13
Blackbelly eelpout	*Lycodopsis pacifica*	1,961	1.7	81	9.4
Rex sole	*Glyptocephalus zachirus*	1,605	1.4	63*	25
Northern anchovy	*Engraulis morday*	1,566	1.4	50	6.3
Roughback sculpin	*Chitonotus pugetensis*	1,562	1.4	81	44
Queenfish	*Seriphus politus*	1,545	1.4	69	9.4
Longspine combfish	*Zaniolepis latipinnis*	1,536	1.4	94	19
Splitnose rockfish	*Sebastes diploproa*	1,491	1.3	53*	41
Shiner perch	*Cymatogaster aggregata*	986	0.9	81	13
Hornyhead turbot	*Pleuronichthys verticalis*	846	0.7	100	13
Blacktip poacher	*Xeneretmus latifrons*	779	0.7	47*	13
Shortspine combfish	*Zaniolepis frenata*	632	0.6	81	6.3
Bigmouth sole	*Hippoglossina stomata*	491	0.4	100	19
White seaperch	*Phanerodon furcatus*	387	0.3	97	19
Subtotal		108,331	95.2		
Additional 86 species		5,517	4.8		
TOTAL		113,848	100.0		

*Deepwater species (abundance or frequency of occurrence affected by deletion of deepwater station in September 1974).

Table 2. Comparison of coefficients of variation (CV's) of mean values/survey for four catch variables measured in 32 surveys off Orange County, 1969-77.

	Mean/Survey ± Standard Error	CV of Mean/Survey (%)	Range of Survey Means
No. of fish/haul	469 ± 25.5	30.7	224–793
No. of species/haul	15.9 ± 0.49	17.5	8.6–20.8
Shannon-Weaver diversity/haul	1.62 ± 0.03	12.1	1.06–1.91
Catch of fish ≤55 mm, SL/haul	101 ±14.4	72.9	29–376