WILLIAMS, L. W.
1983. Larval fish assemblages of lower Mobile Bay. M.S. Thesis, Univ. South Alabama, Mobile, 55 p.

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UTILIZATION OF A WASHINGTON ESTUARY BY JUVENILE ENGLISH SOLE, *PAROPHRYS VETULUS*

The use of west coast estuaries and protected bays as nursery grounds by English sole, *Parophrys vetulus* Girard, a significant component of Pacific coast groundfish landings, has been well documented (Westerheim 1955; Kendall 1966; Smith and Nitsos 1969; Misitano 1970). From data collected off Oregon, Laroche and Holton (1979) showed that English sole also utilize nearshore areas along the open coast as nursery grounds. Krygier and Pearcy (1986) determined that estuarine dependence for juvenile English sole was indeed significant relative to the open coastal area off Oregon, although their survey design made it difficult to compare absolute abundance in these areas. In addition, the estuaries studied by Krygier and Pearcy were much smaller than the Washington estuaries of Grays Harbor and Willapa Bay, making it difficult to extrapolate their results.

In the present study our objectives were to 1) compare relative density and estimates of abundance of 0-age English sole between a Washington estuary, Grays Harbor, and the adjacent area along the open coast; 2) compare fish density between several subareas (strata) of each system; and 3) note timing of immigration to and emigration from the estuary. Specific gear was developed to efficiently sample small benthic organisms and was used in both the estuary and open coast survey areas, eliminating the need for gear selectivity intercalibration. In addition, the statistical design of the survey enabled population estimates with confidence intervals to be made for each area.

Methods and Materials

Survey Design

For this study, we specifically developed a plumb staff beam trawl with an effective width of 2.3 m. We designed it for a quantitative assessment of juvenile fishes and crustaceans closely associated with the bottom. Its fine mesh (4 mm) cod end liner retained newly settled flatfish (15–25 mm total length). A complete account of its construction, method of deployment, and field testing was given by Gunderson and Ellis (1986).

We selected two separate survey areas for the study, the Grays Harbor estuary and the adjacent nearshore area along the open coast. The estuarine survey was based on a stratified random statistical design and the open coast survey on a systematic trackline. Both areas were surveyed in 1983 and 1984.

The estuary was stratified into four geographic areas (Fig. 1). Each stratum was divided into 1 × 1 km grids (1 km intervals in the case of narrow channels), and several stations were then randomly selected with the constraint that no two be adjacent. Additional stations were added in both STR (stratum) 1 and 2 for the 1984 survey.

For the open coastal survey, three tracklines oriented perpendicular to the bathymetry were located off Copalis Head, Westport, and Willapa Bay (Cape Shoalwater) (Fig. 2). We established a systematic series of stations along each trackline at 9 m depth intervals from 9 to 64 m. Whenever wave conditions permitted, we sampled an additional station at 5.5 m. In 1984, the 64 m stations were dropped on each trackline because of consistent gear damage in 1983. Also in 1984, replicate tows were made at the 27 and 37 m stations.

Sampling Schedule

We sampled the estuary twice monthly from April through September 1983 and 1984, and a single trip was made in January 1984 for continuity. The two

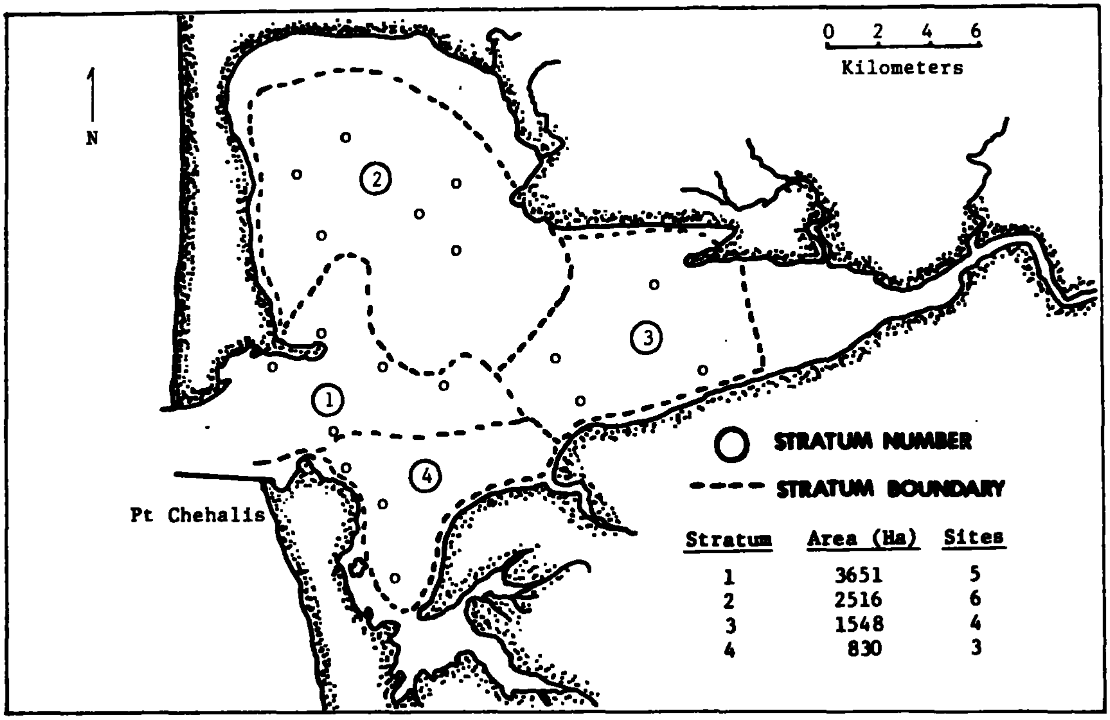

FIGURE 1.—Chart of Grays Harbor, WA, showing the four strata and random trawl sites selected from grid lines.

trips per month coincided with low tides when navigation and location of stations within the narrow channels characteristic of the North Bay and Inner Harbor would be easiest. Stations situated in the shallow, unmarked channels were sampled at low water, while stations in more navigable areas were sampled during the following periods of high water. All hauls were confined to slack tide periods so that strong tidal currents would not interfere with the operation of the beam trawl. We sampled the offshore study area once a month from April through September.

Field Techniques

Within the estuary, the plumb staff beam trawl was operated from a 6 m outboard boat, while offshore, either a 17 m or 20 m vessel was chartered. Mechanical or hydraulic winches allowed the retrieval of the beam trawl while underway, reducing escapement of captured organisms from the net.

At all stations, the beam trawl was hauled for a distance dependent on the amount of epibenthic material expected. Hauls of <10 minutes duration (200–300 m) were necessary within the estuary because the small mesh cod end liner would clog with mud and organic debris, making the net difficult to retrieve. Although the same problem existed in the open coast survey area, hydraulic lifting gear enabled hauls of up to 20–30 min duration (800–1,000 m) at most stations. We attempted to tow at 3 km/h with a scope of about 5:1; at depths <5 m, the scope was increased to 10:1.

Within the estuary, marker buoys were deployed where we estimated the trawl started and stopped fishing. The distance fished was determined by measuring between buoys with an optical rangefinder. Along the open coast, Loran C readings were recorded at points we estimated the trawl first contacted and left bottom and were later converted to distance fished.

We sorted most of the catch by species (some fishes to family only), and information was recorded for total weight and number per haul. Random subsampling of the catch (never <20% by weight) was performed when necessary to speed processing. Length frequencies and individual lengths and weights were recorded for selected species.

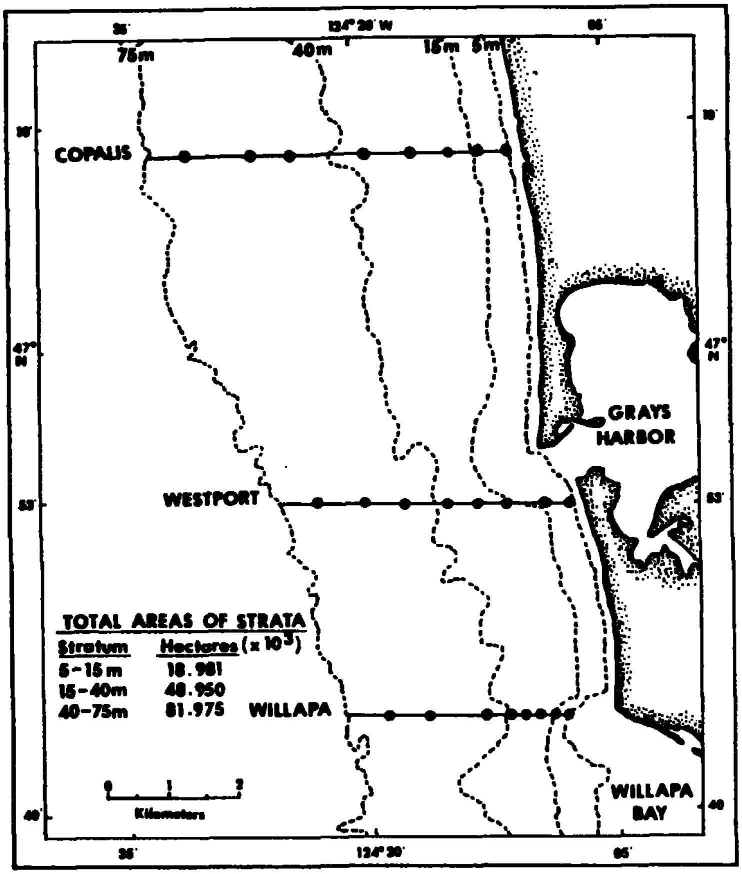

FIGURE 2.—Chart of the open coast adjacent to Grays Harbor, WA, showing the isobaths, tracklines, and systematic trawl stations.

Data Analyses

Nautical charts of Grays Harbor and the adjacent open coast were digitized and strata areas were calculated (Figs. 1, 2), using computerized algorithms available in the software library of the NWAFC Resource Assessment and Conservation Engineering Division. Strata were defined for the offshore area by first extending the north and south boundaries 5 nmi from the Copalis and Willapa transects, respectively, and then determining the area between the 5, 15, 40, and 75 m depth contours.

Estimates of mean density of young English sole by stratum by month, population by stratum, and total population for each survey area were calculated, using slight modifications of the methods of Pereyra et al. (1976). In calculating density estimates (number/hectare) from catch per kilometer, the efficiency coefficient of the gear was assumed to be unity (i.e., all fishes in the path would be captured). Length frequencies for 5 mm (TL) size intervals were used to calculate size composition. Age classes were then determined by visual inspection of the resultant length-frequency histograms. Afterwards, the proportion of individuals within the size range of the 0-age group in a particular month was multiplied by the total population for that month to provide an estimate of the abundance of 0-age recruits.

Results

Over the course of the 2-yr study, we completed a total of 592 trawls, 349 within Grays Harbor and 243 along the open coast (Table 1). Hauls within the

TABLE 1.—Allocation of sampling effort indicating the number of successful trawls completed for each trip.

Survey area	1983 Month	1983 Trips	1983 Trawls	1984 Month	1984 Trips	1984 Trawls
Estuary	Apr.	2	9,13	Jan.	1	13
	May	2	13,16	Apr.	1	5
	June	2	16,14	May	2	15,16
	July	2	16,16	June	2	18,18
	Aug.	2	14,16	July	2	18,17
	Sept.	1	16	Aug.	2	19,17
	Oct.	1	16	Sept.	1	18
Total			175			174
Open coast	May	1	17	Apr.	1	19
	July	1	20	May	1	23
	Aug.	1	25	June	1	26
	Sept.	1	48	Aug.	1	32
				Sept.	1	33
Total			110			133

estuary averaged 0.25 km at 2.52 km/h, while in the coastal study area they averaged 0.91 km at 3.32 km/h.

Distribution and Abundance

We captured a total of 13 species of flatfishes in the two study areas during the 2-yr survey (Table 2). Juvenile sanddab, sand sole, and English sole were found to be abundant both in Grays Harbor estuary and along the open coast. Two species in particular, English sole and starry flounder, were found to have much higher densities in the estuary than along the open coast (Table 2). English sole were found to be the most abundant flatfish in the estuary for both years and along the open coast in 1984.

For both years within Grays Harbor, densities of English sole generally were highest in STR 1, 2, and 4 and lowest densities in STR 3 (Table 3). Apart from changes due to recruitment, fluctuation in abundance in the four areas of the estuary was likely affected by movement of juveniles between strata and between the estuary and open coast. Along the open coast, greatest densities were observed nearshore (Table 4) in depths <40 m. In 1984, English sole were most abundant at 5–15 m owing to the presence of high numbers of 0-age fish.

Mean density (all months combined) within the estuary was over 20 times greater than the open coast in 1983. Settlement of fish <25 mm TL was much greater in 1984 than 1983 in both areas, but estuarine density was still higher than that of the open coast. A t-test was performed on log-transformed CPUE (Zar 1984) because catch data are typically nonnormally distributed. Results showed a significantly greater density ($P < 0.0001$) of juvenile English sole in the estuary than along the open coast for both 1983 (562 vs. 23 mean no./ha) and 1984 (1,149 vs. 178 mean no./ha).

Population Estimates

In making population estimates, mean densities of fish less than age V by month were multiplied by strata areas. Comparison of length frequencies of fish we collected with published age-at-length relationships (Van Cleve and El Sayed 1969) indicated that fish beyond age IV were rarely captured. Older fish may not have been present in the study areas

TABLE 2.—Stratified mean densities and 2 SE (in parentheses) for juvenile flatfish captured in the two survey areas for 1983–84.

Species	1983 densities (no./ha) Estuary	1983 densities (no./ha) Open coast	1984 densities (no./ha) Estuary	1984 densities (no./ha) Open coast
English sole, *Parophrys vetulus*	562(132)	23(10)	1,149(237)	178(101)
Pac. Sanddab, *Citharichthys sordidus*	147(30)	94(24)	94(33)	65(22)
Butter sole, *Isopesetta isolepsis*	<1	37(10)	<1	13(4)
Sand sole, *Psettichthys melanosticus*	27(11)	10(6)	36(14)	23(11)
Dover sole, *Microstomus pacificus*	—	11(5)	—	8(4)
Rex sole, *Glyptocephalus zachirus*	—	10(5)	—	2(2)
Slender sole, *Lyopsetta exilis*	—	2	—	1
Starry flounder, *Platichthys stellatus*	25(16)	<1	10(7)	1
Petrale sole, *Eopsetta jordani*	—	<1	—	<1
Rock sole, *Lepidopsetta bilineata*	—	<1	—	<1
C-O sole, *Pleuronichthys coenosus*	<1	<1	—	—
Curlfin sole, *Pleuronichthys coenosus*	<1	<1	—	<1
Cal. tonguefish,[1] *Symphurus atricauda*	<1	<1	—	—

[1]Occurrence considered anomolous (Dinnel and Rogers 1986).

TABLE 3.—Population estimates for juvenile English sole in the estuary survey area by date (month/year) and by stratum (1–4). The 95% confidence interval for the total population is obtained by adding or substracting the value in parentheses.

Date	Stratum	Density (no./ha)	Population (millions)	Date	Stratum	Density (no./ha)	Population (millions)
4/83	1	82	0.301	1/84	1	66	0.239
	2	127	0.318		2	100	0.251
	3	312	0.483		3	207	0.320
	4	383	0.318		4	158	0.131
	Total		1.421 (0.851)		Total		0.942 (0.472)
5/83	1	1,138	4.154	5/84	1	2,191	7.999
	2	297	0.747		2	4,858	12.223
	3	84	0.130		3	575	0.890
	4	1,825	1.515		4	2,045	1.697
	Total		6.545 (5.045)		Total		22.808 (8.686)
6/83	1	681	2.488	6/84	1	1,092	3.986
	2	961	2.417		2	1,049	2.639
	3	71	0.110		3	160	0.248
	4	801	0.665		4	835	0.693
	Total		5.679 (3.089)		Total		7.565 (4.195)
7/83	1	717	2.616	7/84	1	1,360	4.966
	2	775	1.950		2	2,470	6.214
	3	222	0.344		3	212	0.328
	4	740	0.614		4	1,087	0.902
	Total		5.524 (3.836)		Total		12.411 (5.569)
8/83	1	648	2.365	8/84	1	1,285	4.691
	2	662	1.666		2	939	2.362
	3	390	0.604		3	417	0.645
	4	468	0.388		4	402	0.333
	Total		5.023 (2.898)		Total		8.031 (3.557)
9/83	1	765	2.793	9/84	1	124	0.451
	2	291	0.733		2	558	1.403
	3	195	0.301		3	755	1.169
	4	524	0.435		4	262	0.217
	Total		4.262 (2.772)		Total		3.241 (1.745)
10/83	1	125	0.457				
	2	598	1.505				
	3	564	0.873				
	4	115	0.095				
	Total		2.931 (1.251)				

or, more likely, were better able to avoid the narrow beam trawl.

Within the estuary, English sole were most numerous in May of both years, but the peak of 22.8 million in 1984 was more than 3 times higher than the peak of 6.5 million in 1983 (Table 3). Although the distribution of the English sole population within the estuary was highly variable, the bulk of the population was in STR 1 or STR 2 for most months. Along the open coast, the English sole population peaked at the same time and at generally the same levels as the estuary for both years, about 5.9 and 23.2 million for 1983 and 1984, respectively (Table 4). Comparable populations of young fish occurred in both areas despite the 18 times greater geographic extent of the offshore survey area.

Recruitment

Relative recruitment to the two survey areas was measured in terms of populations of 0-age fish. Within the estuarine study area, recently transformed (<25 mm TL; Laroche et al. 1982) English sole were observed from April to July in 1983, and in January and from May to August in 1984. Peak abundance of this size range was observed in May of both years, but it is highly likely that early spring peaks were missed since our study lacked adequate coverage of fall, winter, and early spring months. Duration of settlement along the Oregon coast is known to be much longer than observed in our study (Laroche and Richardson 1979; Boehlert and Mundy 1987). Along the open coast, settlement seemed to

TABLE 4.—Population estimates for juvenile English sole in the open coast survey area by date (month/year) and by stratum (1–4). The 95% confidence interval for total population is obtained by adding or substracting the value in parentheses.

Date	Depth (m)	Density (no./ha)	Population (millions)	Date	Depth (m)	Density (no./ha)	Population (millions)
5/83	5–15	6	0.115	4/84	5–15	165	3.124
	15–40	100	4.881		15–40	47	2.318
	40–75	11	0.887		40–75	55	4.525
	Total		5.883 (4.666)		Total		9.967 (7.071)
7/83	5–15	2	0.044	5/84	5–15	190	3.598
	15–40	20	0.983		15–40	80	3.911
	40–75	8	0.680		40–75	191	15.667
	Total		1.707 (1.840)		Total		23.176 (19.225)
8/83	5–15	54	1.028	6/84	5–15	226	4.282
	15–40	35	1.709		15–40	48	2.356
	40–75	12	0.991		40–75	9	0.732
	Total		3.728 (2.390)		Total		7.370 (3.110)
9/83	5–15	12	0.230	8/84	5–15	903	17.133
	15–40	32	1.547		15–40	14	0.670
	40–75	3	0.269		40–75	21	1.724
	Total		2.045 (0.902)		Total		19.527 (18.981)
				9/84	5–15	97	1.836
					15–40	322	15.761
					40–75	5	0.402
					Total		18.000 (11.494)

be of shorter duration, though again, the survey lacked sampling effort from October through March. Recently transformed juveniles were captured only during May in 1983 and were found from April to September in 1984. Peak abundance was observed in May as in the estuary.

Populations of 0-age fish were determined using estimates of total juvenile population (Tables 3, 4) and size-frequency data (Table 5). These estimates show that English sole had higher recruitment to the estuary than to the open coast for early spring of both years. The estuarine population of young-of-the-year exceeded that of the open coast by over four times (6.4 vs. 1.5 million) in May 1983. The difference was less pronounced in May 1984, but the estuarine population was again higher (22.8 vs. 19.0 million). Later in summer in both years, the estuarine population of 0-age fish declined to a greater extent than that along the open coast, but some of the relative change is likely due to emigration from the estuary.

Densities were plotted by 5 mm length interval for the estuarine and open coast study areas for May each year, a period of high settlement (Fig. 3). Densities of juveniles <25 mm were more than 10 times greater in the estuary, indicating disporportionately higher direct settlement and/or higher mortality of newly settled juveniles in the open coast area. When

TABLE 5.—Length ranges (mm TL) of 0-age English sole determined from visual inspection of length-frequency distributions by study area and by date (month/year). Modal and mean lengths, and the proportion of total population comprised by the 0-age group are also indicated.

Study area	Date	Range (mm)	Mode (mm)	Mean (mm)	Proportion
Estuary	4/83	19– 84	65	57.6	0.85
	5/83	19– 99	30	50.5	0.97
	6/83	18–114	40	62.5	0.98
	7/83	26–119	55	73.8	0.99
	8/83	43–124	70	79.1	0.99
	9/83	49–145	80	87.0	1.00
	10/83	62–130	85	92.8	1.00
	1/84	25– 54	35	34.9	0.58
	5/84	15– 84	20	26.9	1.00
	6/84	20– 99	30	46.4	0.96
	7/84	25–114	85	66.9	0.99
	8/84	30–124	90	84.8	0.99
	9/84	50–135	90	92.0	1.00
Open coast	5/83	21– 60	35	33.3	0.25
	7/83	99–115	100	104.0	0.07
	8/83	43–165	120	115.4	0.80
	9/83	53–200	110	134.7	0.89
	4/84	15– 35	20	19.5	0.90
	5/84	15– 90	20	26.5	0.82
	6/84	15–120	30	48.6	0.87
	8/84	20–160	95	91.0	0.98
	9/84	20–180	130	119.0	0.89

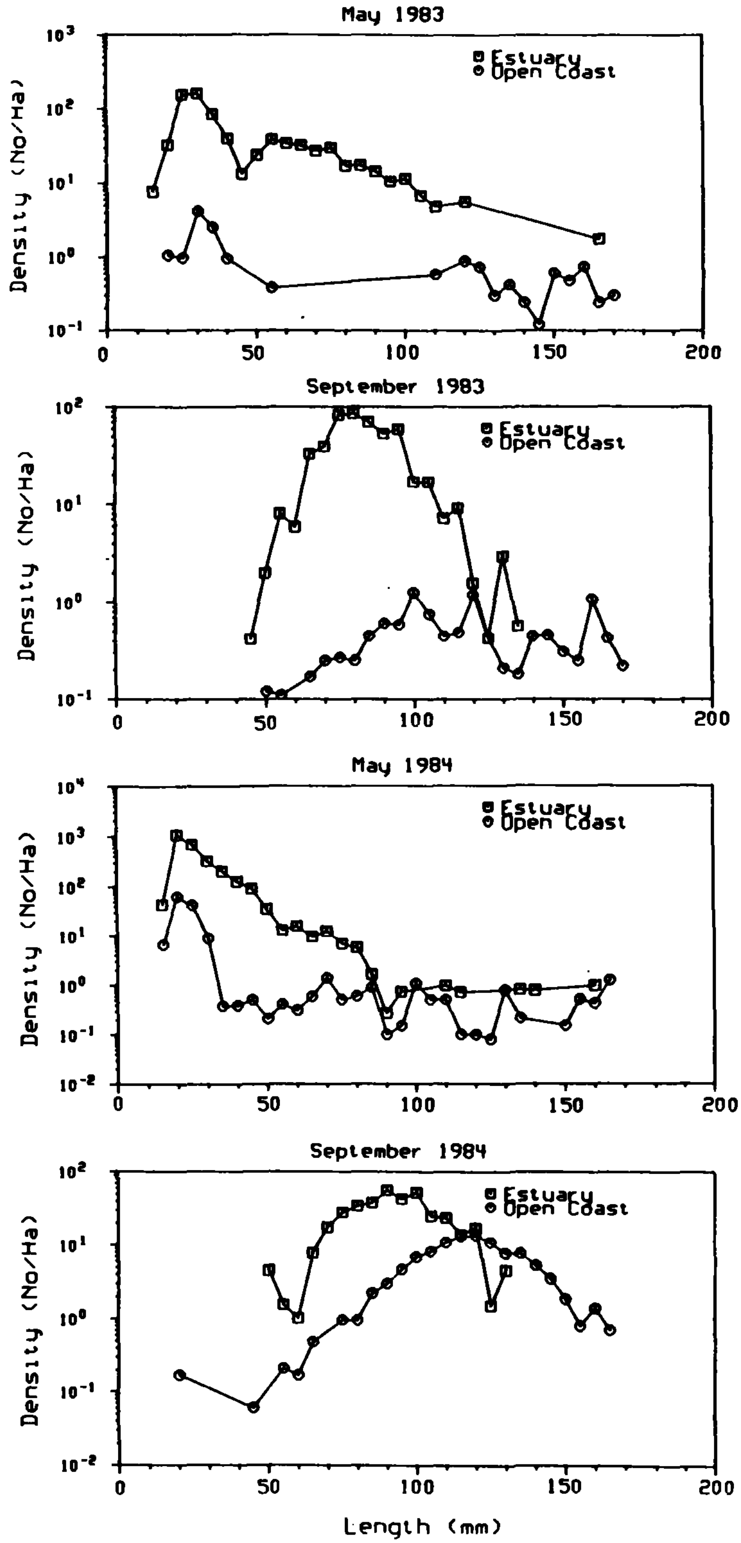

FIGURE 3.—Density of juvenile English sole by length interval for May and September of 1983 and 1984. Note the higher density of 0-age fish in the estuary each spring.

densities were plotted by length interval the following September of each year, it was evident that fish over 140 mm were not available in the estuary and had probably emigrated to the open coast.

Discussion

If there is an adaptive advantage in utilizing estuarine nursery grounds rather than the open coast, there must exist a mechanism for 0-age fish to enter estuarine systems. Although English sole larvae are abundant in coastal waters (Richardson and Pearcy 1977), early stages have not been prevalent in estuarine larval surveys (Pearcy and Meyers 1974; Misitano 1977). Large transforming larvae (18–23 mm) have been collected in Humboldt Bay and Columbia River estuary (Misitano 1976, 1977), and in Yaquina Bay (Boehlert and Mundy 1987). Immigration of 0-age English sole to the Grays Harbor estuary may be accomplished by direct settlement of transforming larvae after simple advection by ocean water into the bay, or by movements of newly settled benthic juveniles. Such movement could be accomplished either actively or by selective tidal transport as noted for juvenile flatfishes in the North Sea (DeVeen 1978).

During the period of this study, newly transformed English sole were found both within the Grays Harbor estuary and along the adjacent open coast. English sole have also been shown to enter Yaquina Bay after settlement (Boehlert and Mundy 1987) so it is likely that both transforming larvae and settled juvenile English sole may enter Grays Harbor. Krygier and Pearcy (1986) found newly transformed English sole to be more abundant in open coastal areas and presumed movement into Oregon estuaries to occur predominantly after transformation. The occurrence of recently transformed benthic juveniles in such high numbers throughout Grays Harbor suggests direct settlement of late stage larvae after advection into the estuary may also be an important mode of entry.

Emigration of the largest fish to the open coast took place during late summer, and all fish larger than 140 mm were found exclusively in the open coast area by September. Studies of other estuarine nursery areas have indicated that the emigration process involves the larger size classes of 0-age fish (Herke 1971; Weinstein 1983). Emigration from Yaquina Bay of the larger 0-age English sole has been noted in the fall (Westrheim 1955; Olsen and Pratt 1973; Bayer 1981). Angell et al. (1975) observed a similar phenomenon for young English sole in a Puget Sound nursery area.

The departure of larger juveniles later in summer may be in response to changing environmental conditions and may be indicative of the limits of the carrying capacity of estuaries being exceeded for populations of juvenile fish (Krygier and Pearcy 1986). Alternatively, a change in dietary preferences of larger 0-age fish may cause them to leave estuaries in search of prey items (Toole 1980), thus reducing intraspecific competition. The advantage in utilization of estuarine nurseries then, may be more for protection of vulnerable sizes rather than for accelerated growth (Rosenberg 1982).

Even though our study found a great deal of interannual variability, the Grays Harbor estuary and other nearby estuaries (Shi 1987) clearly are important nursery grounds for juvenile English sole, which had similar size populations in the estuarine and offshore study areas despite the greater geographic extent of the latter. Peak population estimates for 0-age English sole for the month of May show that 81% and 54% of 0-age fish in the Grays Harbor area were found in the estuary in 1983 and 1984, respectively. This is probably an underestimate of the degree of estuarine dependence, however, because some juveniles may move into the estuary later in the summer. Nevertheless, our results show that at least half of the 0-age English sole in the Grays Harbor nearshore area make use of an estuary during the first year of life. This kind of information will prove useful in assessing the economic impact on commercial fisheries from navigation and industrial development projects, which may contribute to habitat degradation in Grays Harbor.

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Literature Cited

ANGELL, C. S., B. S. MILLER, AND S. R. WELLINGS.
1975. Epizootiology of tumors in a population of juvenile English sole (*Parophrys vetulus*) from Puget Sound, Washington. J. Fish. Res. Board Can. 32:1723–1732.

BAYER, R. D.
1981. Shallow-water intertidal ichthyofauna of the Yaquina estuary, Oregon. Northwest Sci. 55:182–193.

BOEHLERT, G. W., AND B. C. MUNDY.
1987. Recruitment dynamics of metamorphosing English sole, *Parophrys vetulus*, to Yaquina Bay, Oregon. Estuarine Coastal Shelf Sci. 255:261–281.

DEVEEN, J. F.
1978. On selective tidal transport in the migration of North Sea plaice (*Pleuronectes platessa*) and other flatfish species. Neth. J. Sea. Res. 12(2):115–147.

DINNEL, P. A., AND C. W. ROGERS.
1986. Northern range extension for California tonguefish, *Symphurus atricauda*, to Washington State. Calif. Fish Game 72:119–221.

GUNDERSON, D. R., AND I. E. ELLIS.
1986. Development of a plumb staff beam trawl for sampling demersal fauna. Fish. Res. 4:35–41.

HERCKE, W. H.
1971. Use of natural and semi-impounded Louisiana tidal marshes as nurseries for fishes and crustaceans. Ph.D. Thesis, Louisiana State Univ., Baton Rouge, 264 p.

KENDALL, A. W., JR.
1966. Sampling juvenile fishes on some sandy beaches of Puget Sound, Washington. M.S. Thesis, Univ. Washington, Seattle, 77 p.

KRYGIER, E. E., AND W. G. PEARCY.
1986. The role of estuarine and offshore nursery areas for young English sole, *Parophrys vetulus* Girard, of Oregon. Fish. Bull., U.S. 84:119–132.

LAROCHE, J. L., AND S. L. RICHARDSON.
1979. Winter-spring abundance of larval English sole, *Parophrys vetulus*, between the Columbia River and Cape Blanco, Oregon during 1972–1975 with notes on occurrences of three other pleuronectids. Estuarine Coastal Mar. Sci. 8:455–476.

LAROCHE, J. L., S. L. RICHARDSON, AND A. ROSENBERG.
1982. Age and growth of a Pleuronectid, *Parophrys vetulus*, during the pelagic larval period in Oregon coastal waters. Fish. Bull., U.S. 80:93–104.

LAROCHE, W. A., AND R. L. HOLTON.
1979. Occurrence of 0-age English sole, *Parophrys vetulus*, along the Oregon coast: An open coast nursery area? Northwest Sci. 53:94–96.

MISITANO, D. A.
1970. Aspects of the early life history of English sole (*Parophrys vetulus*) in Humboldt Bay, California. M.S. Thesis, Humboldt State College, Arcata, CA, 57 p.
1976. Size and stage of development of larval English sole, *Parophrys vetulus*, at time of entry into Humboldt Bay. Calif. Fish Game 62:93–98.
1977. Species composition and relative abundance of larval and post-larval fishes in the Columbia River estuary, 1973. Fish. Bull., U.S. 75:218–222.

OLSEN, R. E., AND I. PRATT.
1973. Parasites as indicators of English sole (*Parophrys vetulus*) nursery grounds. Trans. Am. Fish. Soc. 102:405–411.

PEARCY, W. G., AND S. S. MEYERS.
1974. Larval fishes of Yaquina Bay, Oregon: a nursery ground for marine fishes? Fish. Bull., U.S. 72:201–213.

PEREYRA, W. T., J. E. REEVES, AND R. G. BAKKALA.
1976. Demersal fish and shellfish resources of the Eastern Bering Sea in the baseline year 1975. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NWAFC Proc. Rep., 619 p.

RICHARDSON, S. L., AND W. G. PEARCY.
1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fish. Bull., U.S. 75:125–145.

ROSENBERG, A. A.
1982. Growth of juvenile English sole, *Parophrys vetulus*, in estuarine and open coastal nursery grounds. Fish. Bull., U.S. 80:245–252.

SHI, Y.
1987. Population dynamics of juvenile English sole, *Parophrys vetulus*, in the estuarine and adjacent nearshore areas of Washington. M.S. Thesis, Univ. Washington, Seattle, 86 p.

SMITH, J. G., AND R. J. NITSOS.
1969. Age and growth studies of English sole, *Parophrys vetulus*, in Monterey Bay, California. Pac. Mar. Fish. Comm. Bull. 7:73–79.

TOOLE, C. L.
1980. Intertidal recruitment and feeding in relation to optimal utilization of nursery areas by juvenile English sole (*Parophrys vetulus*: Pleuronectidae). Environ. Biol. Fishes 5: 383–390.

VAN CLEVE, R., AND S. Z. EL-SAYED.
1969. Age, growth, and productivity of an English sole (*Parophrys vetulus*) population in Puget Sound, Washington. Pac. Mar. Fish. Comm. Bull. 7:51–71.

WEINSTEIN, M. P.
1983. Population dynamics of an estuarine-dependent fish, the spot (*Leiostomus xanthurus*), along a tidal creek-seagrass meadow coenocline. Can. J. Fish. Aquat. Sci. 40:1633–1638.

WESTRHEIM, S. J.
1955. Size composition, growth and seasonal abundance of juvenile English sole (*Parophrys vetulus*) in Yaquina Bay. Fish. Comm. Oreg. Res. Briefs 6:4–9.

ZAR, J. H.
1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ, 718 p.

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