# DISTRIBUTION AND DURATION OF PELAGIC LIFE OF LARVAE OF DOVER SOLE, *MICROSTOMUS PACIFICUS;* REX SOLE, *GLYPTOCEPHALUS ZACHIRUS;* AND PETRALE SOLE, *EOPSETTA JORDANI,* IN WATERS OFF OREGON

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## ABSTRACT

Dover and rex sole larvae attain an exceptionally large size and have a long pelagic life. Dover sole larvae (9-65 mm standard length) were collected in mid-water trawls and plankton nets during all months of the year. Judging from growth of larvae and occurrence in bottom trawls of recently metamorphosed juveniles, Dover sole are pelagic during their first year of life. Large larvae (50-65 mm standard length) are probably pelagic for over a year and few apparently are recruited to benthic populations. Dover sole larvae were most common in oceanic waters beyond the continental slope and in the upper 50 m of the water column.

The rex sole larvae captured were 5-89 mm long. Average size and stage of development of larvae increased from March through February, and juveniles were common on the bottom during winter on the outer shelf. Thus the pelagic phase usually lasts about a year. Both rex and Dover sole may utilize the outer continental shelf-upper slope region for a nursery during early benthic life.

Petrale sole larvae (10-22 mm standard length) were rare. They were collected only from March to June and appear to have a pelagic life of about 6 mo. Age-group 0 juveniles, uncommon in bottom trawl collections, were only captured on the inner continental shelf in the fall.

Dover sole, *Microstomus pacificus;* petrale sole, *Eopsetta jordani;* and rex sole, *Glyptocephalus zachirus,* are commercially important flatfishes of the northeastern Pacific. They ranked first, third, and fourth respectively in 1973 Oregon flatfish landings (Bruneau et al.[3]). Despite the abundance of Dover, rex, and petrale sole in bottom trawl catches, their larvae are not common in plankton or mid-water trawl collections (Table 1; Ahlstrom and Moser 1975).

Dover sole apparently spawn in specific sites in offshore waters deeper than 400 m (Hagerman 1952; Demory[4]). Rex sole, which do not appear to have specific spawning sites, spawn between the 100- and 300-m depth contours (Hosie[5]). Petrale sole are known to spawn in fairly well-defined locations in deep water (Ketchen and Forrester 1966; Alderdice and Forrester 1971). The rarity of Dover and rex sole larvae may be partially due to their reproductive strategy of producing relatively low numbers of large eggs (Table 2). Although development time to hatching is unknown, it is probably long for both Dover sole and rex sole. Petrale sole, on the other hand, produces smaller eggs in greater numbers; yet petrale larvae are perplexingly rare (Table 1). The incidence of larval capture of these three species certainly does not reflect their abundance as adults.

Larvae of two of these pleuronectids are unusual because they attain a large size. The genera *Microstomus* and *Glyptocephalus* both have giant larvae. Metamorphosis of *Microstomus kitt* and *M. pacificus* larvae takes place at lengths over 30 mm (Norman 1934; Hagerman 1952), and *M. pacificus* larvae 50 to 60 mm long have been collected (Table 1; Ahlstrom and Moser 1975). We are not aware of published reports on the size at metamorphosis of *Glyptocephalus zachirus* larvae although Ahlstrom and Moser (1975) stated that it is not unusual to collect larvae that are 50 to 60 mm SL. Metamorphosis in the congeneric *G. cynoglossus* and *G. stelleri* occurs at 40 to 60 mm in length (Pertseva-Ostroumova 1961; Okiyama 1963).

Because they attain a large size, Dover and rex sole larvae presumably have long pelagic lives. Hence they may be susceptible to dispersal and drift by currents for many months, a factor that

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[3]Bruneau, C., J. M. Meehan, and J. Robinson. 1974. Groundfish and shrimp investigations. Annu. Rep. 1973, Fish. Comm. Oreg., 25 p.
[4]Demory, R. L. 1975. The Dover sole. Oreg. Dep. Fish. Wildl. Inf. Rep. 75-4, 4 p.
[5]Hosie, M. J. 1976. The rex sole. Oreg. Dep. Fish. Wildl. Inf. Rep. 76-2, 5 p.

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TABLE 1.—Summary of captures of larvae of *Microstomus pacificus, Glyptocephalus zachirus,* and *Eopsetta jordani* from mid-water trawls and plankton tows in the northeast Pacific.

| Study | Location | Time | No. hauls | No. hauls with | | | | No. larvae taken | No. Pleuronectid larvae | No. *Microstomus* larvae | No. *Glyptocephalus* larvae | No. *Eopsetta* larvae |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Pleuronectids | *Microstomus* | *Glyptocephalus* | *Eopsetta* | | | | | |
| Aron[1] | Calif. to Alaska | July-Sept. 1957 June-Oct. 1958 | 564 | 67 | 24 | 10 | 0 | 7,400 | 232 | 66 (14-64 mm) | 12 (15-77mm) | 0 |
| Porter (1964) | Northern Calif. | Jan. 1959-Jan. 1964 | 59 | 21 | 0 | 4 | 2 | [2]192 | 154 | 0 | 10 (25-62 mm TL) | 2 (21-22 mm TL) |
| LeBrasseur[3] | NE Pacific | 1956-59 | >3,000 | 70 | 30 | 9 | 0 | 1,287 | 98 | 35 | 13 | 0 |
| Waldron (1972) | Oreg. to B.C. | Apr.-May 1967 | 88 | 19 | 4 | 4 | 0 | 4,577 | 626 | 4 | 10 | 0 |
| Naplin et al.[4] | Wash. to B.C. | Oct.-Nov. 1971 | 30 | 3 | 1 | 1 | 0 | 343 | 14 | 1 | 1 | 0 |
| Richardson (1973) | Oreg. | May-Oct. 1969 | 354 | 52 | 9 | 18 | 4 | 55,049 | 123 | 10 (12-61 mm SL) | 31 (22-89 mm SL) | 4 (13-21 mm SL) |
| This study | | | | | | | | | | | | |
| Bongo transect | Oreg. | Jan. 1971-Aug. 1972 | 287 | | 32 | 41 | 1 | 23,578 | | 75 (5-26 mm SL) | 107 (4-67 mm SL) | 1 (20 mm SL) |
| Bongo grid | Oreg. | Mar.-Apr. 1972, 1973 Mar. 1974, 1975 | 306 | | 36 | 75 | 1 | 34,029 | | 51 (4-21 mm SL) | 181 (5-24 mm SL) | 1 (18 mm SL) |
| Mid-water trawls | Oreg. | 1961-74 | ≈2,200 | | 313 | 199 | 25 | | | 568 (9-65 mm SL) | 360 (11-89 mm SL) | 44 (10-22 mm SL) |

[1]Aron, W. 1960. The distribution of animals in the eastern North Pacific and its relationship to physical and chemical conditions. Dep. Oceanogr. Univ. Wash. Tech. Rep. 63, 65 p.
[2]Flatfishes only.
[3]LeBrasseur, R. 1970. Larval fish species collected in zooplankton samples from the northeastern Pacific Ocean 1956-1959. Fish. Res. Board Can. Tech. Rep. 175, 47 p.
[4]Naplin, N. A., J. R. Dunn, and K. Niggol. 1973. Fish eggs, larvae, and juveniles collected from the northeast Pacific Ocean, October-November 1971. NOAA-NMFS, Northwest Fish. Cent. MARMAP Surv. I Rep. 10, 39 p. + 121 tables.

TABLE 2.—Egg diameter and fecundity of Dover, rex, and petrale sole.[1]

| Species | Egg diameter | No. eggs/female |
|---|---|---|
| Dover sole | 2.04-2.57 mm | 51,900 at 42.5 cm<br>265,800 at 57.5 cm |
| Rex sole | 1.98-2.34 mm | 34,191 at 36 cm<br>238,144 at 59 cm |
| Petrale sole | 1.21-1.25 mm | 400,000 at 42 cm<br>1,200,000 at 57 cm |

[1]Data from Hagerman 1952; Harry 1959; Alderdice and Forrester 1971; Hart 1973; Hosie 1975; Ahlstrom and Moser 1975; J. R. Dunn and N. A. Naplin pers. commun.

may affect survival and subsequent year-class strengths of these species which are known to be variable (Demory and Hosie[6]).

## COLLECTIONS

We examined the catches of 593 bongo net tows and over 2,200 Isaacs-Kidd Midwater Trawls taken off Oregon to provide information on the distribution, dispersal, and length of larval life of these three species. The bongo nets had 70-cm mouth diameters with 0.571-mm mesh nets. Tows were made obliquely through the water column from the bottom or 150 m to the surface at a speed of 2-3 knots. Two data sets were examined. One set consisted of 287 samples collected on an east-west transect off Newport, Oreg., at stations 2, 6, 9, 18, 28, 37, 46, 56, 65, 74, 93, and 111 km from the coast (Figure 1). Samples were taken every month from January 1971 to August 1972 except January and February 1972. The other set consisted of 306 samples collected along 12 transects between the Columbia River and Cape Blanco, Oreg., with stations located 2, 9, 18, 28, 37, 46, and 56 km from the coast. Samples were taken in March and April 1972 and 1973, and March 1974 and 1975. Not all stations were sampled on each cruise.

Isaacs-Kidd Midwater Trawl collections were made with trawls having a mouth width of 1.8, 2.4, and 3.1 m, a 5-mm (bar measure) mesh, and a 0.5-m diameter cod end of 0.571-mm mesh at stations 28, 46, 84, and 120 km offshore (Figure 1). Stations from 158 to 306 km offshore (at 37-km intervals) were sampled less frequently. Tows were mainly taken along four transect lines perpendicular to the coast (Figure 1) during

[6]Demory, R. L., and M. J. Hosie. 1975. Resource surveys on the continental shelf of Oregon. Fish Comm. Oreg., Annu. Rep. July 1, 1974 to June 30, 1975, 9 p.

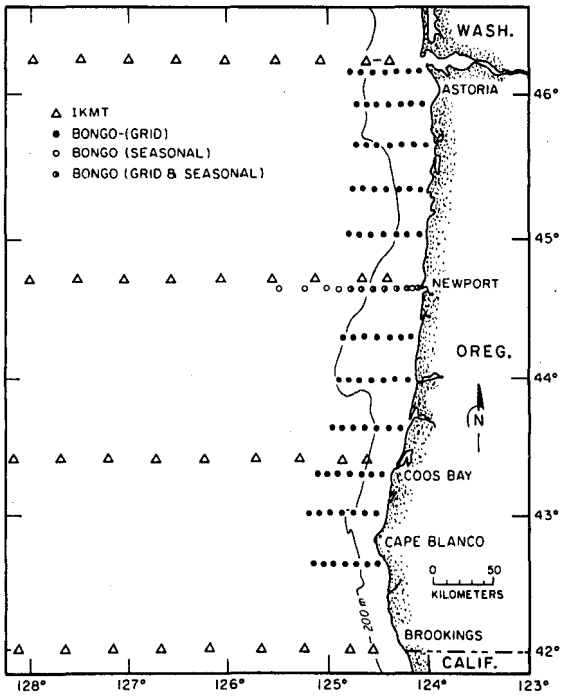


FIGURE 1.—Location of sampling stations off Oregon.

1961-69. These tows were generally oblique from 200 m (depth permitting) to the surface at a speed of 5-6 knots. A series of opening-closing mid-water trawl collections (Pearcy et al. in press) was also made 100-150 km off Newport within the upper 1,000 m during 1971-74. Considering all the collections, all seasons were sampled about equally.

Benthic fishes were sampled with a 3-m beam trawl (with 13-mm stretch mesh) on nine cruises during all seasons over the continental shelf off central Oregon (115 collections) and with a 5-m otter trawl on monthly cruises from January 1971 to August 1973, 7 to 11 km off Newport.

## LARVAL STAGES

Standard length (SL) of larvae was measured to the nearest millimeter. Larvae were assigned to an arbitrary developmental stage depending primarily on position of the left eye:

Stage I: Larvae symmetrical. Left eye has not yet begun to migrate.

Stage II: From time left eye has begun to migrate to time it is on middorsal ridge of head. The eye is considered to be on the middorsal ridge when a line extended forward from the dorsal fin transects any part of the eyeball for Dover and petrale sole, or when such a line transects the middle of the eyeball and the eyeball itself is directed upward for rex sole.

Stage III: Left eye is on middorsal ridge as defined under Stage II. For Dover sole, this stage was divided into two parts on the basis of pigment pattern, which appeared to correlate reasonably well with eye migration.

Stage IIIa: Five or six dorsal and four or five ventral horizontally elongated streaks of pigment along the central body musculature.

Stage IIIb: Dorsal and ventral pigmentation streaks along the central body musculature joined to form continuous lines.

Stage IV: Left eye fully on the right side of head, so that a line extended forward from the dorsal fin does not transect any part of the eyeball.

In Dover sole, the left eye begins to migrate as notochord flexion begins, and the caudal fin is completely formed by the time the eye reaches the middorsal ridge.[7] In rex sole, however, the caudal fin forms completely while the eyes remain symmetrical. Limited evidence suggests petrale may be like Dover sole in this respect.

## GROWTH AND DEVELOPMENT

The number and length of larvae assigned to developmental stages (Table 3) shows that each stage often included a wide range of sizes. Most of the Dover sole captured were stage I in bongo nets, and metamorphosing stage IIIa larvae in mid-water trawls. Only a few larvae 30-40 mm SL were captured, resulting in a bimodal size-frequency distribution. This may be a sampling artifact due to the unavailability of intermediate-sized larvae to our sampling methods, or it may be caused by rapid growth between stages IIIa and IIIb. A

[7] We found one abnormal Dover sole larva, a 43-mm SL tailless fish collected 125 miles off Newport, Oreg., in February 1964. This lack of caudal fin condition has also been reported for post-metamorphosed Dover sole (Demory 1972a).

TABLE 3.—The number and lengths of *Microstomus pacificus*, *Glyptocephalus zachirus*, and *Eopsetta jordani* larvae in assigned developmental stages, I to IV. Numbers in parentheses denote catches in bongo nets, excluding grid tows; numbers without parentheses are mid-water trawl catches.

| Standard length | *M. pacificus* | | | | | *G. zachirus* | | | | *E. jordani* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mm) | I | II | IIIa | IIIb | IV | I | II | III | IV | I | II | III | IV |
| 4-5 | (7) | | | | | (5) | | | | | | | |
| 6-7 | (38) | | | | | (28) | | | | | | | |
| 8-9 | (10) | 2 | | | | (41) | | | | | | | |
| 10-11 | (4) | 13 (2) | 6 | | | 1 (5) | | | | 1 | 1 | | |
| 12-13 | | 10 (6) | 20 | | | 1 (2) | | | | 1 | 3 | | |
| 14-15 | | 8 (4) | 55 (1) | | | (2) | | | | 1 | 1 | | |
| 16-17 | | 2 (1) | 90 | | | (4) | | | | | 1 | 12 | |
| 18-19 | | 1 | 72 | | | 3 (1) | | | | | | 12 | |
| 20-21 | | | 79 (1) | | | 4 (1) | | | | | | 8 (1) | 1 |
| 22-23 | | | 45 | | | 3 | | | | | | 2 | |
| 24-25 | | | 25 | | | 5 (2) | | | | | | | |
| 26-27 | | | 16 (1) | | | 3 (2) | | | | | | | |
| 28-29 | | | 11 | | | 3 | | | | | | | |
| 30-31 | | | 7 | | | 8 (2) | | | | | | | |
| 32-33 | | | 1 | | | 8 (1) | | | | | | | |
| 34-35 | | | | 2 | | 7 (1) | 1 | | | | | | |
| 36-37 | | | 3 | | | 9 | | | | | | | |
| 38-39 | | | 1 | 3 | | 13 (1) | | | | | | | |
| 40-41 | | | | 3 | | 14 (1) | 4 | | | | | | |
| 42-43 | | | | 2 | 2 | 8 (1) | 6 | | | | | | |
| 44-45 | | | | 4 | | 7 (3) | 3 (1) | | | | | | |
| 46-47 | | | | 4 | 4 | 6 | 4 | | | | | | |
| 48-49 | | | | 2 | 6 | 4 (1) | 5 | 1 | 1 | | | | |
| 50-51 | | | | 5 | 11 | 6 | 10 | | 3 | | | | |
| 52-53 | | | | 6 | 12 | 7 | 9 | | 5 | | | | |
| 54-55 | | | | 5 | 5 | 3 | 3 (1) | 2 | 5 | | | | |
| 56-57 | | | | 5 | 5 | 1 | 5 | 1 | 3 | | | | |
| 58-59 | | | | | 3 | 3 | 10 | 1 | 3 | | | | |
| 60-61 | | | | 6 | 4 | 2 | 7 | 2 | | | | | |
| 62-63 | | | | 1 | | | 8 | 1 | | | | | |
| 64-65 | | | | | 1 | | 9 | 1 | | | | | |
| 66-67 | | | | | | | 1 (1) | | | | | | |
| 68-69 | | | | | | 2 | 1 | 1 | | | | | |
| 70-71 | | | | | | | 4 | | | | | | |
| 72-73 | | | | | | | 2 | 1 | | | | | |
| 74-75 | | | | | | | | 1 | | | | | |
| 89 | | | | | | | 1 | | | | | | |
| Totals | (59) | 36(13) | 431(13) | 48 | 53 | 131(104) | 93(3) | 12 | 20 | 3 | 6 | 34(1) | 1 |

progression of increasing size with later developmental stages is apparent from stages I through IIIa, but little growth in length is evident between stage IIIb and IV. Larvae over 40-50 mm SL included both partially metamorphosed individuals with the left eye on the dorsal ridge and little pigmentation on the right side, and fully transformed individuals with heavy pigmentation on the eyed side. The largest larva was a partially metamorphosed individual of 65 mm.

Most rex sole larvae were classified as premetamorphosed stage I. This stage included a surprising length range, from 4 to 69 mm. Most of the growth in length apparently occurs during stage I before the left eye begins to migrate. The median length of stage IV larvae was actually shorter than that of stage II or III, suggesting reduction in length during metamorphosis. The largest larva was 89 mm (see Richardson 1973), apparently a record for any species of *Glyptocephalus*.

Petrale larvae occupied a small length range compared with Dover and rex sole larvae. Most of the larvae were stage III. Larvae smaller than 10 mm were never taken.

## SEASONALITY, GROWTH, AND LENGTH OF LARVAL LIFE

The relative abundance of the stages of Dover sole larvae collected during different months in bongo nets and mid-water trawls is illustrated in Figure 2. Stage I larvae were the predominant stage in the bongo net catches from March to July; stage II larvae were most common during the summer (bongos) and fall (mid-water trawls), suggesting a progression of larval stages from spring to fall. The continuation of this trend is not apparent from the catches of stage IIIa larvae, the most abundant developmental stage during all months in mid-water trawl catches. Stage IV were most common during fall and winter months.

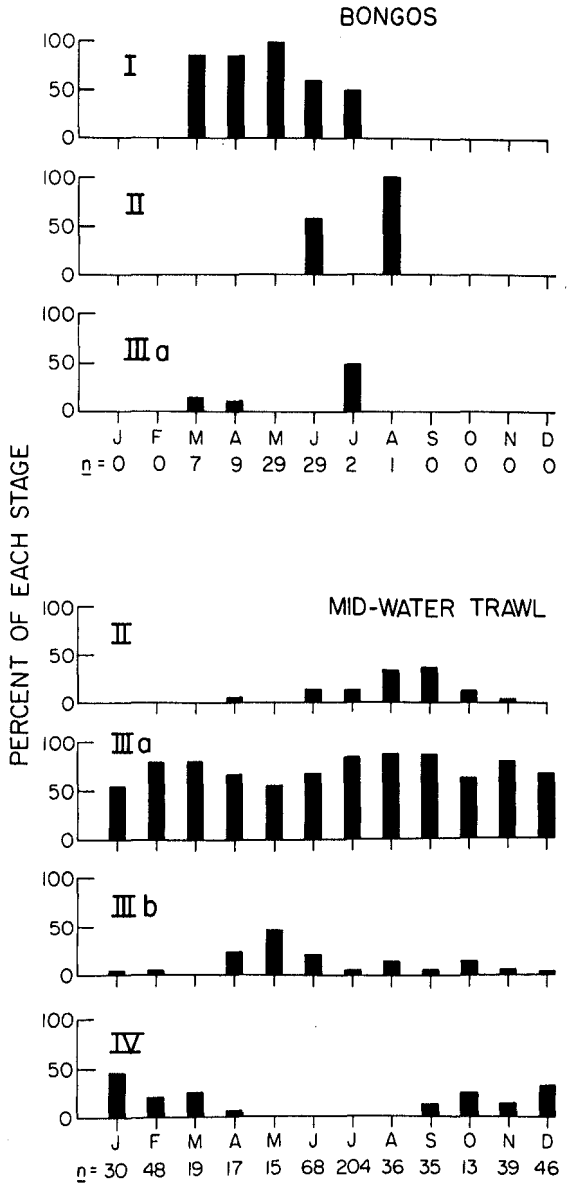


FIGURE 2.—The relative abundance of each stage of Dover sole larvae in bongo transect and mid-water trawl collections during all months.

Dover sole are known to spawn off Oregon primarily in winter, November through March (Hagerman 1952; Harry 1959), when stage III and IV larvae were present. It appears that Dover sole larvae are pelagic for at least a year. The large proportion of stage IIIa larvae during all months is puzzling, since relatively few of this stage would be expected during the winter and early spring if the larval period lasts a year or less.

Interpretation of growth and length of larval life is facilitated by the length-frequency data in Table 4. A trend for increasing average size of larvae is evident from April of one year to March of the next year for larvae <30 mm SL. This suggests growth only to at least 20-30 mm during the first year of life, and a pelagic life that lasts at least a year. No growth trends are apparent for large larvae, which were present all months of the year. Our interpretation of these data is that larvae begin to settle out at 30-50 mm and metamorphose after about 1 yr. Juvenile Dover sole of 40 mm have been captured in bottom trawls in February off Oregon. Possibly few 30- to 40-mm larvae were available to our gear because they were close to the sea floor. Larger larvae (>50 mm) may then represent a residual pelagic population that has not had an opportunity to begin benthic life, perhaps because they resided in water too deep during the period of settlement of most larvae. Information on the size and seasonal occurrence of juvenile Dover sole on the bottom, discussed in a later section, supports these contentions. Such an extended period of pelagic life after 1 yr suggests that Dover sole larvae may delay metamorphosis and settlement to the bottom if favorable conditions are not present, a phenomenon known for some benthic invertebrate larvae (Wilson 1968) but to our knowledge not for any fishes.

Mearns and Gammon[8] also reported Dover sole larvae year-around in waters off southern California with peak numbers in July. They showed a distinct growth trend from about 5-9 mm SL in April to 35-50 mm in October, suggesting that larvae may attain a size of 50 mm or larger during the first year of life. Ahlstrom and Moser (1975) collected Dover sole larvae chiefly during April through July off California.

The trends for rex sole are more readily interpretable than those for Dover sole. Rex sole were also captured in every month, but a progression of stages was obvious through the year (Figure 3). All larvae collected in March, April, and May were stage I, and all were stage IV by the following February. Since rex sole spawn off Oregon from January to June (Hosie 1975), pelagic life apparently lasts about a year. The presence of stage IV larvae in November and December and

[8]Mearns, A. J., and R. Gammon. A preliminary note on multiple recruitment of Dover sole populations (*Microstomus pacificus*) off Southern California. Unpubl. manuscr., 7 p. Southern California Coastal Water Research Project, 1500 East Imperial Highway, El Segundo, CA 90245.

TABLE 4.—Length-frequency distributions of *Microstomus pacificus* larvae collected during various months. Numbers in parentheses denote larvae caught in bongo nets; numbers without parentheses denote larvae caught in mid-water trawls.

| Standard length (mm) | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-5 | (1) | | (2) | | | | | | | | | (3) |
| 6-7 | (7) | (23) | (5) | | | | | | | | | (3) |
| 8-9 | | (3) | (7) | 2 | | | | | | | | |
| 10-11 | 1 | (1) | 10(4) | 6(1) | 1 | | | | | | | |
| 12-13 | | 1 | 9(6) | 19 | 1 | | | | | | | |
| 14-15 | 1 | 2 | 15(4) | 33(1) | 6 | 4 | 1 | 1 | | | | |
| 16-17 | | 1 | 13 | 59 | 4(1) | 3 | | 4 | 5 | 1 | 2 | |
| 18-19 | 1 | 1 | 3 | 35 | 4 | 6 | 2 | 10 | 5 | 2 | 4 | |
| 20-21 | 1(1) | 2 | 3 | 21 | 6 | 9 | 3 | 10 | 8 | 4 | 9 | 3 |
| 22-23 | | | | 10 | 6 | 4 | 2 | 4 | 3 | 4 | 9 | 3 |
| 24-25 | 1 | | 1 | 5 | 1 | 1 | | 1 | 6 | 1 | 6 | 2 |
| 26-27 | 1 | | | 3 | 1 | 1 | | 2 | 1 | 1 | 1 | 4(1) |
| 28-29 | | | | 1 | 1 | 1 | | | 1 | 1 | 5 | 1 |
| 30-31 | 2 | 1 | | | | | | | 1 | 2 | 1 | 1 |
| 32-33 | 1 | | | | | | | | | | | |
| 34-35 | | | 1 | | | | | | | 1 | | |
| 36-37 | 2 | | | | | | | | | | | 1 |
| 38-39 | 1 | | | 1 | 1 | | | | 1 | | | |
| 40-41 | | | 1 | | 1 | | 1 | | | | | |
| 42-43 | | | | | | | | | | 1 | 3 | |
| 44-45 | 1 | | 1 | | | | 1 | 1 | | | | |
| 46-47 | | 1 | | 2 | | | | 1 | | 2 | 1 | 1 |
| 48-49 | 1 | | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 |
| 50-51 | | | 3 | | 1 | 1 | | 1 | 5 | 3 | 1 | 1 |
| 52-53 | 1 | 2 | 3 | 1 | | 2 | | | 2 | 4 | 3 | |
| 54-55 | 1 | 1 | 2 | | | 2 | 1 | 1 | 1 | 1 | | |
| 56-57 | 1 | 2 | 1 | | 1 | | 2 | | 2 | | 1 | |
| 58-59 | | | | | | | | 1 | 2 | | | |
| 60-61 | | 1 | 1 | 3 | 1 | 1 | | | 1 | 1 | | 1 |
| 62-63 | | | | 1 | | | | | | | | |

their absence in the spring suggest that some larvae may settle out in less than a year. Conversely, the presence of large larvae (>50 mm) during June, shortly after the end of spawning season (Table 5), suggests that some larvae may be pelagic for over a year, like some Dover sole larvae. Powles and Kohler (1970) believed that *G. cynoglossus* larvae in the North Atlantic are also pelagic for the first year of life.

Petrale sole larvae were only found during 4 mo, March-June (Figure 4). No distinct progression of stages was apparent, though stage I larvae were only collected in March and April and stage IV only in June. Petrale sole spawn in winter and early spring, November to April in the northeastern Pacific (Harry 1959; Porter 1964; Alderdice and Forrester 1971), so our limited data indicate an egg and larval period of about 6 mo.

## INSHORE-OFFSHORE AND NORTH-SOUTH DISTRIBUTION

Both Dover and rex sole larvae were widely distributed offshore. All three species of flounders are considered to have "offshore" larvae by Richardson and Pearcy (1977).

Bongo nets collected Dover sole larvae at all but the 6-km station (Table 6), although the larvae were most frequent and abundant at the offshore stations (56-111 km), where 84.8% of all larvae were taken. Peak abundance occurred at the 111-km station. Rex sole were taken at all stations but were more abundant offshore (46-111 km) where 80.5% of all larvae occurred. Peak abundance was at 46 km. One specimen of petrale sole was taken 56 km offshore.

Largest mid-water trawl catches of Dover sole larvae were usually made in oceanic waters more than 46 km offshore along all four station lines (Table 7). Some larvae were taken as far as 550 km offshore. Rex sole larvae were most common at the 28- to 83-km stations over the outer shelf and slope, but were also captured farther offshore. The farthest offshore a rex sole larva was collected was 195 km. Petrale sole larvae were collected from 2 to 120 km from the coast. About half the petrale larvae were caught 83-120 km offshore.

Lengths of larvae at varying distances from the coast provide clues to inshore-offshore dispersal. In the bongo net transect data, Dover sole larvae <11 mm were collected at all stations except 6 km, but the greatest numbers of small larvae were at the 93- and 111-km stations. Larger larvae (11-26 mm) occurred only at stations 56 to 111 km

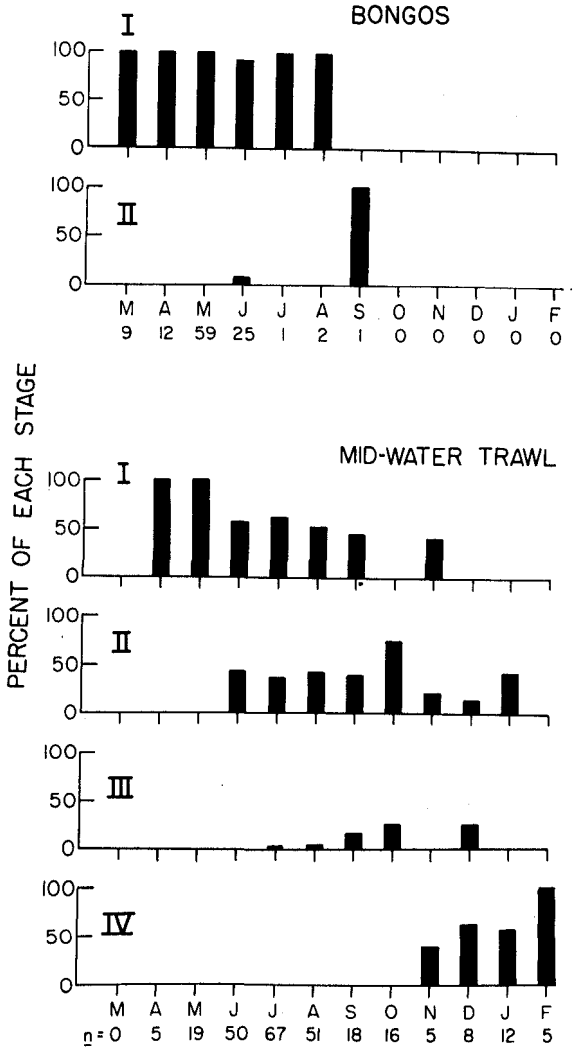


FIGURE 3.—The relative abundance of each stage of rex sole larvae in bongo transect and mid-water trawl collections during all months.

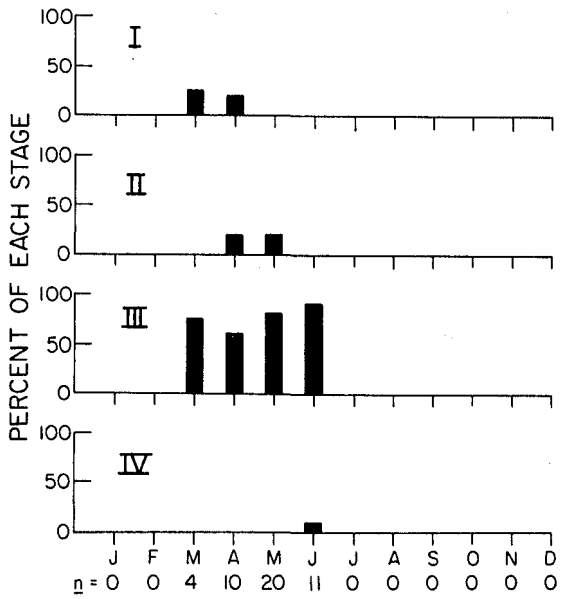


FIGURE 4.—The relative abundance of each stage of petrale sole larvae in bongo transect and mid-water trawl collections during all months.

offshore. Similarly, rex sole larvae <11 mm were taken at all stations but greatest numbers occurred at the 46-km station. All but 2 of the 29 rex sole larvae ≥11 mm (11-67 mm) were taken at stations 37 to 111 km offshore. These trends suggest that larvae >11 mm of both species are most common in waters beyond the continental shelf. In the bongo net grid samples, Dover and rex sole larvae, which were mostly smaller than 10 mm SL, were widely distributed. They were taken at all distances 2 to 56 km from the coast, but always in low numbers. Mean numbers per 10 $m^2$ sea surface were less than 0.30 for Dover sole larvae and 0.70 for rex sole larvae.

No obvious trend of increasing mean size of large Dover or rex sole larvae with distance offshore was apparent from mid-water trawl collections. However, the eight rex sole larvae <30 mm SL in mid-water trawl collections were all captured between 9 and 83 km offshore.

In mid-water trawl samples, the ratio of Dover larvae ≤30 mm to those larvae >30 mm during the summer (May-September) was 15:1 and 6:1 at stations inshore and offshore of 83 km, respectively. This indicates a preponderance of "smaller" larvae over the shelf and slope, probably a result of spawning the previous winter. During winter (October-April) these ratios were 1:2 inshore and 2:1 offshore of 83 km, reflecting a greater proportion of large larvae during the winter especially over the shelf and slope where they will settle.

North-south trends were not as obvious. In the bongo grid samples, Dover sole larvae were taken on 9 of the 12 lines with the mean number per 10 $m^2$ on each line always less than 0.26. Rex sole larvae were taken on all 12 lines. Mean number per 10 $m^2$ on each line ranged from 0.24 to 1.26 with the greatest numbers occurring over Heceta Bank. One petrale sole larva was taken 37 km offshore just north of Cape Blanco. In the mid-water trawl samples the mean catch per tow of Dover sole was about the same along the three northern station lines, and was about twice as

TABLE 5.—Length-frequency distributions of *Glyptocephalus zachirus* larvae collected during various months. Numbers in parentheses denote larvae caught in bongo nets; numbers without parentheses denote larvae caught in mid-water trawls.

| Standard Length (mm) | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-5 | (1) | (4) | | | | | | | | | | |
| 6-7 | (3) | (20) | (2) | | | | | | | | | (3) |
| 8-9 | (6) | (28) | (3) | | | | | | | | | (5) |
| 10-11 | (1) | (2) | (1) | | | | | | | | | |
| 12-13 | 1 | (2) | | | | | | | | | | |
| 14-15 | | (1) | (1) | | | | | | | | | |
| 16-17 | (1) | (1) | (2) | | | | | | | | | |
| 18-19 | 1 | | 1(1) | | 1 | | | | | | | |
| 20-21 | 1 | 1 | 1(1) | | 1 | | | | | | | |
| 22-23 | | 2 | | 1 | | | | | | | | |
| 24-25 | 1 | 1 | 2(2) | 1 | | | | | | | | |
| 26-27 | | | 1(2) | 2 | | | | | | | | |
| 28-29 | | | 1 | 2 | | | | | | | | |
| 30-31 | 1 | 2 | 2(2) | 3 | | | | | | | | |
| 32-33 | | 1 | 3 | 2 | 2(1) | | | | | | | |
| 34-35 | | | 1(1) | 4 | | 2 | | | | | | |
| 36-37 | | | 3 | 4 | 2 | | | | | | | |
| 38-39 | | 1 | 1(1) | 5 | 4 | 1 | | 1 | | | | |
| 40-41 | | 3 | 1 | 5 | 5(1) | 2 | 1 | | 1 | | | |
| 42-43 | | 1 | 2(1) | 6 | 1 | 2 | 2 | | | | | |
| 44-45 | | 2 | (3) | 2(1) | 3 | | 1 | 1 | | | | |
| 46-47 | | | 2 | 4 | 4 | | | | | | | |
| 48-49 | | 1 | 1(1) | 6 | 1 | | 1 | 1 | | | | |
| 50-51 | | | 2 | 5 | 5 | 1 | 3 | | | 3 | | |
| 52-53 | | 1 | 4 | 4 | 4 | | 1 | 2 | | 4 | 1 | |
| 54-55 | | | 3(1) | 1 | 1 | | 1 | | 2 | | 4 | |
| 56-57 | | 1 | 1 | | 3 | 2 | 1 | | 1 | 2 | | |
| 58-59 | | | 3 | 4 | 3 | 2 | 2 | | 3 | | | |
| 60-61 | | | 2 | 1 | 4 | 3 | | | | 1 | | |
| 62-63 | | | 3 | 2 | 2 | 2 | | | | | | |
| 64-65 | | | 2 | 1 | 4 | | 2 | | | 1 | | |
| 66-67 | | | | | | 1(1) | | | | | | |
| 68-69 | | | 3 | | | | 1 | | | | | |
| 70-71 | | | 3 | | | | | | | 1 | | |
| 72-73 | | | 1 | 1 | | | | | 1 | | | |
| 74-75 | | | | 1 | | | | | | | | |
| 89 | | | | | 1 | | | | | | | |

TABLE 6.—Catches of Dover sole and rex sole larvae from bongo net collections taken on the transect off Newport, Oreg., from January 1971 to August 1972. Numbers of larvae in each sample were standardized to number under 10 $m^2$ sea surface.

| Item | Station (kilometers from coast) 2 | 6 | 9 | 18 | 28 | 37 | 46 | 56 | 65 | 74 | 93 | 111 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. tows | 29 | 27 | 30 | 30 | 23 | 25 | 21 | 25 | 18 | 21 | 20 | 18 |
| Frequency of Dover | 2 | 0 | 2 | 1 | 2 | 1 | 2 | 3 | 2 | 4 | 6 | 7 |
| Mean no. Dover/10 $m^2$ | 0.07 | 0 | 0.09 | 0.03 | 0.11 | 0.08 | 0.16 | 0.34 | 0.51 | 0.38 | 0.95 | 1.75 |
| Frequency of rex | 2 | 2 | 4 | 4 | 3 | 3 | 5 | 4 | 3 | 5 | 3 | 3 |
| Mean no. rex/10 $m^2$ | 0.03 | 0.05 | 0.23 | 0.15 | 0.21 | 0.25 | 2.27 | 0.69 | 0.52 | 0.55 | 0.32 | 0.51 |

TABLE 7.—Catches of Dover sole and rex sole larvae at various distances from shore. The data are from mid-water trawl collections taken during all seasons of the year, 1961-67, along four transect lines (Figure 1).

| Item | Distance offshore (kilometers) 9 | 28 | 46 | 83 | 120 | 158-306 |
|---|---|---|---|---|---|---|
| Columbia River: | | | | | | |
| No. tows | 2 | 15 | 18 | 16 | 12 | 9 |
| No. Dover (no./tow) | 1(0.50) | 3(0.20) | 4(0.22) | 2(0.12) | 3(0.25) | 5(0.55) |
| No. rex (no./tow) | 0(0) | 1(0.07) | 3(0.17) | 1(0.06) | 0(0) | 1(0.11) |
| Newport: | | | | | | |
| No. tows | 2 | 53 | 57 | 61 | 62 | 54 |
| No. Dover (no./tow) | 0(0) | 1(0.02) | 3(0.05) | 11(0.18) | 40(0.64) | 17(0.31) |
| No. rex (no./tow) | 0(0) | 11(0.21) | 24(0.42) | 32(0.52) | 9(0.14) | 8(0.15) |
| Coos Bay: | | | | | | |
| No. tows | 0 | 15 | 15 | 14 | 6 | 15 |
| No. Dover (no./tow) | - | 2(0.13) | 6(0.40) | 6(0.42) | 1(0.17) | 4(0.27) |
| No. rex (no./tow) | - | 7(0.47) | 4(0.27) | 7(0.50) | 0(0) | 1(0.07) |
| Brookings: | | | | | | |
| No. tows | 7 | 8 | 12 | 12 | 8 | 37 |
| No. Dover (no./tow) | 0(0) | 0(0) | 10(0.83) | 10(0.83) | 2(0.25) | 22(0.59) |
| No. rex (no./tow) | 3(0.43) | 6(0.75) | 9(0.75) | 5(0.42) | 2(0.25) | 7(0.19) |

high off Brookings, Oreg. Mean abundance of rex sole larvae was lowest off the Columbia River (Table 7).

Certainly the distribution of these larvae is related to both alongshore and inshore-offshore currents over the continental shelf and slope as well as to spawning location of adults. The predominant flow throughout the year off Oregon is alongshore, yet current reversals occur (south in summer, north in winter) and subsurface countercurrents are present (Huyer et al. 1975). There is additional transport of surface waters offshore in summer, and inshore in winter (Wyatt et al. 1972). Perhaps these interacting current systems serve to maintain the majority of these larvae within areas favorable for settling, even though they have extended pelagic lives and the continental margin off Oregon is narrow.

## VERTICAL DISTRIBUTION

Information was obtained on vertical distribution of Dover sole larvae from a series of opening-closing mid-water trawl collections from the upper 1,000 m, 120 km off Newport. There, water depth was about 2,800 m. All but two larvae were found in the upper 600 m, revealing that this species may occupy a broad depth range (Table 8), nearly as extensive as the bathymetric range of adult Dover sole (Alton 1972). Larvae were most abundant (196 larvae/$10^5$ $m^3$) in the upper 50 m. Convincing evidence for diel vertical migration was absent, although the vertical distribution of larvae during the July 1971 cruise appeared to be shallower by night than by day. Rae (1953) concluded that *Microstomus kitt* larvae exhibited diel vertical migration of 10-20 m into near-surface waters at night. Such a shallow migration would not be detectable from our samples.

TABLE 8.—Average catches (number/$10^5$ $m^3$ water filtered) of *Microstomus pacificus* larvae in an opening-closing mid-water trawl during one cruise in July 1971 and five cruises July 1971-September 1974, 120 km off the central Oregon coast; water depth was 2,800 m. D = day, N = night.

| Depth (m) | Total numbers | | | | No. per $10^5$ $m^3$ | | | |
|---|---|---|---|---|---|---|---|---|
| | July 1971 | | 1971-74 | | July 1971 | | 1971-74 | |
| | D | N | D | N | D | N | D | N |
| 0-50 | 27 | 15 | 53 | 29 | 188 | 196 | 15 | 4 |
| 50-100 | 6 | 11 | 14 | 13 | 20 | 127 | 6 | 2 |
| 100-150 | 21 | 1 | 21 | 1 | 156 | 5 | 11 | <1 |
| 150-200 | 2 | 5 | 4 | 5 | 8 | 52 | 2 | 2 |
| 200-300 | 3 | 1 | 12 | 16 | 6 | 5 | 2 | 4 |
| 300-400 | 0 | 0 | 23 | 9 | 0 | 0 | 2 | 1 |
| 400-500 | 17 | 0 | 31 | 4 | 24 | 0 | 4 | 1 |
| 500-600 | 4 | 0 | 11 | 0 | 7 | 0 | 3 | 0 |
| 600-700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 700-800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 800-900 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 900-1,000 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |

## BENTHIC JUVENILES

The season and depth of occurrence of the smallest benthic juveniles are important indicators of the lengths of the pelagic phase of these fishes. Hagerman (1952) reported that young Dover sole become demersal between 50 and 55 mm total length (TL). Mearns and Gammon (see footnote 8) caught juvenile Dover sole of 45-75 mm SL during both mid-autumn and early spring off southern California, suggesting two major periods of recruitment. Demory (1971, see footnote 4, and pers. commun.) caught the largest numbers of small juvenile Dover sole (40-70 mm TL) in February in bottom trawls between 130 and 183 m depth off northern Oregon. According to Demory, these fish, which were 1 yr of age, subsequently move into shallow water in the summer. Though not common, we have taken Dover sole of 40-50 mm SL in the winter in beam trawl collections on the outer shelf off central Oregon. These results indicate that Dover sole off Oregon usually complete metamorphosis and take up a benthic life on the outer continental shelf after about 1 yr, when they are less than 50 mm long. Larger larvae are probably older than a year and have delayed complete transformation to the benthic juvenile form. These large, "holdover" larvae may contribute little to the juvenile and subsequent adult age-groups, based on Demory's (1972b for methods, pers. commun.) observation of two circuli patterns in the scales of small juvenile Dover sole. These were: a dominant pattern with 6-9 circuli, and another rarer pattern with 20 or more circuli. Thus fish with the larger number of circuli probably represent our large larvae, which become benthic well after 1 yr.

Juvenile rex sole, 40-60 mm SL, were common in our beam trawl collections on the outer edge of the continental shelf (150-200 m depth) during the winter months off central Oregon. We also collected 22 *G. zachirus* larvae of 46-60 mm TL (stage III) in an otter trawl at 230-260 m depth off Coos Bay, Oreg., in September. We do not know if these rex sole larvae were benthonic before metamorphosis was completed or if they were living pelagically when caught by the trawl. From these data, we surmise that rex sole settle to the bottom mainly on the outer continental shelf during the winter when they are about 1 yr old. It is possible

that they use this area as a nursery during early benthic life as has been suggested for *G. cynoglossus* on the east coast (Powles and Kohler 1970; Markle 1975). Rex sole smaller than and larger than 180 mm TL have broadly overlapping depth ranges off Oregon (Demory 1971), unlike *G. cynoglossus* which occupies distinct depth zones as juveniles and adults (Powles and Kohler 1970).

Juvenile *E. jordani* were uncommon in bottom trawls. Only two small individuals (65 and 83 mm SL) were found in 115 beam trawl collections. We found only 28 small petrale sole (62-107 mm TL), collected in October and November at 64-82 m depth, from extensive otter trawl collections off Newport in 1972. Examination of otoliths indicated these petrale sole were all in their first year of growth. This suggests that metamorphosis of this species occurs during the fall of their first year when they settle to the bottom of the inner continental shelf off Oregon. Our findings are corroborated by those of other researchers. In British Columbia waters, Ketchen and Forrester (1966) found a few 0-age petrale sole only at depths of 18-90 m between May and August. From extensive otter trawl collections off northern California Gregory and Jow (1976) reported 17 petrale sole (60-100 mm TL) in September and October between 28 and 73 m.

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