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FISHERIES OCEANOGRAPHY Fish. Oceanogr. 2:2, 97–100, 1993

Occurrence of an exceptional catch of pelagic juvenile lingcod (*Ophiodon elongatus*) off Point Reyes, California

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ABSTRACT

An exceptionally large catch of pelagic juvenile lingcod (*Ophiodon elongatus*) was made just offshore of Point Reyes, California in 1990. Results of 678 midwater trawls from annual surveys from 1983 to 1990 show that pelagic juvenile lingcod have a strong nearshore distribution and were most abundant in the Gulf of the Farallones, with a mean abundance of 5.0 per trawl. Otoliths from fish taken in the large catch were used to estimate parameters of a log-transformed Gompertz growth model, which was then used to calculate hatch dates. Hatching peaked around 24 March and ranged from 10 March to 19 April, implying a January–February spawning season for lingcod off central California. The large catch was associated with an anticyclonic eddy which would lead to water being trapped near the coast; convergence of fish associated with the eddy may have been due to either physical or biological effects.

Key words: anticyclonic eddy, larval abundance, lingcod, otoliths

INTRODUCTION

Patchy spatial distributions are common in trawl surveys (Lenarz and Adams, 1980; Pennington, 1986) and are frequently most extreme in surveys of pelagic fishes (Smith and Hewitt, 1985). Here we report on the occurrence of an unusually large catch of pelagic juvenile young-of-the-year lingcod (*Ophiodon elongatus*) taken during a series of annual surveys conducted off central California. To estimate the hatch dates of the lingcod in this one catch we construct a growth model for the first 5 months of life. Local oceanographic features in the area at the time of the unusual catch are also described.

Lingcod have a complex form of reproduction (Cass *et al.*, 1990). In British Columbian waters, peak spawning occurs from January to February, after mature fish have migrated into shallow (< 30 m) rocky areas. Males establish territories and remain to guard a demersal egg mass until hatching is complete after 7 weeks. Larval lingcod hatch at a standard length (SL) of 7–9 mm and, while planktonic, undergo juvenile transformation at ≈20 mm SL. They remain pelagic until early summer, when they settle to benthic habitats at ≈70–80 mm SL.

METHODS

Lingcod were collected incidentally during annual trawl surveys of pelagic juvenile young-of-the-year rockfish (*Sebastes* spp.). Since 1983, sampling has been conducted 1–4 times per year at a fixed series of stations off central California (Fig. 1, Table 1) using a 26 × 26 m

Table 1. Summary of midwater trawl surveys conducted for pelagic fishes off the central California coast (1983–90). See Wyllie Echeverria *et al.* (1990) for a detailed description.

Year	Cruise	Dates Begin	 End	Number of hauls
1983	1	8 June	24 June	21
1984	1	12 June	27 June	25
1985	1	5 June	30 June	30
1986	1	3 June	25 June	90
1987	1	10 April	22 April	35
1987	2	23 May	21 June	106
1988	1	16 April	22 April	29
1988	2	22 May	18 June	105
1989	1	14 May	13 June	100
1990	1	28 March	6 April	38
1990	2	13 May	10 June	99
			Total	678

Received for publication September 22, 1992
Accepted for publication December 10, 1992

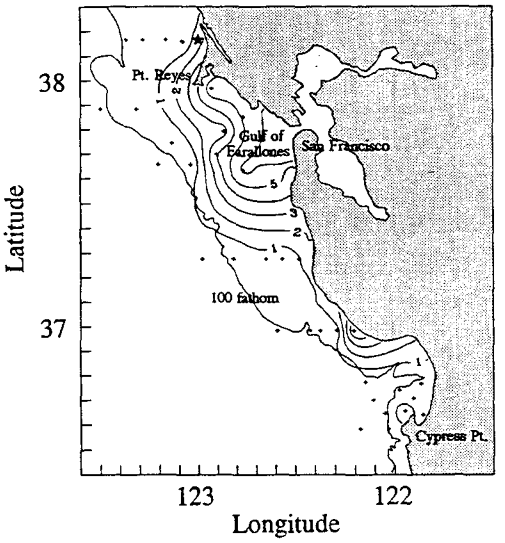


Figure 1. Spatial contours of the average number of lingcod caught per trawl (1983–90). The locations of the 36 standard stations upon which the lines are based are shown as plus signs. The location of the exceptional 29 May 1990 lingcod catch is marked with a star.

Cobb midwater trawl equipped with a 0.945 cm (⅜ inch) stretched-mesh inner liner. Depending on bottom depth, the net was towed horizontally with the headrope at 6 or 32 m below the water's surface for 15 minutes at a speed of 1.0 knot. Survey methods have been described in detail elsewhere (Wyllie Echeverria *et al.*, 1990).

To determine the overall spatial pattern of lingcod within the study region, the abundance of lingcod from all trawls, excluding one large and exceptional catch, was spatially contoured by kriging. Patchiness was measured using the negative binomial coefficient κ (Jahn and Smith, 1987).

A series of 20 conductivity–temperature–depth (CTD) casts were made in a grid centered over the location of the exceptional lingcod catch. These casts were all completed within 24 h of the time the trawl was conducted and constituted a routine part of survey procedures (e.g. Schwing *et al.*, 1990). All CTD data were collected with a Sea-Bird Electronics SEACAT-SBE-19 profiler cast to maximum depths of 500 m. The CTD data were analysed by spatially contouring the density of water (σ_t) over a series of depths, particularly at 10 m (approximate depth of the tow).

In the laboratory, the SL of each fish was measured and sagittal otoliths were removed from 63 specimens that spanned the full size distribution of fish caught. Otoliths were processed following methods described in Laidig *et al.* (1991).

To supplement these samples, lingcod larvae were collected along the central California coast between Point Reyes and Cypress Point from 10 to 15 February 1991. Specimens were collected with a 1 m bongo net (505 μm mesh) using standard CalCOFI protocols (Smith and Richardson, 1977). Plankton samples were placed in 80% ethanol and larvae were later sorted in the laboratory where otoliths were removed.

Counts of daily increments in the otolith were initiated at the first dark check mark that both completely encircled the primordium and was subsequently enveloped by complete rings of smaller width. The otolith radius (OR) at this mark was 28.6 μm (± 1.6 μm), which agreed well with a prediction of the size of the otolith at hatch (32.0 μm) produced from a regression of OR on SL and known size at hatch (7 mm SL; Giorgi, 1981).

The age and SL data were modeled with a four-parameter growth equation (Schnute, 1981). From the initial estimates, the model was simplified to the three-parameter Gompertz growth function. The log-transformed version of the equation was fitted owing to heteroscedastic variance (Zweifel and Lasker, 1976), i.e.

$$\log_e [SL] = \log_e [l_0] + k(1 - e^{-gt}) \qquad (1)$$

where l_0 is length at birth, k is instantaneous rate of growth, g is the rate of decrease of k, and t is age (days). Using Giorgi's (1981) estimate of size at hatch, the intercept term in the final fit was fixed at $l_0 = 7.0$ mm. The inverse of the fitted growth model was used to predict the age of each lingcod taken in the trawl. The distribution of hatching dates was then calculated by subtracting each predicted age from the date of capture.

RESULTS

Pelagic juvenile lingcod were most abundant in the Gulf of the Farallones and showed a strong nearshore distribution (Fig. 1). Contour plots showed mean abundances of 5.0 lingcod per trawl at depths less than 50 m in the Gulf of the Farallones, decreasing to 1.0 per trawl in deeper waters. Pelagic juveniles were not taken off the continental shelf, i.e. deeper than 183 m (100 fathom contour).

Juvenile lingcod have a very patchy distribution (κ = 0.03). This low value of κ is influenced greatly by one exceptional catch of 230 fish made on 29 May 1990 at

04:15 just offshore of Point Reyes, California (location marked in Fig. 1). This one sample represented 0.148% of the 678 trawls conducted from 1983 to 1990, but accounted for 29.7% of all lingcod captured. The 230 fish from this trawl compare with an overall mean of 0.97 lingcod/trawl (SE = 0.23) taken in the remaining 677 trawls. Moreover, the fish demonstrated a wide size range, from a minimum of 25.7 mm SL to a maximum of 77.1 mm SL. The size distribution peaked between 50 and 60 mm, and was slightly skewed toward larger fish.

The fit of the log-transformed Gompertz equation to the age data was good (Fig. 2; $F_{0.05} = 49778.0$, d.f. = 2,63; $r^2 = 0.854$). Parameter estimates were $\hat{k} = 3.669 \pm 0.316$ and $\hat{g} = 0.0124 \pm 0.0016$ day^{-1}. Although not used in fitting the model, we have included in the figure the age data from four larvae sampled in 1991. The proximity of the data to the regression line suggests that the juvenile equation may also apply to larval lingcod.

The estimated hatch date distribution of fish from the large sample peaked around 24 March and ranged from 10 March to 19 April (Fig. 3). The distribution had a wide spread of hatch dates; the extremes ranged over 40 days, indicating that the lingcod in the catch did not come from one egg mass.

A geostrophic interpretation of the density field (σ_t) at several depths offshore of Point Reyes suggests that an anticyclonic eddy existed south-west of the site of the large lingcod catch (Fig. 4). Clockwise circulation of this eddy would transport water coastally and create a nearshore region of diminished stagnant flow. Anticyclonic flow immediately north of Point Reyes has been observed during the upwelling season (Schwing *et al.*, 1990). The area is directly inshore of a persistent streamer of cold upwelled water that moves south along the coast of northern California and offshore at Point Reyes (Schwing *et al.*, 1991). Water trapped near the coast off Tomales Point contrasts with strong southerly flow offshore.

Figure 2. Predicted length (SL) from the log-transformed Gompertz equation as a function of age in days (solid curve). The open circles are lengths versus age data used in the model fit. The filled squares are data from four larvae sampled in 1991, which were not included in the fit.

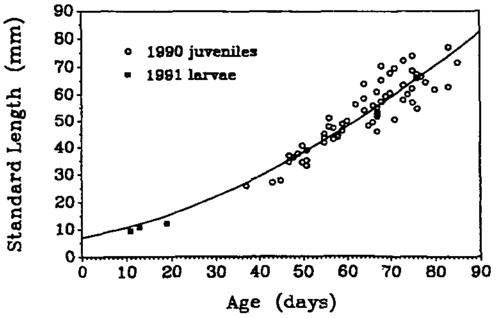
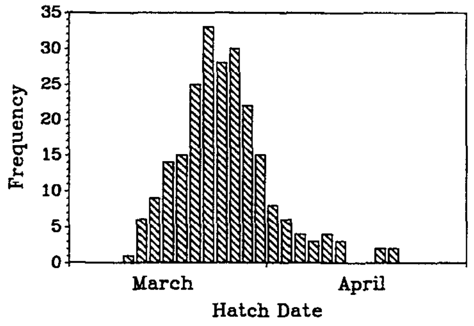


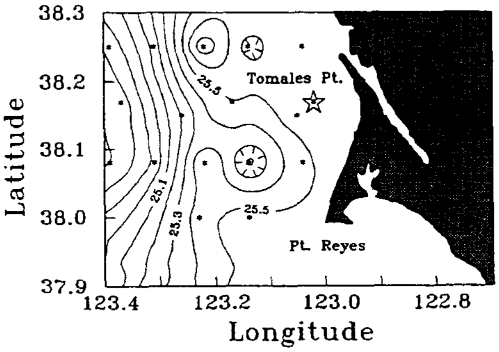
Figure 3. Frequency distribution of hatch dates for 230 juvenile lingcod taken in the 29 May 1990 sample.



DISCUSSION

The data presented here indicate that lingcod off central California hatch during March and April, grow rapidly, and are patchily distributed nearshore as juveniles. Hatching during March and April implies a January–February spawning season for lingcod, assuming that 7 weeks represents the length of the demersal egg stage (Cass *et al.*, 1990). These findings are consistent with reported spawning dates of mid-January to mid-

Figure 4. Spatial contouring of the density of water (σ_t) at 10 m depth from a series of 20 CTD casts made on 28–29 May 1990. The location of the large lingcod catch is marked with a star. Seventeen of the 20 CTD locations are shown as asterisks; the remaining three occurred just west of the figure.



February and hatch dates of mid-March to April for lingcod in British Columbia (Cass *et al.*, 1990).

Lingcod growth during the pelagic juvenile stage is rapid; fish reach 70 mm SL in 80 days. Also, the Gompertz growth model provided a good fit and it may be possible to extend it to other years, because the ages and lengths of four larval fishes caught in 1991 (Fig. 2) lay close to the regression.

Pelagic juvenile lingcod are distributed in a very patchy manner. The estimated negative binomial coefficient ($\hat{k} = 0.03$) is quite low for pelagic early life history stages, which are typically < 0.4 (Jahn and Smith, 1987). Adult groundfish values usually range from 0.1 to 1.0 (Lenarz and Adams, 1980).

Beyond suggesting an association with the eddy, we cannot provide an explanation for the occurrence of this unusual catch. The convergent effect of the eddy may have been due to either physical or biological mechanisms. For example, passive drifters transported south in the persistent offshore current could be shunted to the stagnant water near the coast where they could accumulate. A biological explanation is that the eddy somehow resulted in conditions favorable to the survival of juvenile lingcod. Either explanation is consistent with the observed wide distribution of hatch dates.

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