EVALUATING INCIDENTAL CATCHES OF 0-AGE PACIFIC HAKE TO FORECAST RECRUITMENT

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ABSTRACT
Incidental catches of 0-age Pacific hake (*Merluccius productus*) in California Department of Fish and Game trawl surveys for pelagic fishes were evaluated for use in estimating relative year-class strength. Indices of catch per unit of effort and frequency of occurrence of 0-age hake in surveys from 1965 to 1981 were compared with recruitment at age 3 as determined by cohort analysis. Five strong year classes appeared in the cohort analysis from 1965-81, and these same year classes also were strongest in the pelagic survey catches. We conclude that the surveys are useful for qualitative determination of relative year-class success or failure. Suggestions are made for improving the surveys with respect to hake.

RESUMEN
Capturas incidentales de la merluza del Pácifico de edad cero, en las prospecciones de peces pelágicos del departamento de Fish and Game de California fueron evaluadas, para estimar la dominancia relativa de clases anuales de merluza. Indices de captura por unidad de esfuerzo y frecuencia de ocurrencia de merluza a la edad cero en las prospecciones de 1965-81 fueron comparadas con los reclutamientos a la edad de tres años, determinada por análisis de cohorte. En el análisis de cohorte se observaron cinco generaciones dominantes, las cuales fueron también abundantes en la prospección de peces pelágicos. Concluimos que las prospecciones son útiles para la determinación cualitativa del éxito o fracaso relativo de las clases anuales de edad. Se proponen varias sugerencias para mejorar las prospecciones de merluza.

INTRODUCTION
Surveys for young fish can be useful in forecasting year-class strength (Rauck and Zijlstra 1978; Smith 1981; Burd 1985). Such forecasts can benefit management of fisheries that are heavily dependent on recruiting new fish. Furthermore, surveys for juvenile fish can reveal at what stage relative abundance levels are established, which is information that augments studies on the causes of variations in recruitment.

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Juvenile Pacific hake (*Merluccius productus*) are caught as an incidental species during pelagic trawl surveys conducted by the California Department of Fish and Game. In this report, we evaluate these catches for use in forecasting year-class strength.

Pacific hake is the dominant groundfish species in the California Current region of the Pacific west coast. There has been a large foreign fishery on hake since 1966, with annual catches up to 240,000 tons. In recent years a joint-venture domestic fishery has developed. Recruitment to the fishery, which occurs at 3 years of age, is quite variable and possibly influenced by abiotic conditions during early life stages (Bailey 1981). Hake spawn primarily from January through March off the southern and central coast of California. Juveniles generally are distributed from the spawning grounds into southern Oregon. Juvenile hake are the third most frequently occurring fish in pelagic trawl surveys of the California Department of Fish and Game (Mais 1974).

METHODS
The pelagic fish surveys of the California Department of Fish and Game have employed standardized methodology since 1965; in this study we used data from the 1965-84 surveys. A detailed description of survey methodology is presented in Mais (1974). In general, hydroacoustic surveys were conducted during the daytime along predetermined tracklines. At night, the trackline was retraced, and a midwater trawl with a 50- or 60-foot-square mouth opening was deployed, usually for 20 minutes in the upper 15 fathoms of the water column unless the echo sounder indicated that fish were deeper. The mesh size of the cod end was 0.5 inches. Some surveys consisted entirely of trawling at predetermined stations without the use of sonar. The surveys generally extended seaward to the 1,000-fathom depth contour or a minimum of 35 miles offshore.

The number of cruises and tows and the seasons covered are listed in Table 1. In the case of hake, the number of fish caught in the trawl were counted, or estimated if the catch was extremely large; length ranges and sometimes length frequencies were recorded. The length range of 0-age juvenile hake in each season was estimated as: April-May, 10-80 mm; June-

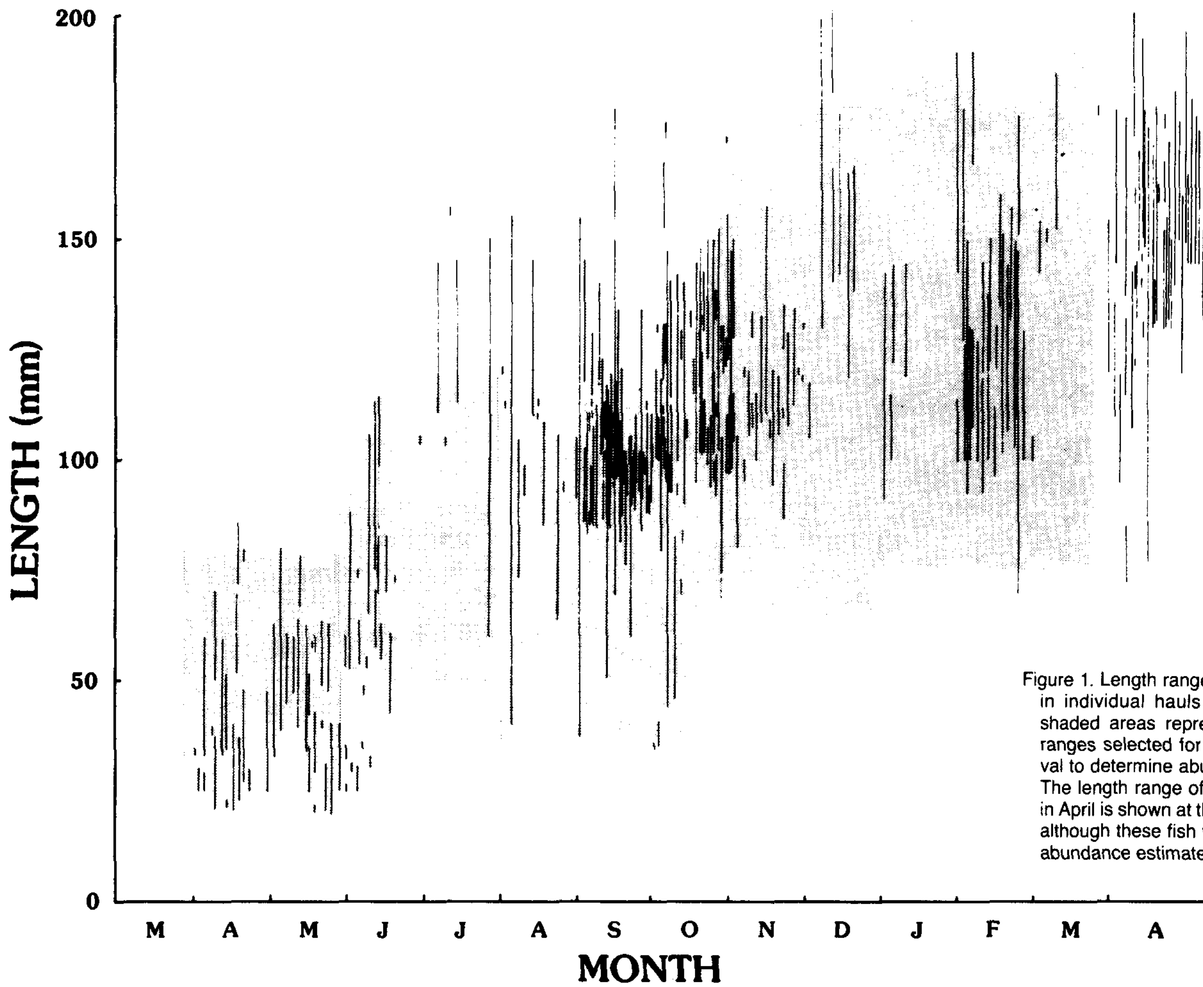

Figure 1. Length ranges of 0-age hake in individual hauls by month. The shaded areas represent the length ranges selected for each time interval to determine abundance indices. The length range of 1-year-old hake in April is shown at the extreme right, although these fish were not used in abundance estimates.

TABLE 1
California Fish and Game Midwater Trawl Surveys Used in This Study

Year class	Number of cruises	Seasons[1]	Number of tons
1965	3	sp, a	96
1966	5	sp, su, a	102
1967	4	sp, a, w	133
1968	4	sp, a	178
1969	5	sp, su, a, w	225
1970	4	sp, a, w	158
1971	3	sp, a	92
1972	3	sp, a, w	91
1973	2	sp, a	72
1974	4	sp, a, w	129
1975	3	sp, a	86
1976	8	sp, a, w	337
1977	6	sp, a, w	229
1978	1	w	60
1979	3	sp, a, w	283
1980	3	a, w	337
1981	4	sp, a, w	506
1982	3	su, a, w	339
1983	2	a	234
1984	1	a	128

[1]sp = spring; su = summer; a = autumn; w = winter

July, 25-120 mm; August-October, 35-150 mm; November-December, 65-180 mm; and January-March, 80-200 mm (Figure 1).

A standardized survey subarea of 30°-35°N was chosen because it was consistently occupied during most surveys. With the exception of numerous catches in Monterey Bay, this appears to be the main area inhabited by 0-age hake (Figure 2).

Catches of 0-age hake were combined for all surveys from April until March of the next year. Percent occurrence was calculated as the percent of all hauls that recorded catches of 0-age hake. Catch per unit of effort (CPUE) for annual estimates of relative 0-age juvenile abundance was calculated as:

$$\text{CPUE} = \sum_{\text{tows}=1}^{n} \ln\,[(\text{number fish/hours trawled}) + 1]/n$$

where n is the number of tows. Recruitment was estimated by the number of 3-year-old hake derived by cohort analysis (Francis 1985).

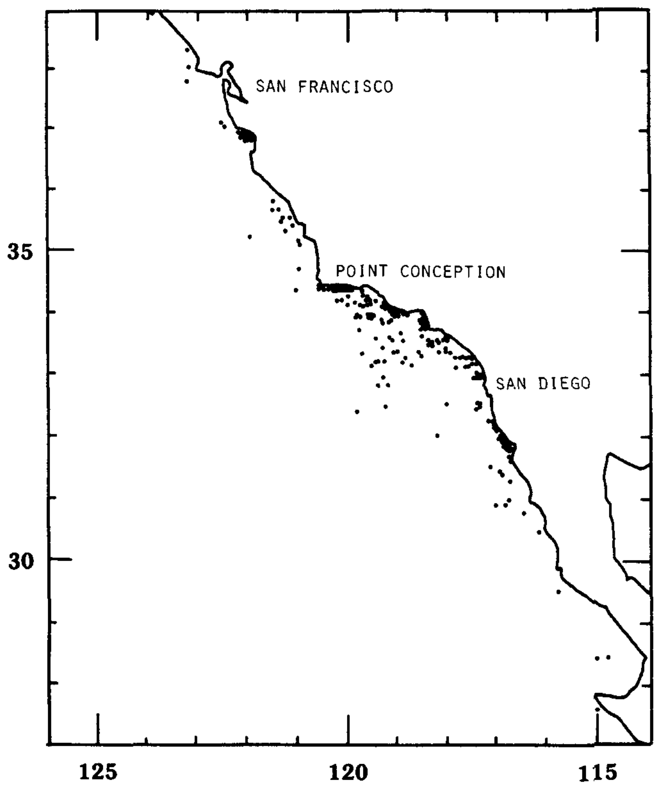

Figure 2. Locations of catches of 0-age hake in midwater trawls of the California Department of Fish and Game used in this study, 1965-84.

RESULTS AND DISCUSSION

The California Fish and Game trawl surveys for pelagic fish resources were not targeting on juvenile hake, but their incidental catches of 0-age hake appear to be useful in forecasting year-class strength of this species. Figure 3 demonstrates the relationship between catches of 0-age hake in the surveys and year-class strength as determined by cohort analysis. During the interval from 1965 to 1981, five large year classes of hake appeared in the population (1967, 1970, 1973, 1977, and 1980). These five year classes were also the most abundant as 0-age juveniles monitored by the surveys.

The surveys apparently are not accurate in ordering the rank of strong year classes when compared with results of the cohort analysis. For example, 0-age hake were more abundant in the 1973 surveys than in the 1970 surveys, but the cohort analysis indicated that the 1970 year class was stronger than the 1973 year class. Predicting strong year classes is important, but in a management context it is equally important to recognize year-class failure; in this analysis all weak year classes were accurately indicated by the surveys.

Since the cohort analysis extends only to the 1981 year class, we can use the 0-age catches in the surveys to forecast the relative recruitment strengths of the

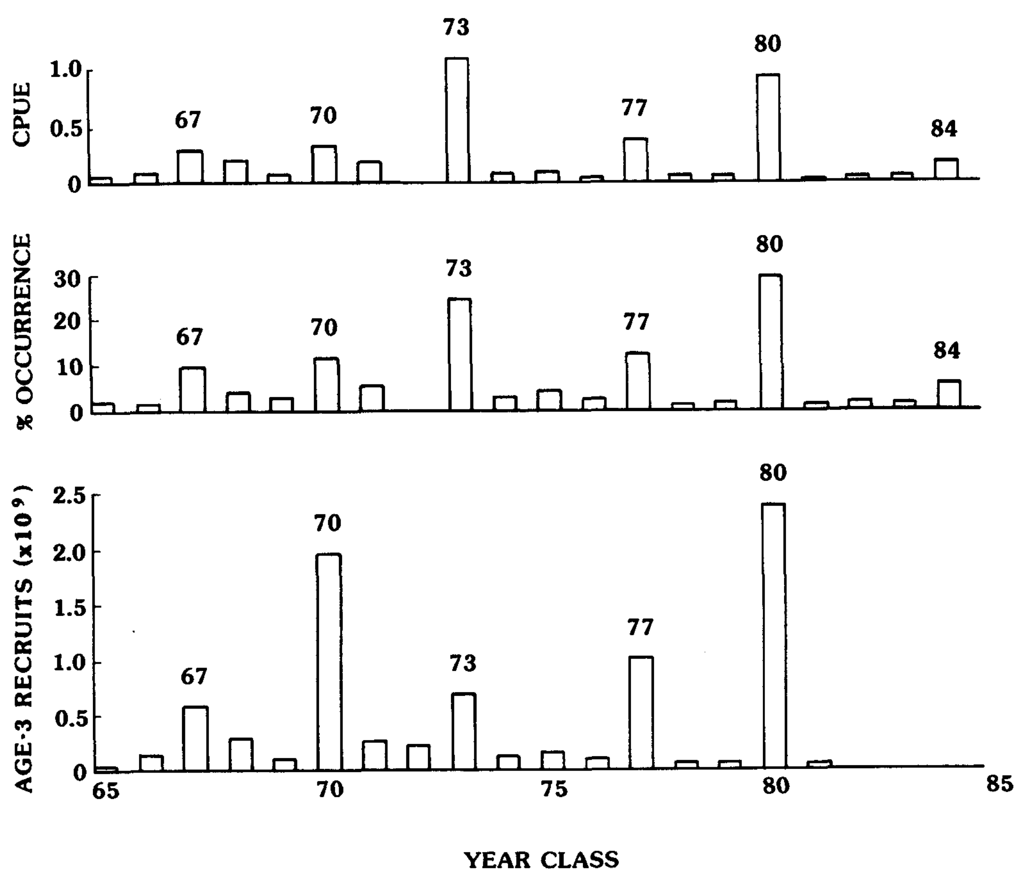

Figure 3. Catch per unit effort (CPUE; *top*) and percent occurrence (*middle*) of 0-age hake in midwater trawl surveys compared with year-class strength determined by cohort analysis (*bottom*).

1982-84 year classes. The juvenile surveys indicate that the 1982-83 year classes will be weak. The 1984 year class may be moderately strong. However, both the 1983 and 1984 surveys may have underestimated the abundance of juvenile hake, because spawning apparently shifted northward during these warm-water years. In fact, there are anecdotal reports of a strong 1984 year class.

From these results it is apparent that the relative recruitment strength of hake year classes is established within the first year of life. Furthermore, the 1967, 1970, 1973, and 1977 year classes were detectable as strong year classes in surveys from April to June in those years. This indicates that relative year-class strength may be established within the first three to five months after spawning (there was no spring survey in 1980). The early establishment of year-class strength may be more apparent for hake than for other species because of the boom-or-bust nature of recruitment to the hake population; survival is either very good or poor.

Because of the close relationship of recruitment success to stock abundance, we consider such surveys to be a valuable and inexpensive asset to stock management. Evaluation and assessment of the hake resource for management of the U.S. fishery is currently based on stock projections that take into account estimates of recruitment up to three years into the future based on the results of the 0-age surveys (Francis 1985). At this stage, the surveys can only be considered rough relative indices of year-class strength, and the precision of the indices cannot be addressed. To improve the assessment of prerecruit abundance of hake, preliminary studies on vertical and geographic distribution and behavior of juveniles are required. These factors may affect catchability and the utility of survey CPUE as a relative index. Further improvement of hake assessment would result from extending the northern boundary of the survey area, and implementing a more statistically rigorous survey design.

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