A TAGGING STUDY OF THE CALIFORNIA HALIBUT (*PARALICHTHYS CALIFORNICUS*)

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ABSTRACT

During a study that spanned forty years, the California Department of Fish and Game tagged 16,827 California halibut (*Paralichthys californicus*). A total of 858 tags were returned, for a return rate of 5.1 percent. Statistical analyses of the data indicated that this species remained in a localized area throughout its adult life. The mean distance traveled by California halibut during this study was 13.4 km. California halibut larger than 500 mm total length (TL) tended to travel markedly greater distances than halibut smaller than 500 mm TL.

INTRODUCTION

The California halibut (*Paralichthys californicus*) is important to both the recreational and commercial fishing industries of southern and central California. The California halibut ranges from Magdalena Bay, Baja California (Gilbert and Scofield 1898), to the Quillayute River in Washington (Pattie and Baker 1969), but is most common from Morro Bay south (Fitch and Lavenberg 1971). The movement of California halibut is of particular interest to fishery biologists, since this species occurs across a political border (Mexico/USA) and a biological border (Oregonian/San Diegan biogeographic provinces).

Researchers from the California Department of Fish and Game have been tagging California halibut since the 1950s. Young (1961) briefly summarized some of the early results of the tagging program, but the analysis was not rigorous. The subsequent accumulation of additional tag return data, and the recent publication of numerous papers on California halibut (see Haugen 1990), warranted a reexamination of the data.

MATERIALS AND METHODS

The California Department of Fish and Game tagged California halibut from 1955 through 1960, in 1965, and from 1989 through 1994. Tagging operations were conducted from Bahía Sebastián Viscaíno, Baja California, to Tomales Bay, California. Most halibut were tagged between Oceanside and Santa Barbara, California. Most halibut were captured with trawl gear, but many were also captured with gill nets and hook and line. The tagging method changed as the program evolved. A small percentage of the halibut were tagged with Peterson discs and silver pins; after these tags were found unacceptable, the fish were tagged with spaghetti tags. In recent years Floy T-bar anchor tags have been used.

Upon capture, each halibut was tagged below the dorsal fin just behind the head. Each fish was measured to the nearest mm total length and released at the site of capture. Tag returns came from the continued trawling efforts of the tagging program, commercial trawlers, commercial gill netters, and sport anglers. Size and location data were recorded for each recapture. Because California halibut are not sexually dimorphic, the sex of individual fish was recorded only when provided upon recapture.

Migration distances were plotted and recorded in nautical miles, the standard unit of measure on nautical charts, and later converted to kilometers (km). The direction of migration was also recorded. Migration distance was analyzed for relationships with the following: TL, sex, time at liberty, and direction of migration. Migration rate, defined as migration distance divided by time at liberty, was also analyzed with respect to the above variables, with the exception of time at liberty. Direction of migration was also examined with respect to TL. The variables of interest were tested for normality (Shapiro-Wilk W test), and nonparametric methods were used where appropriate.

The chi-square test of independence was used to determine if there were relationships between total length and migration distance/rate, time at liberty and migration distance, direction of migration and total length, direction of migration and migration distance/rate, and sex and migration distance/rate. Spearman rank correlation coefficients were also used to test for a relationship between time at liberty and migration distance/rate, and total length and migration distance/rate. All statistical analyses were performed with the Statistical Analysis System (SAS 1988).

The TL value used for all of the above tests was the length at time of tagging. This length was used rather than recovery lengths because of the unreliability of reported lengths from anglers and commercial fishers, the relative lack of data on recovery lengths, and preliminary results that showed no difference between length at tagging and length at recovery.

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RESULTS

During this study 16,827 halibut were tagged. The tagged fish ranged from 280 to 1005 mm TL (table 1), but the majority were less than 500 mm (figure 1). A total of 858 tags were recovered, resulting in a return rate of 5.1 percent. Of these returns, 839 included location of recovery; only 332 (39.6%) of these returns indicated that the fish had moved at least two km. Length of fish was indicated in 410 returns, and sex of the specimen in 87 returns.

Days at liberty for individual fish ranged from 1 to 1921, with a mean of 128 (table 1), but the majority were at liberty for fewer than 100 days (figure 2). Migration distances ranged from 0 to 365 km, with a mean of 13.4 km (table 1). Although some halibut rapidly migrated long distances, most returns showed no movement at all (figure 2). Time at liberty and migration distance were used to calculate a mean migration rate of 0.21 km/day (table 1).

From the data grouped by intervals of total length, average migration distance for every length group was 38 km or less (table 2). Halibut larger than 500 mm behaved differently from smaller halibut. The larger fish migrated farther and faster ($P < 0.001$ for both; tables 2–4). From the data grouped by time at liberty (table 5), halibut migrated farther when they were at liberty longer ($P < 0.001$, table 4). Spearman rank correlation coefficients also showed that these three trends were statistically significant: total length vs. migration distance ($r_s = 0.24$, $P < 0.001$); total length vs. migration rate ($r_s = 0.22$, $P < 0.001$); and time at liberty vs. migration distance ($r_s = 0.23$, $P < 0.001$).

However, sex vs. migration distance, and sex vs. migration rate were statistically not significant ($P = 0.20$

TABLE 1
Descriptive Statistics of 839 Tagged Halibut

	Mean value	Minimum value	Maximum value	Standard deviation
Migration distance (km)	13.4	0	364.8	39.8
Days at liberty	127.5	1	1921	198.3
Size (mm) when tagged	473.0	280	1005	108.8
Migration rate (km/day)	0.21	0	16.7	0.9

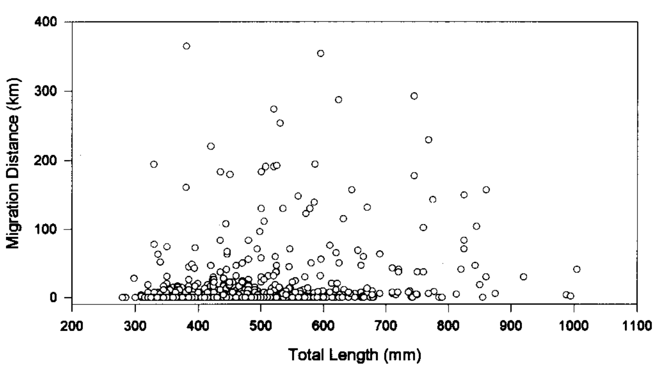

Figure 1. Migration distance (km) for 839 tagged halibut, versus total length (mm).

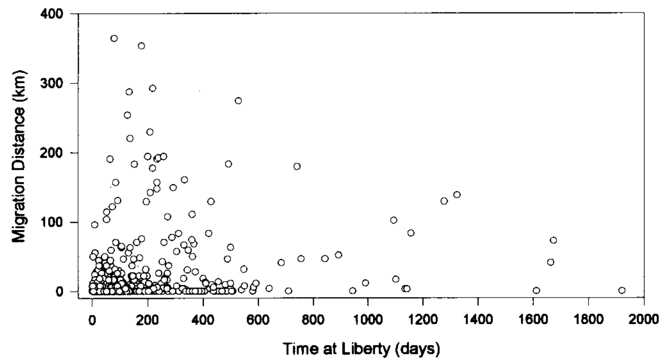

Figure 2. Migration distance (km) for 839 tagged halibut, versus days at liberty.

TABLE 2
Average Migration Distance (km) of Halibut, by Total Length (TL)

TL (mm)	N	Minimum	Maximum	Mean	SD
201–350	80	0	194	8.1	26.1
351–400	125	0	365	8.0	36.6
401–450	205	0	220	8.0	26.5
451–500	184	0	183	7.3	21.2
501–550	104	0	274	19.1	50.4
551–600	55	0	353	25.0	62.4
601–1200	86	0	292	37.8	62.3

TABLE 3
Average Migration Rate (km/day) of Halibut, by Total Length (TL)

TL (mm)	N	Minimum	Maximum	Mean	SD
201–350	80	0	7.41	0.15	0.84
351–400	125	0	4.62	0.12	0.49
401–450	205	0	1.85	0.14	0.36
451–500	184	0	10.7	0.12	0.80
501–550	104	0	2.93	0.22	0.48
551–600	55	0	16.67	0.59	2.36
601–1200	86	0	5.56	0.48	0.85

TABLE 4
Chi-Square Test Results

Relationships	P-value	N
Total length vs. migration distance	<0.001	839
Total length vs. migration rate	<0.001	839
Time at liberty vs. migration distance	<0.001	839
Direction of migration vs. total length	0.30	313
Direction of migration vs. migration distance	0.01	313
Direction of migration vs. migration rate	0.05	313
Sex vs. migration distance	0.20	87
Sex vs. migration rate	0.20	87

TABLE 5
Average Migration Distance (km) of Halibut, by Days at Liberty

Days at liberty	*N*	Minimum	Maximum	Mean	SD
1–50	357	0	96	3.9	9.7
51–100	184	0	365	10.9	37.2
101–150	94	0	287	14.9	46.3
151–200	65	0	354	19.4	56.7
201–400	88	0	293	37.4	63.3
401–600	31	0	274	29.6	61.5
601–2000	20	0	180	48.4	53.7

for both, table 4). Males and females did not exhibit different migratory patterns. The direction of migration vs. total length was statistically not significant ($P = 0.30$, table 4). Thus, size did not influence the direction of movement.

Because of the predominately north-to-south orientation of the California coast, all but three migrations were classified as north or south. Two of the three exceptions were east-west movements within large bays; the third was movement from the mainland coast to Catalina Island. Six fish moved from south of Point Conception to areas north of the point. No fish were reported moving from north to south of the point. The mean distance of northern migration was 47.1 km (n = 157); the mean distance of southern migration was 22.7 km (n = 156).

The difference between the number of halibut moving north and the number moving south, 157 vs. 156, was obviously not significant. The difference in migration distance with respect to direction (north vs. south) was statistically significant ($P = 0.01$, table 4). Of the fish moving north, 31 percent traveled more than 0.5 km/day; 19 percent of the fish moving south traveled more than 0.5 km/day. The difference in migration rate with respect to direction was statistically significant ($P = 0.05$, table 4). Thus halibut moving north tended to travel greater distances and at a faster rate.

DISCUSSION

Although some California halibut made distant, rapid migrations, clearly this behavior was unusual. The halibut tagged during this study tended to remain in a local area. This localized behavior may have important implications for the effective management of the species.

Young (1961) stated that "small halibut tend to move south (and) large fish north." This did not hold true during our analysis, and Young did not indicate how he reached his conclusion. However, we observed that halibut that moved northward moved significantly greater distances at a greater rate. There are no clear explanations for this phenomenon, which may be a result of biased reporting of tag recaptures. Most of our tagging effort was in southern California, and tagged fish that migrated large distances to the south may have ended up in Mexican waters. It is reasonable to assume that tagged halibut caught in Mexico have a much lower probability of being reported than tagged halibut caught in the United States, thereby biasing our results.

It is interesting to note that very few halibut tagged south of Point Conception were recovered north of Point Conception, and no fish migrated from north to south of the point. The relatively small number of halibut tagged north of Point Conception may explain the lack of recorded migrations from north to south, but a large number of halibut were tagged south of Point Conception (Ventura Flats). We do not feel confident in labeling Point Conception as a geographic barrier to halibut migration, but we believe the issue may warrant more research.

The short mean time at liberty may be due to a high incidence of tag shedding. California halibut do not have the dorsal spines or associated interneural bones that normally anchor T-bar tags. High rates of fishing mortality and natural mortality could also contribute to short times at liberty.

We speculate that the dramatic increase in average migration distance and rate for large halibut results from an important event in the life history of this species. Such events may be reproduction or shift in preferred prey. This topic needs further research. The large halibut, however, were estimated to represent a small percentage of the population (Domeier, data from biomass estimate).

California halibut use shallow-water embayments as nursery areas (Haaker 1975; Allen 1988; Kramer 1990); more detailed studies of migration from these nursery areas are needed. Migration of halibut from nursery areas to adult habitats may be the most significant migration of their life history, aside from larval dispersal. If juvenile migration is limited, an area that historically produces large numbers of halibut could become unproductive if the local nursery areas are destroyed.

Given the limited movement of adult halibut, future research should focus on recruitment pathways. It is not known whether local populations are self-recruiting or if larval dispersal occurs over a much larger area. If local populations are largely self-recruiting, then management becomes a localized problem, and different management practices may be justified in different areas. Electrophoretic work by Hedgecock and Bartley (1988) suggests the possibility of genetically distinct populations of California halibut even within the Southern California Bight. Further studies at the molecular level may provide valuable insight into the population structure and amount of gene flow between regions within this species' range.

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