Otolith Size versus Weight and Body-Length Relationships for Eleven Fish Species of Baja California, Mexico

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Identification of otoliths recovered from scats or stomachs of marine mammals has been used in feeding-habit studies in recent years (Fitch and Brownell 1968, Brown and Mate 1982, Antonelis et al. 1984, Aurioles et al. 1984). Because of the relatively large number of pinniped scats available, this method has proven useful for identifying prey. However, the method depends on the laborious collection of otoliths from fish in the study area. The relative frequency of a prey species in the diet is determined by the number of otoliths (either right or left) counted. However, two prey species with the same otolith count may not be of equal importance in the diet because of differences in biomass. Antonelis et al. (1984) addressed this problem by estimating the biomass of fish and one species of squid off California, from regressions of weight (biomass) versus the size of otoliths (or squid beaks). The relationship of otolith length to fish size or weight has been reported for other areas (Frost and Lowry 1981, Wyllie Echeverria 1987).

Eleven known species of California sea lion *Zalophus californianus* prey (Aurioles et al. 1984, Lowry and Oliver 1986) were sampled to obtain weight, body length, and otolith length to estimate regressions. These results will be useful for estimating prey size and weight in feeding-habit studies in areas where these fish species occur.

Methods

Fish were sampled by bottom trawling with commercial shrimp nets. Trawls were conducted at depths of 30–200 m on the continental shelf off the Pacific coast of Baja California (23°–27°N lat.) and in the southern Gulf of California. Trawling, fish sampling, and fish measurements were conducted aboard the Research Vessel El Puma owned by the Universidad Nacional Autonoma de Mexico during cruises in the summer and fall of 1987 and the summer of 1988.

Standard length (mm) and weight (g) were recorded for fresh fish specimens. Weight (±0.01 g) was measured using a digital scale (Ohaus). Calipers were used to measure the greatest length (anterior tip to posterior projection) of each dissected sagittal otolith. Values were averaged for each otolith pair. Linear regressions were used to determine the relationship between standard length or fish weight and otolith length.

Results and discussion

Eleven fish species were studied (Table 1). Serrano *Serranus aequidens* and yellowbelly lizardfish *Synodus jenkinsi* were collected in Bahia de La Paz (Golfo de California), while the remaining nine species were typically found off the western coast of Baja California.

The standard length of fishes sampled in this study fell within lengths reported in the literature (Miller and Lea 1976, Eschmeyer et al. 1983) (Table 1). Linear regression of otolith length (mm) against fish length for all species are given in Table 2.

A high correlation coefficient was obtained for the longfin sanddab *Citharichthys xanthostigma* (r 0.974) in spite of the small sample size (Table 2). This was probably due to the relatively large size range of individuals in the sample. Scatter plots of fish length on otolith length for 8 of the 11 species are shown in Figures 1–8. The remaining three species had correlation coefficients smaller than r 0.86 and were not plotted.

The equation for hake (Table 2) was the highest for the sampled species. Antonelis et al. (1984) calculated a regression equation for Pacific hake *Merluccius productus* collected off California. Using an otolith of 6 mm in length in their equation ($Y = 26.2 + 19.38x$), the predicted fish length would be 142.5 mm. Using the equation in Table 2 for hake collected in this study yields a length of 113.76 mm. A "dwarf" Pacific hake in Baja California waters was reported by Vrooman and Paloma (1977). Inada (1981) in an extensive study of the genus stated that the "dwarf" form is actually Panama hake *Merluccius angustimanus*. It is probable that our sample specimens were this species, which is limited in range to the area between 24° and 27°N latitude. According to Vrooman and Paloma (1977), and confirmed by several cruises conducted by the Centro de Investigaciones Biologicas de B.C.S (CIB), the southern limit of distribution of the "large" form of Pacific hake is probably near Bahia Sebastian Vizcaino (28°N lat.).

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Table 1
Lengths and weights of fish collected off Baja California that are known prey of the California sea lion *Zalophus californianus*.

Scientific name	Common name*	Maximum standard length (mm)**	n	Ranges of lengths and weights (mm)	(g)
Hippoglossina stomata	Bigmouth sole	400	83	95–230	11.8–240
Lepophidium prorates	Pink cusk eel	—	39	107–223	3.6–62
Ophidion scrippsae	Basketweave cusk eel	280	106	160–242	37.8–115
Serranus aequidens	Serrano	—	43	89–166	13.3–88.5
Prionotus stephanophrys	Lumptail searobin	390	193	67–240	5.6–263
Merluccius angustimanus	Panama hake	910	183	89–220	5.4–103.6
Calamus brachysomus	Pacific porgy	610	36	163–350	141.3–1135.6
Citharichthys xanthostigma	Longfin sanddab	250	46	59–200	1.8–161
Porichthys myriaster	Specklefin midshipman	510	75	140–350	25.7–527.5
Synodus lucioceps	California lizardfish	640	34	160–430	29.4–578
Synodus jenkinsi	Yellowbelly lizardfish	—	41	185–406	46.5–580.2

*Common name assigned in this study.
**Data from Miller and Lea 1976, Eschmeyer et al. 1983.

Table 2
Regression equations for fish length (Y) vs. otolith length (X) for fish collected off Baja California that are known prey of the California sea lion *Zalophus californianus*.

Species	n	Equation* Y = a + bX	Correlation coefficient	Percent r^2
Bigmouth sole	83	Y = (−5.976) + 5.47X	0.873	76.26
Pink cusk eel	39	Y = (−3.103) + 23.76X	0.915	83.77
Basketweave cusk eel	106	Y = (3.408) + 29.30X	0.930	87.86
Serrano	43	Y = (1.539) + 1.830X	0.857	73.56
Lumptail searobin	193	Y = (−17.649) + 27.26X	0.928	86.22
Panama hake	183	Y = (13.564) + 16.7X	0.979	95.89
Pacific porgy	36	Y = (−10.337) + 4.174X	0.945	89.31
Longfin sanddab	46	Y = (−3.898) + 31.48X	0.974	94.97
Specklefin midshipman	75	Y = (−4.518) + 2.92X	0.954	91.05
California lizardfish	34	Y = (1.694) + 4.975X	0.821	67.44
Yellowbelly lizardfish	41	Y = (−2.515) + 5.827X	0.864	74.78

*$P = 0.01$ for all equations.

Since equations for both the California and the Baja California samples were highly significant, the observed differences cannot be explained by measurement errors or data variation, but probably reflect different hake species.

Fish weight was regressed against otolith and fish lengths (Tables 3 and 4). When otolith size was used to estimate fish weight directly, the correlation coefficient, and consequently percent r-squared for some species (Table 3), was slightly smaller than the respective values of fish weight estimated from fish length (Table 4). Regression lines and scatter plots for eight fish species studied are shown in Figures 1–8.

Coefficients of fish weight on fish length were the highest (Table 4). The value of r^2 was greater than 90% in all cases. Thus, when comparing prey importance based on biomass in feeding-habit studies, both equations (Tables 3 and 4) should be used to estimate weight.

Acknowledgments

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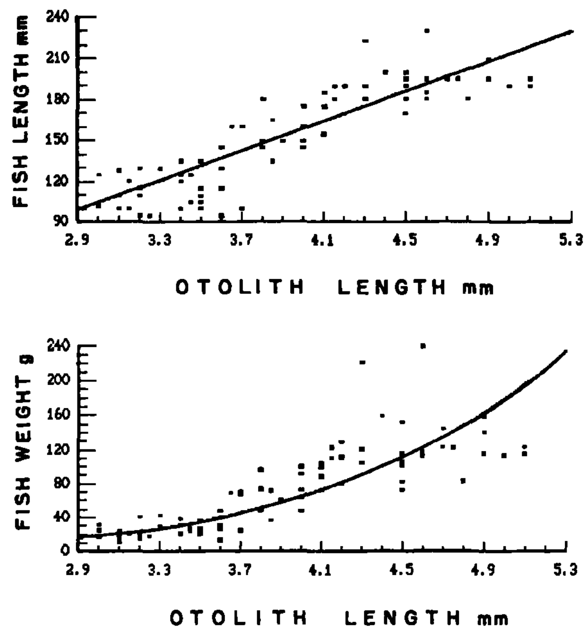

Figure 1
Relationship of fish length and weight to otolith size for bigmouth sole *Hippoglossina stomata* from Baja California.

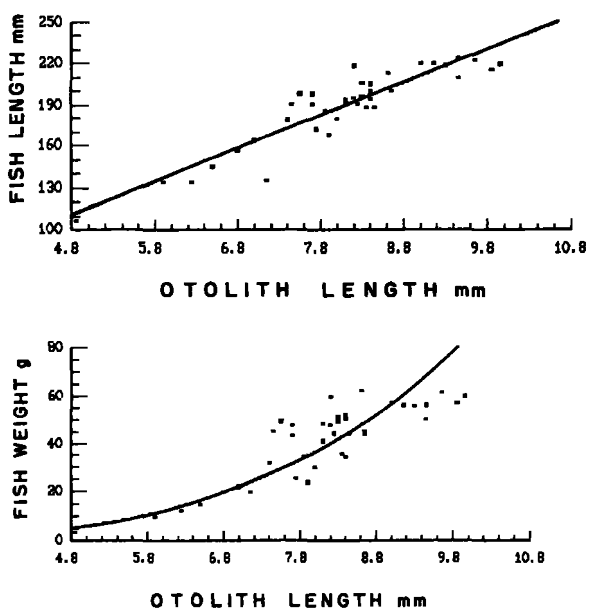

Figure 2
Relationship of fish length and weight to otolith size for pink cusk eel *Lepophidium prorates* from Baja California.

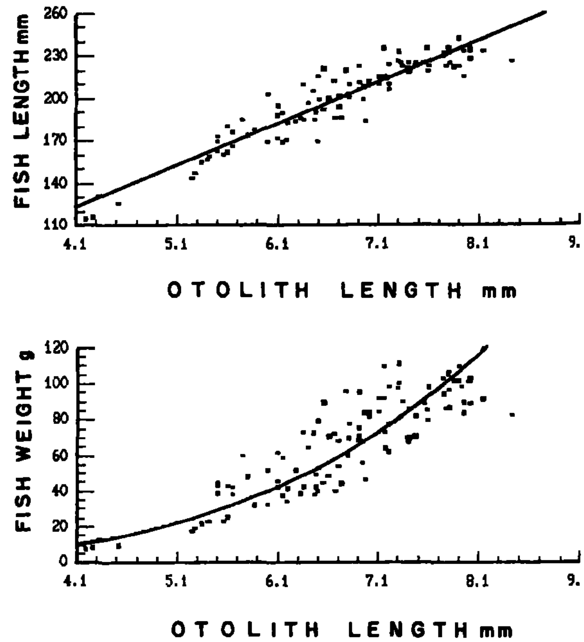

Figure 3
Relationship of fish length and weight to otolith size for basketweave cusk eel *Ophidion scrippsae* from Baja California.

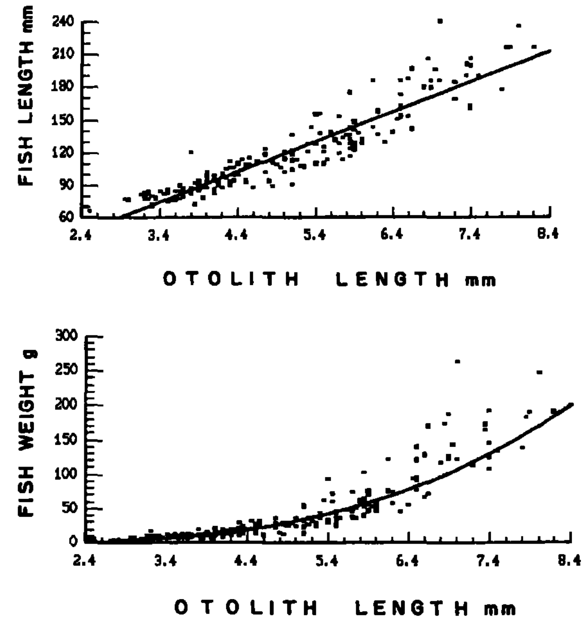

Figure 4
Relationship of fish length and weight to otolith size for lumptail searobin *Prionotus stephanophrys* from Baja California.

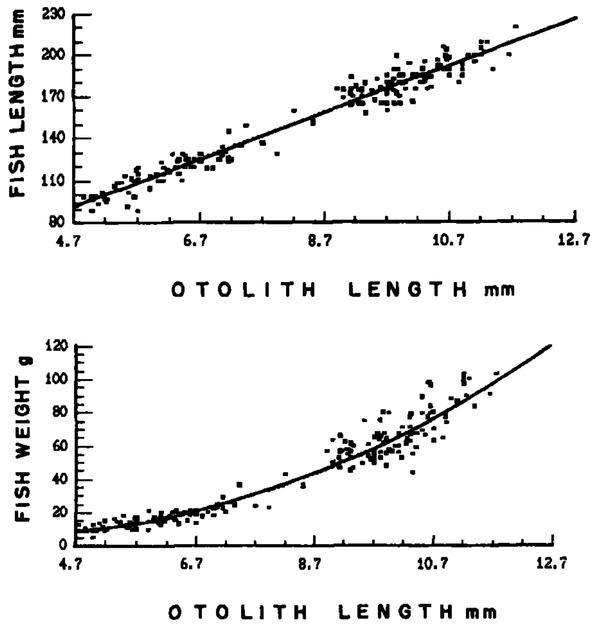

Figure 5
Relationship of fish length and weight to otolith size for Panama hake *Merluccius angustimanus* from Baja California.

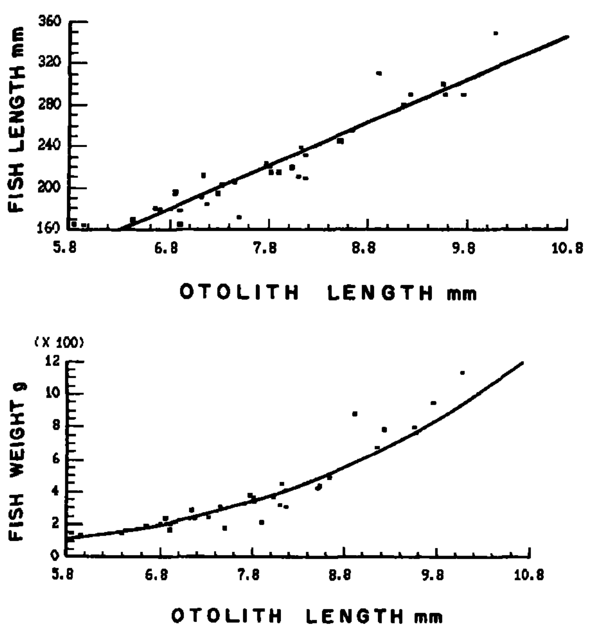

Figure 6
Relationship of fish length and weight to otolith size for Pacific porgy *Calamus brachysomus* from Baja California.

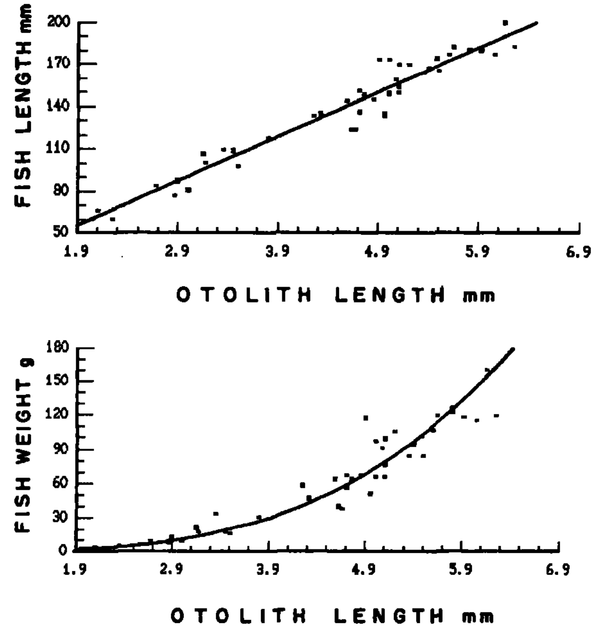

Figure 7
Relationship of fish length and weight to otolith size for longfin sanddab *Citharichthys xanthostigma* from Baja California.

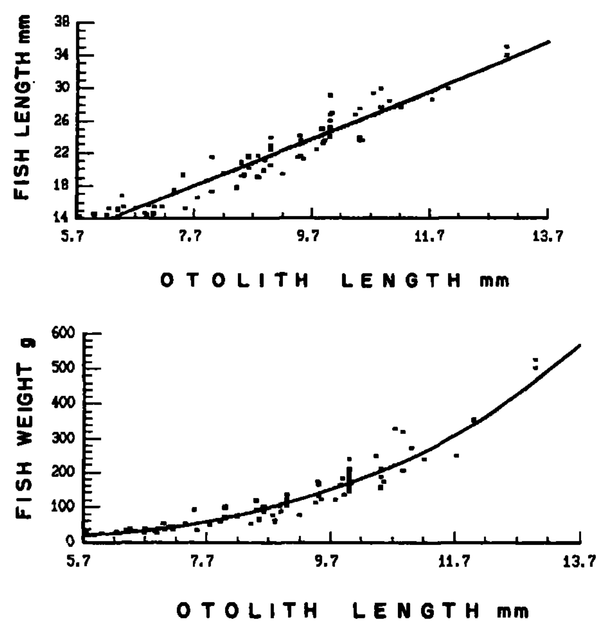

Figure 8
Relationship of fish length and weight to otolith size for specklefin midshipman *Porichthys myriaster* from Baja California.

Table 3

Regression equations for fish weight (Y) vs. otolith length (X) for fish collected off Baja California that are known prey of the California sea lion *Zalophus californianus*.

Species	Equation* $Y = a X^b$	Correlation coefficient	Percent r^2
Bigmouth sole	$Y = (-2.084)\ X^{4.51}$	0.877	76.93
Pink cusk eel	$Y = (-4.222)\ X^{3.75}$	0.912	83.20
Basketweave cusk eel	$Y = (-2.666)\ X^{3.54}$	0.908	82.60
Serrano	$Y = (-1.097)\ X^{2.63}$	0.858	73.69
Lumptail searobin	$Y = (-2.030)\ X^{3.44}$	0.944	89.25
Panama hake	$Y = (-2.091)\ X^{2.71}$	0.973	94.72
Pacific porgy	$Y = (-2.238)\ X^{3.9}$	0.948	89.88
Longfin sanddab	$Y = (-1.507)\ X^{3.6}$	0.979	95.90
Specklefin midshipman	$Y = (-3.756)\ X^{3.85}$	0.961	92.38
California lizardfish	$Y = (-2.65543\text{E-}3)\ X^{3.01}$	0.867	75.17
Yellowbelly lizardfish	$Y = (-0894)\ X^{3.69}$	0.854	73.09

*Intercept in parenthesis is equal to Log of a. $P = 0.01$ for all equations.

Table 4

Regression equations for fish weight (Y) vs. fish length (X) for fish collected off Baja California that are known prey of the California sea lion *Zalophus californianus*.

Species	Equation* $Y = a X^b$	Correlation coefficient	Percent r^2
Bigmouth sole	$Y = (-4.181)\ X^{3.03}$	0.978	95.68
Pink cusk eel	$Y = (-14.51)\ X^{3.46}$	0.968	93.86
Basketweave cusk eel	$Y = (-4.955)\ X^{3.05}$	0.964	93.04
Serrano	$Y = (-3.497)\ X^{2.82}$	0.976	95.34
Lumptail searobin	$Y = (-11.509)\ X^{3.15}$	0.988	97.74
Panama hake	$Y = (-11.213)\ X^{2.95}$	0.981	96.41
Pacific porgy	$Y = (-2.684)\ X^{2.75}$	0.984	97.01
Longfin sanddab	$Y = (-13.13)\ X^{3.46}$	0.992	98.59
Specklefin midshipman	$Y = (-5.001)\ X^{3.16}$	0.981	96.43
California lizardfish	$Y = (-4.953)\ X^{3.0}$	0.962	92.65
Yellowbelly lizardfish	$Y = (-5.801)\ X^{3.31}$	0.979	96.01

*Intercept in parenthesis is equal to Log of a. $P = 0.01$ for all equations.

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