Elasmobranchs

Kevin Fleming

Introduction

Five elasmobranchs were commonly collected in this survey from 1980 to 1995: brown smoothhound, *Mustelus henlei*; leopard shark, *Traikis semifasciatus*; bat ray, *Mylobatis californicus*; big skate, *Raja binoculata*; and spiny dogfish, *Squalus acanthias*. Members of this group share some common traits. In general, they are top marine predators, are long-lived and late maturing, and have long gestation periods.

Although otter trawl data were used for the description of elasmobranch abundance, our otter trawl is not efficient because most elasmobranchs are relatively large and capable of outmaneuvering or outswimming the trawl. Passive sampling gears such as trammel nets and long-lines are more efficient. More leopard sharks, bat rays, and six-gill sharks were collected during 2 weeks of a trammel net survey for sturgeon in San Pablo Bay than were caught in 15 years of monthly otter trawls (CDFG, unpublished).

Brown Smoothhound

Introduction

The brown smoothhound ranges from the Gulf of California to Humboldt Bay and from the intertidal zone to 110 m (Miller and Lea 1972). Throughout its range, it uses bays as nurseries (De Wit 1975, Russo 1975). The brown smoothhound is one of the most common shark species in San Francisco Bay (Herald and Ripley 1951, Russo 1975).

Mature brown smoothhounds give birth in spring (Roedel and Ripley 1950) to 3 to 5 pups (Compagno 1984), between 190 and 230 mm TL (De Wit 1975, Eschmeyer and others 1983). They mature in 2 to 3 years, between 510 and 660 mm TL (Compagno 1984, Yudin and Cailliet 1990) and may reach a maximum of about 950 mm TL (Miller and Lea 1972).

The brown smoothhound is primarily a bottom feeder and consumes mostly small crustaceans and fish (Herald and Ripley 1951, De Wit 1975, Russo 1975). The smaller sharks appear to feed in the intertidal while the larger ones feed in deeper water (Talent 1982).

Methods

Otter trawl data were used to describe abundance and distribution. Age–0 and age–1+ brown smoothhounds were separated based on visual examination of the length frequency data. Cutoff lengths used for separating age–0 fish from age–1+ fish were as follows for January through December: 300, 300, 300, 300, 310, 330, 360, 390, 400, 410, 420 and 430 mm. Different index periods were used for the 2 life stages: April to October for the age 0 and February to October for age 1+.

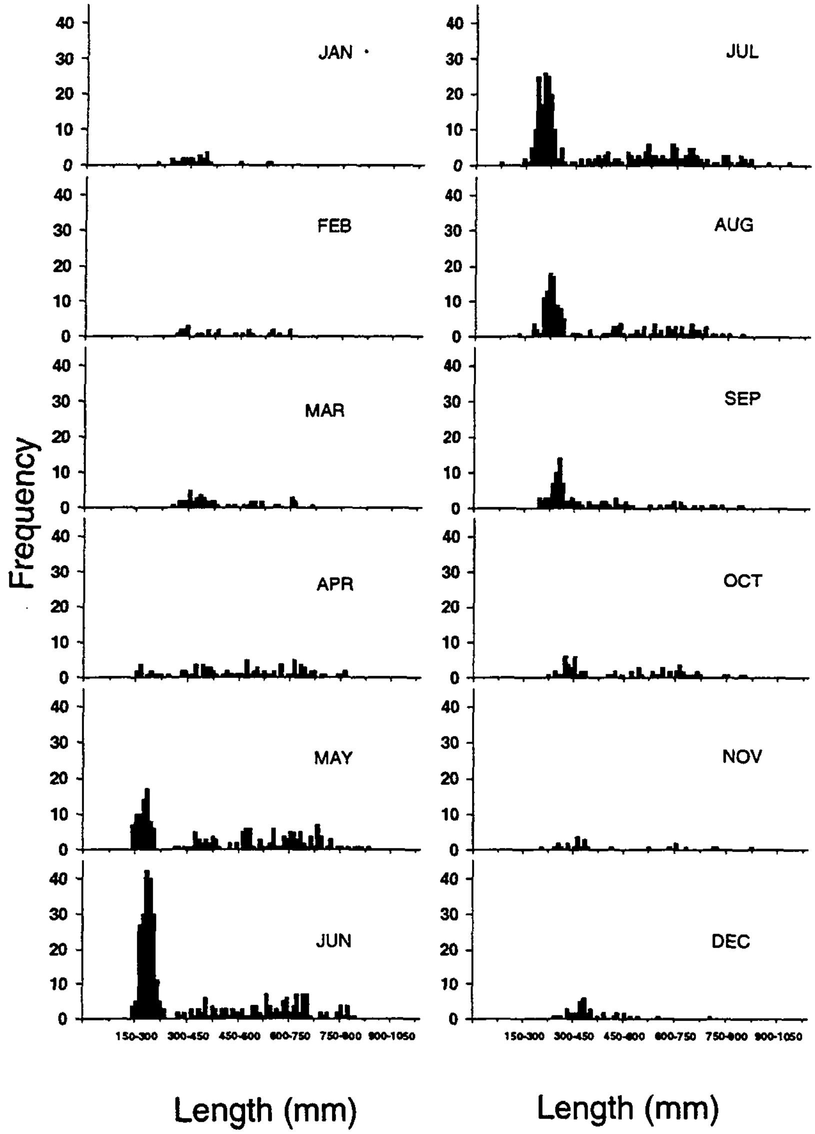

Figure 1 Length distribution of brown smoothhounds by month

Results

Length

There were clear distinctions between the abundance modes of age–0 and age–1+ brown smoothhounds (Figure 1). Both the smallest and largest sharks were collected in spring and early summer. The smallest brown smoothhounds were collected in April or May, soon after their birth. Examination of annual length frequencies reveals several modes (Figure 2). These modes correspond well with estimated ages from the literature (Yudin and Cailliet 1990). From year to year, the numbers and sizes of the age classes varied and appear to be related to water year type. In some dry years (for example, 1988 and 1989), over 5 age classes were discernible and young brown smoothhounds made up a large proportion of the annual catch. In wet years (for example, 1986 and 1995), few age classes were well represented.

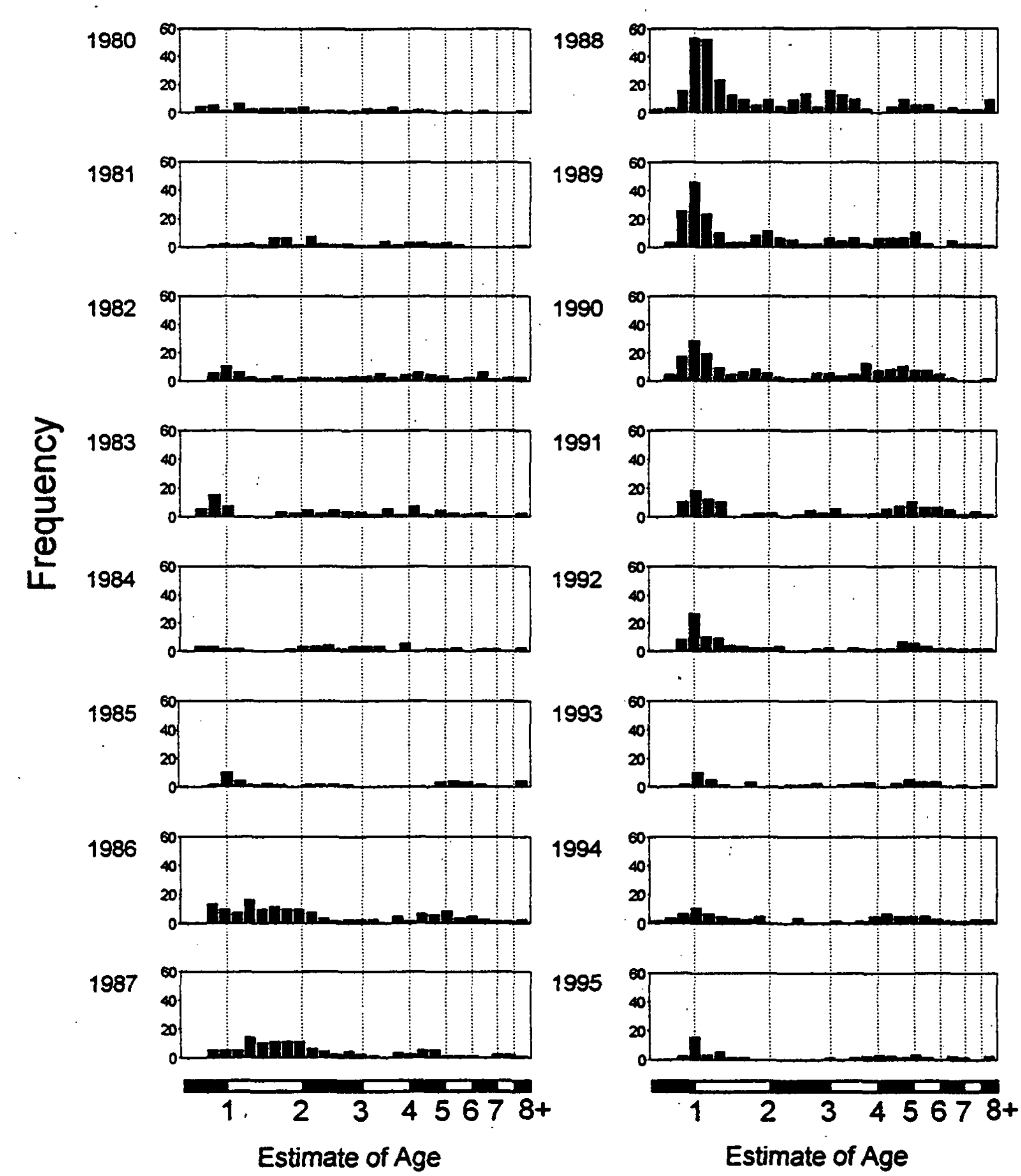

Figure 2 Length distribution of brown smoothhounds by year

Annual Abundance

The age–0 and age–1+ annual abundance indices of brown smoothhounds were significantly correlated (Pearson's $r = 0.908$, $P < 0.05$, $n = 16$). Abundance appeared to be cyclic and modes occurred in 1983 and 1989 (Figure 3, Tables 1 and 2). The abundance indices for both age groups were highest in 1989. The abundance of age–0 brown smoothhounds was lowest in 1984, and the lowest abundance of age–1+ sharks was in 1985.

Seasonal Abundance

The abundance of age–0 brown smoothhounds peaked in late spring or early summer (Figure 4) and was lowest in winter. Age–1+ brown smoothhounds were often collected all year. Their abundance also peaked in spring or summer and was lowest in winter.

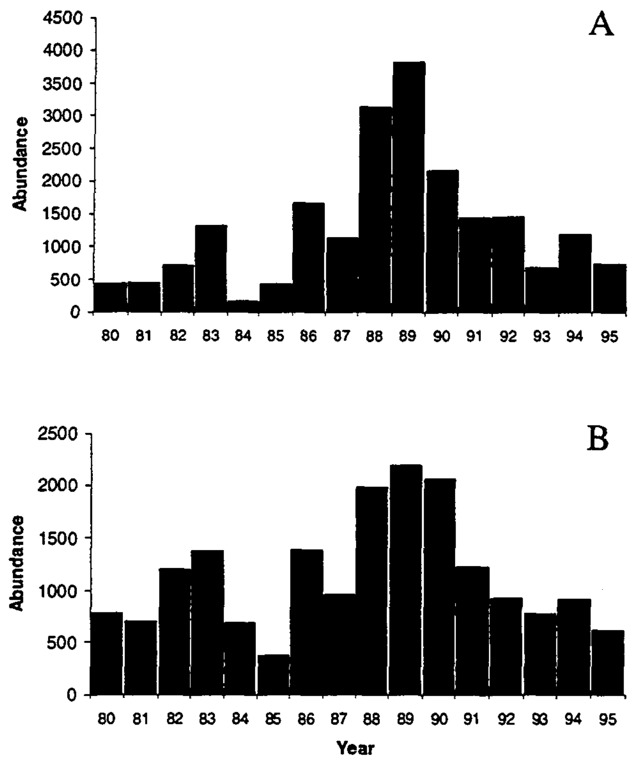

Figure 3 Annual abundance of brown smoothhounds: (A) age 0 and (B) age 1+

Table 1 Monthly abundance indices of age–0 brown smoothhound captured in the otter trawl from 1980 to 1995. The last column is the annual index, the mean abundance from February to October. The bottom row is the average seasonal abundance from 1981 to 1988.

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Index*
1980		0	0	0	1150	816	121	579	275	0	0	617	420
1981	194	0	0	0	0	267	0	449	1572	759	0	824	435
1982	0	0	0	0	1953	1013	1451	138	233	235	1064	531	717
1983	0	0	0	0	1106	6811	1067	147	0	57	0	462	1313
1984	0	0	0	0	0	183	699	138	0	0	0	0	146
1985	0	0	0	0	0	391	2271	0	164	176	0	441	429
1986	0	0	0	0	0	4392	580	3372	1630	1684	981	1178	1665
1987	0	0	0	0	0	2898	705	657	2926	696	1516	1199	1126
1988	0	0	0	267	1432	9838	4945	4310	873	315	260	214	3140
1989	0	0	0	308	305	6728	6545	5207					3819
1990		0	0	247	3636	4067	3347	2340	1455	0			2156
1991		0	0	0	1182	1894	1906	1486	2895	736			1442
1992		0	0	893	3846	1362	2402	918	57	681			1451
1993		0	0	1582	1369	1330	445	0	0	0			675
1994		0	0	542	0	2579	1243	2586	795	603			1193
1995	0	0	0	0	144	610	1454		1909	251	0	267	728
1981–1988	24	0	0	33	561	3224	1465	1151	925	490	478	606	

Table 2 Monthly abundance indices of age–1+ brown smoothhound captured in the otter trawl from 1980 to 1995. The last column is the annual index, the mean abundance from February to October. The bottom row is the average seasonal abundance from 1981 to 1988.

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Index*
1980		1333	1547	535	1686	889	810	0	186	0	206	0	776
1981	534	0	1112	1014	904	190	1192	1461	0	454	0	536	703
1982	813	813	0	705	3712	3519	564	699	244	564	0	195	1202
1983	188	0	0	0	158	4590	4186	2457	356	712	0	237	1384
1984	225	937	1647	898	295	1181	598	464	164	0	0	344	687
1985	0	0	514	164	0	617	855	0	550	654	237	0	373
1986	807	176	559	1829	2572	1596	1417	2884	655	838	397	183	1392
1987	2230	569	684	0	719	2297	444	632	2417	858	671	900	958
1988	284	0	2054	1961	4530	5471	2593	316	475	533	588	0	1993
1989	305	426	0	4514	3663	3526	2715	542					2198
1990		698	2208	5586	1845	3390	2590	535	190	1518			2062
1991		260	908	1245	1497	2510	2417	1148	303	754			1227
1992		637	213	893	1097	1124	1682	290	1087	1296			924
1993		427	0	0	754	641	3503	1439	0	247			779
1994		0	0	356	493	1202	1318	1749	1793	1327			915
1995	0	0	0	213	247	197	3473		388	476	0	0	624
1981-1988	635	312	821	821	1611	2433	1481	1114	608	577	237	299	

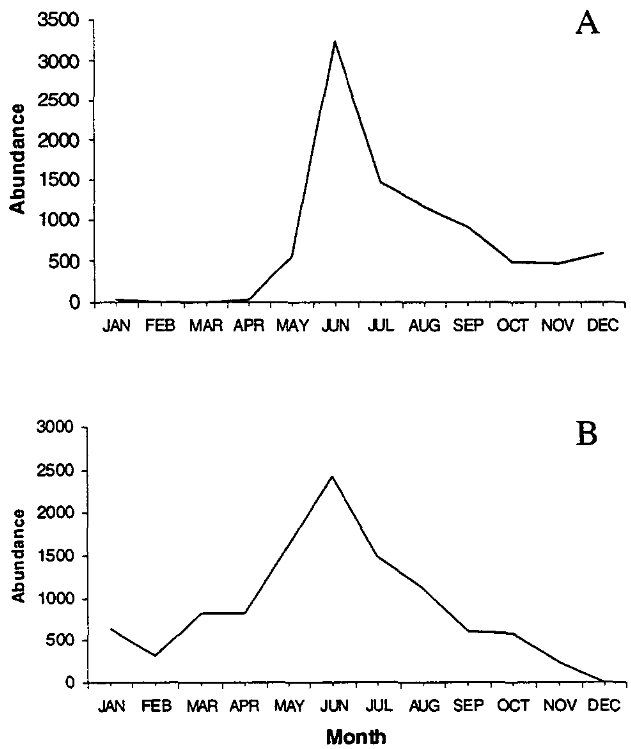

Figure 4 Seasonal abundance of brown smoothhounds from 1981 to 1988: (A) age 0 and (B) age 1+

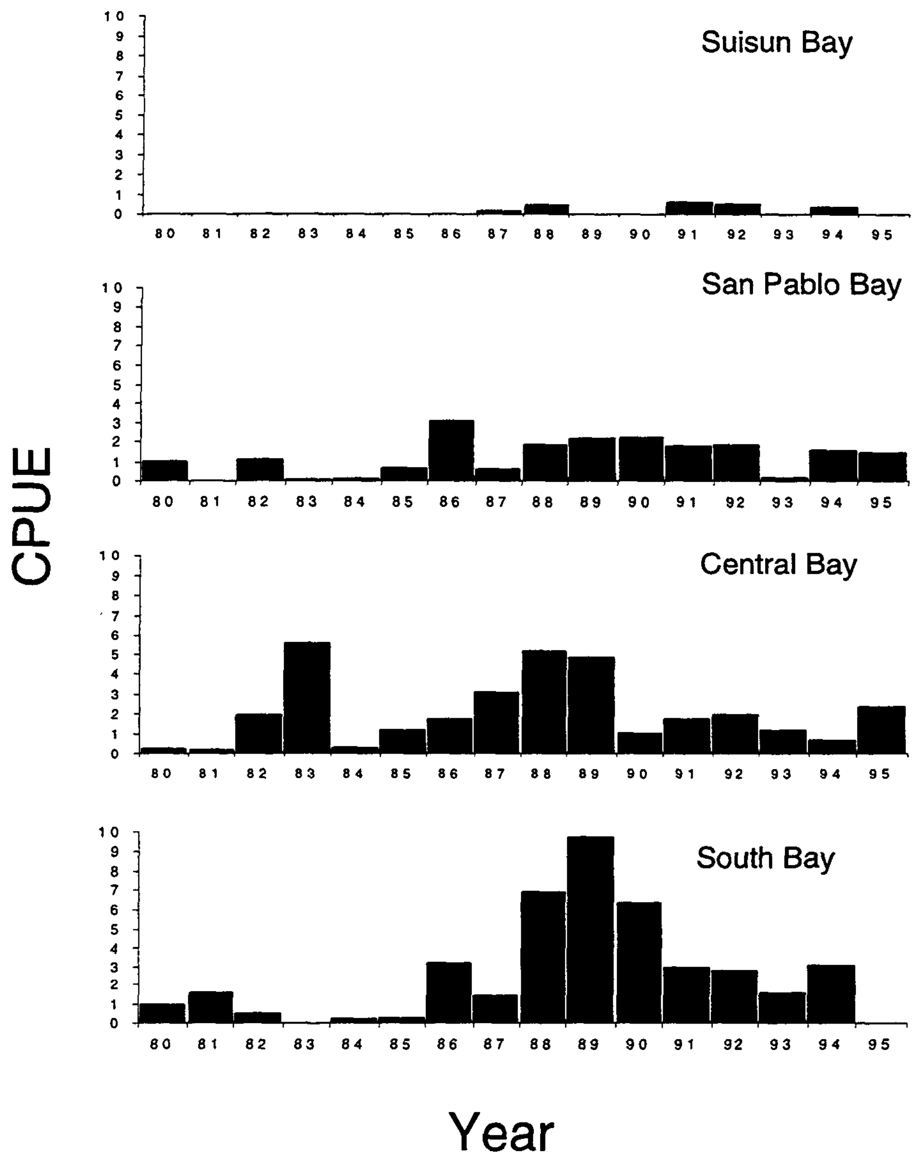

Figure 5 Annual distribution of age–0 brown smoothhounds by region. Values are the average CPUE for April to October.

Annual Distribution

Age–0 brown smoothhounds ranged from South to Suisun bays, but were most common in South and Central bays (Figure 5). In dry years, the CPUE increased in South and San Pablo bays, and the range extended into Suisun Bay. During wet years the CPUE tended to be higher in Central Bay and the range did not extend into Suisun Bay.

Unlike age–0 brown smoothhounds, age–1+ fish were not collected in Suisun Bay and their annual distribution did not vary as much. The highest CPUE, regardless of water year type, was always in Central Bay (Figure 6).

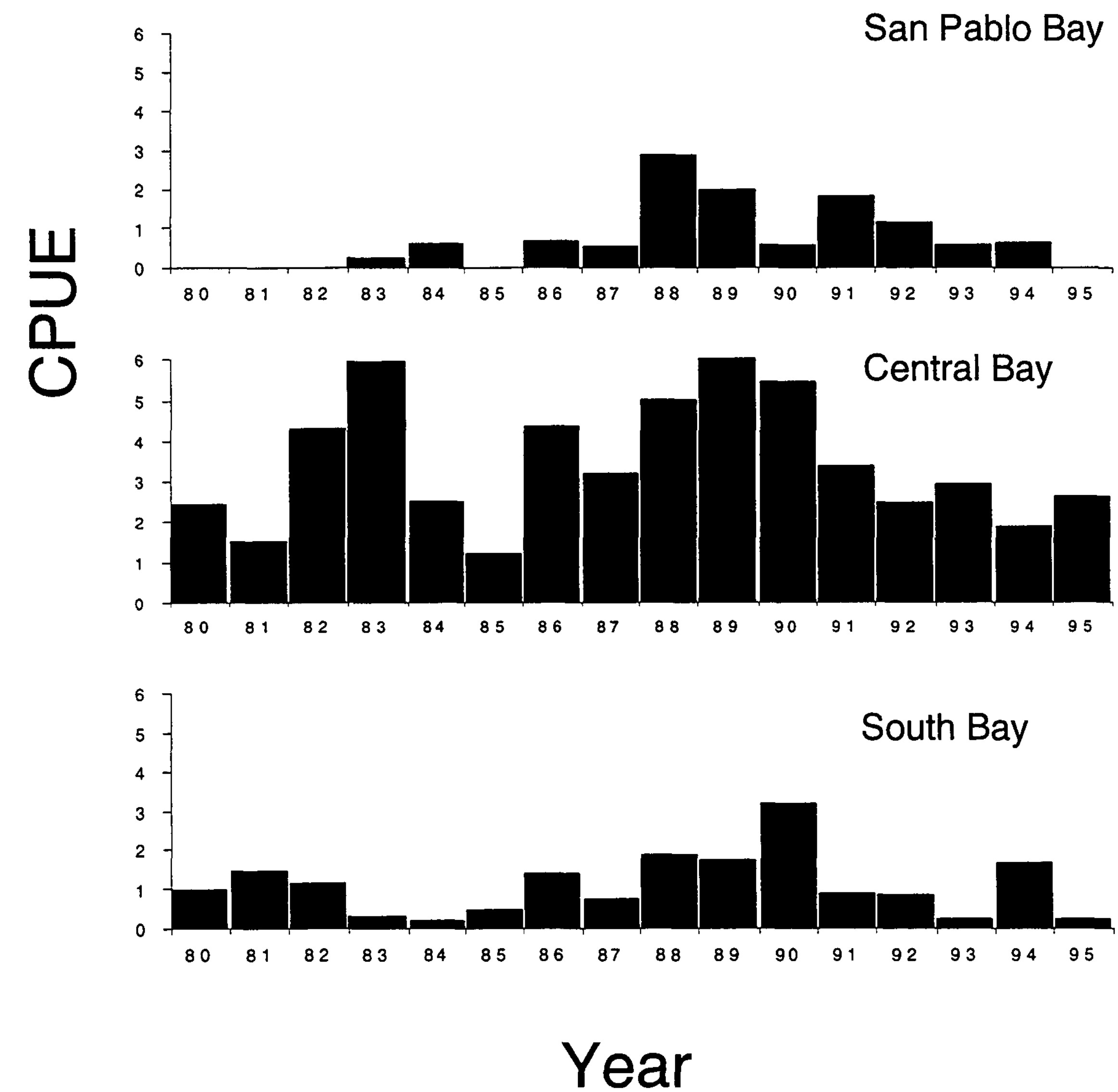

Figure 6 Annual distribution of age–1+ brown smoothhounds by region. Values are the average CPUE for February to October.

Seasonal Distribution

Age–0 brown smoothhounds were first caught in the trawl in spring (Figure 7). Densities, which tended to be higher in Central Bay, peaked in early summer.

Age–1+ brown smoothhounds were collected throughout year in Central and South bays, although many of those collected in winter were stragglers from the previous year class (Figure 8). In San Pablo Bay, age–1+ sharks were collected during spring and summer. The CPUE peaked in June throughout the estuary.

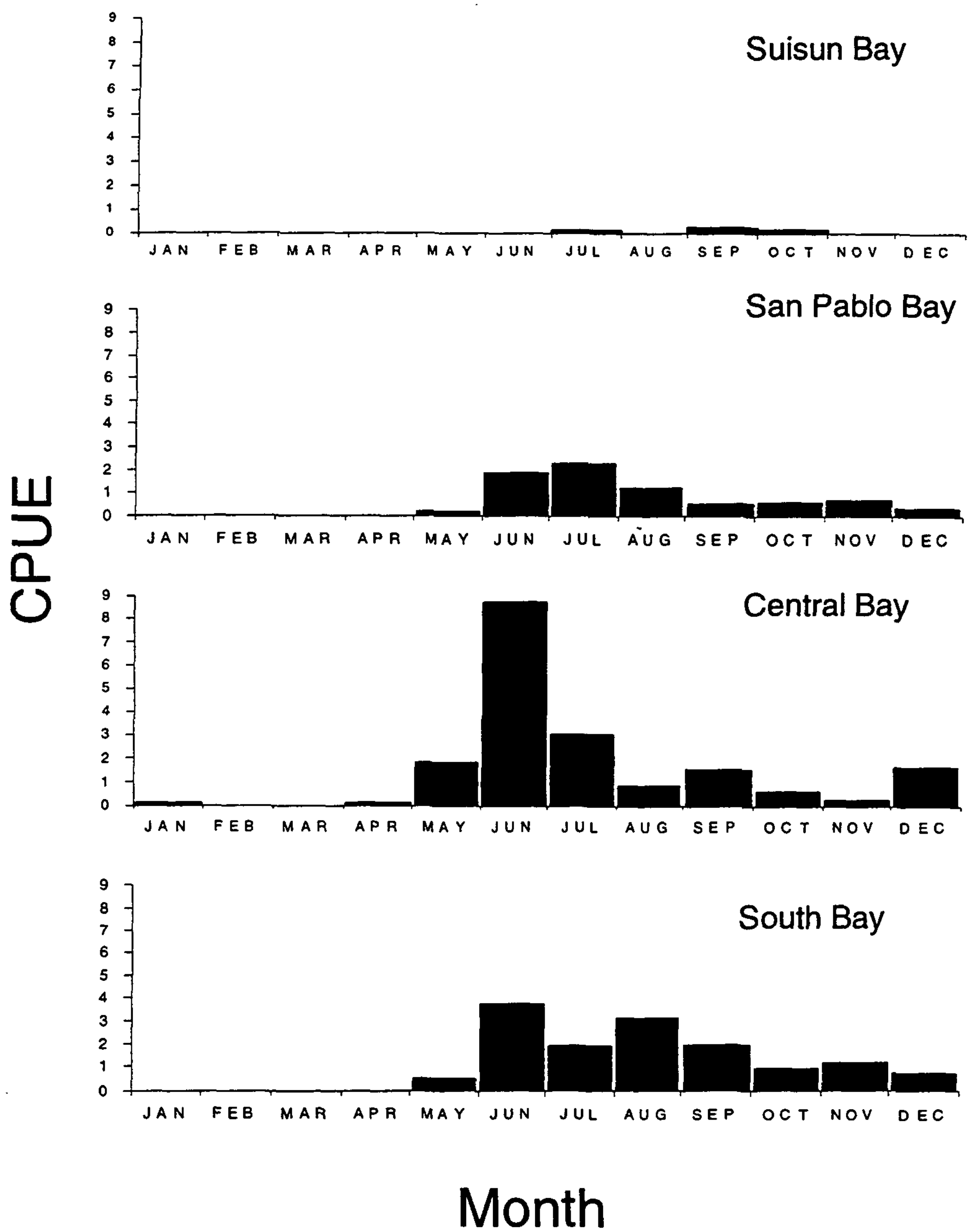

Figure 7 Seasonal distribution of age–0 brown smoothhounds by region. Values are the average CPUE for 1981 to 1988.

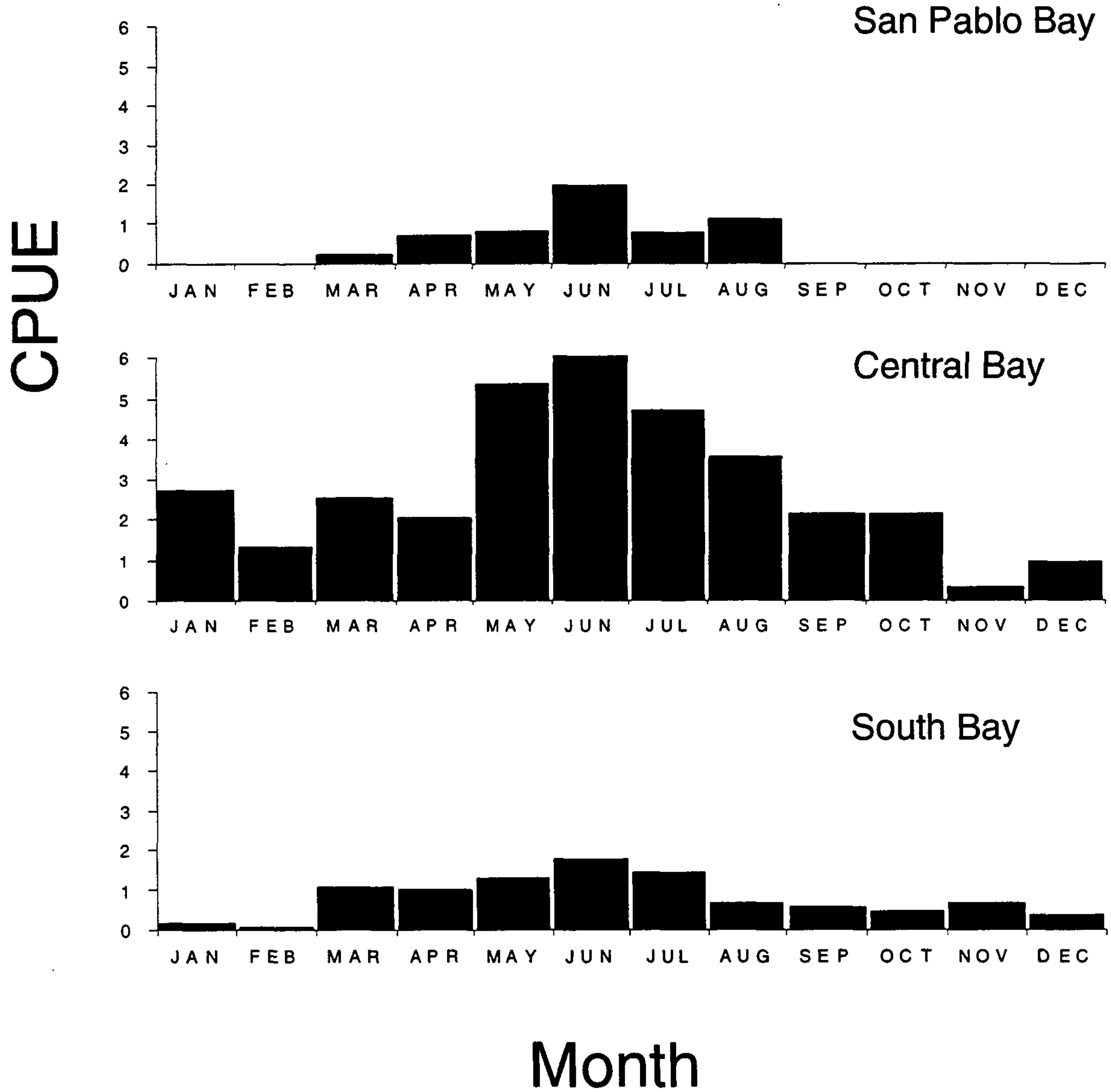

Figure 8 Seasonal distribution of age–1+ brown smoothhounds by region. Values are the average CPUE for 1981 to 1988.

Temperature and Salinity

Brown smoothhounds were primarily restricted to the warmer areas of the estuary (about 14 to 19 °C) that were in upper polyhaline to euhaline salinities (about 24‰ to 32‰) (Figures 9 and 10). Age–0 sharks were found at somewhat warmer temperatures than the age 1+; the mean temperature for age–0 sharks was 17.6 °C and for age–1+ it was 15.7 °C. The mean salinity for age–0 sharks (28.0‰) was close to the mean for age–1+ sharks (28.5‰).

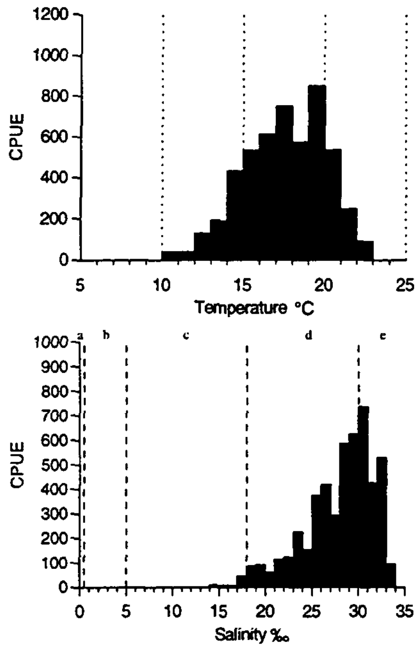

Figure 9 Temperature and salinity distributions of age–0 brown smoothhounds. The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.

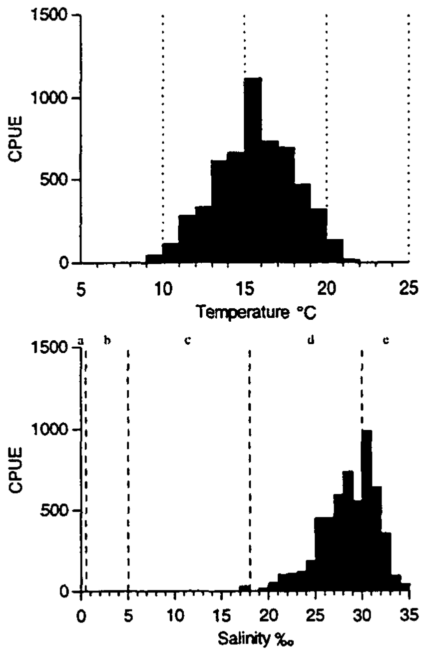

Figure 10 **Temperature and salinity distributions of age–1+ brown smoothhounds.** *The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.*

Discussion

The brown smoothhound was the most abundant shark collected. Brown smoothhounds were found primarily in relatively warm, polyhaline to euhaline waters of South and Central bays. During dry years, their estuarine abundance increased and the age structure appeared more stable.

Brown smoothhounds entered the estuary in spring and summer prior to pupping and left during the fall and winter. This seasonal migration has also been noted in earlier studies (De Wit 1975, Compagno 1984, Yudin and Cailliet 1990). Although (Compagno 1984) suggested that the seasonal movements are in response to changes in salinity, the present data indicates that temperature may also stimulate the migration. During most years, these factors covary closely, decreasing during winter and increasing in summer, and so the movements of brown smoothhounds may be attributed to either factor. However, during the 1987–1992 drought, salinity remained fairly high in winter but the sharks emigrated to the ocean, suggesting that temperature was the stimulus. In all years, their emigration occurred when temperatures dropped below about 14 °C.

High outflows regulated the distribution of mature brown smoothhounds by reducing the salinity of the upper reaches of the estuary and thereby restricting pupping to Central and South bays.

Leopard Shark

Introduction

The leopard shark is common in bays and nearshore areas from Mazatlan, Mexico to Oregon. A small shark, it attains a maximum length of about 195 cm (Miller and Lea 1972). In the San Francisco Estuary, most leopard sharks are resident but some emigrate from the estuary in fall (Smith and Abramson 1990). Leopard sharks are fished both commercially and recreationally, with the recreational fishery accounting for the majority of the catch (Smith and Abramson 1990). Concern over the potential for overfishing led to a sport size and bag limit in 1991.

Primarily a benthic feeder, the leopard shark changes its food habits with growth. Crustaceans are the most important food items for small leopard sharks but as they grow, their diet shifts towards fish (Talent 1976). Although they are often found in the intertidal zone, they apparently spend little time feeding there (Russo 1975).

The leopard shark reproduces only once per year (Smith and Abramson 1990) and has a litter of 4 to 29 pups (Eschmeyer and others 1983), which are born live in April and May (Talent 1985). The males reach maturity between 70 to 119 cm and about 7 years of age, and females between 100 to 129 cm and about 10 years (Ackerman 1971, Compagno 1984, Kusher and others 1992).

Methods

Otter trawl data were used to describe abundance and distribution. Separation of leopard sharks into 2 age classes was based on visual inspection of length frequency data. Cutoff lengths were 230, 230, 230, 270, 320, 360, 370, 380, 390, 410, 420 and 430 mm TL for January through December, respectively.

Results and Discussion

Based upon the literature (Smith 1984), most of the leopard sharks collected appeared to be 3 or 4 years old. Forty-seven age–0 leopard sharks were collected from 1980 to 1995. With the exception of 1982, the catch of age–0 leopard sharks tended to be highest in dry years (Table 3). The highest catches were in 1982 (9) and 1988 (13). No age–0 leopard sharks were collected in 1984, 1985, 1993, and 1995. Age–0 leopard sharks were restricted to South and Central bays and most were collected in South Bay.

The catch trend for the age–1+ leopard sharks was contrary to expectations for a marine species because, generally, more age–1+ sharks were caught in wet years. The highest catch was in 1980 and the lowest in 1985 (see Table 3). Age–1+ leopard sharks were collected all year in South and Central bays, although catches were highest in winter and early spring. Collections in San Pablo Bay occurred only in late spring and summer.

The temperature distribution of leopard sharks was bimodal, which may be an artifact of the low numbers collected. The mean collection temperature was 14.8 °C. Leopard sharks were collected in polyhaline and euhaline salinities at a mean of 26.6‰ (Figure 11).

Table 3 Annual otter trawl catch of sharks and rays

	Year															
Species	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*
Leopard shark, Age–0	1	1	9	5	1	0	2	5	13	1	2	3	1	0	3	0
Leopard shark, Age–1+	52	24	50	42	19	3	20	4	26	37	15	7	7	12	11	22
Leopard shark, All ages	53	25	59	47	20	3	22	9	39	38	17	10	8	12	14	22
Bat ray	13	34	22	12	18	9	36	8	32	18	36	18	26	8	11	18
Big skate	18	17	32	31	16	17	23	40	32	21	19	20	13	6	7	5
Spiny dogfish	3	3	5	4	4	2	2	1	7	4	6	3	4	0	2	1

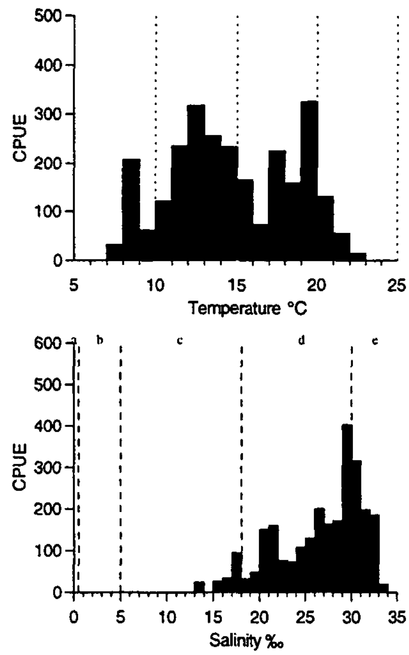

Figure 11 Temperature and salinity distributions of leopard sharks. The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.

Bat Ray

Introduction

Bat rays are common to bays and shallow sandy areas from the Gulf of California to Oregon. They have been found to 46 m deep (Miller and Lea 1972) and are opportunistic bottom feeders, feeding on mollusks and crustaceans (Karl and Obrebski 1976, Karl 1979, Talent 1982). The pits dug by feeding rays open areas for infaunal recolonization and uncover food items for other fish (Karl 1979).

Mating occurs during the summer months and is followed by a gestation period of 9 to 12 months (Martin and Cailliet 1988a). The young are born alive at 305 to 356 mm disk width (DW) and weigh about 0.9 kg (Baxter 1980), although Martin and Cailliet (1988a) reported a disk width of 220 to 305 mm at birth. The largest bat ray reported was a 95 kg female taken in Newport Bay (Baxter 1980). The males mature at 450 to 622 mm DW (2 to 3 years). Half of the females are mature at 881 mm DW (about 5 years).

Methods

Otter trawl data was used to describe bay ray abundance and distribution. Because of the relatively low numbers of bat rays, an abundance index was not calculated.

Results and Discussion

From 1980 to 1995, 319 bat rays were collected in the otter trawl. Based on a disk width and age relationship (Martin and Cailliet 1988b), very few of these (about 21) were age 0. Annual catches were highest in 1986, 1990, and 1992 and were lowest in 1985 and 1987 (see Table 3).

Bat rays were collected all year in South and Central bays and during the spring and summer in San Pablo Bay. Their absence from San Pablo Bay in winter suggests that low salinity limits their upstream distribution. Bat rays were primarily collected in upper polyhaline to euhaline salinities; the average bottom salinity was 28.1‰ (Figure 12). Water temperature did not appear to influence their geographic distribution, as they were collected over a broad temperature range from 9 to 23 °C (mean 17.1 °C).

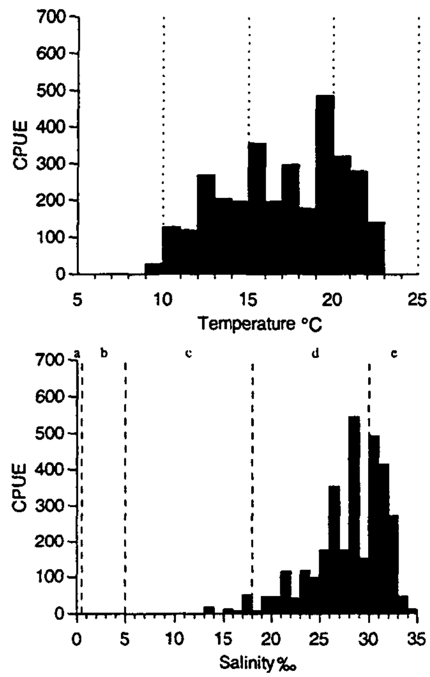

Figure 12 Temperature and salinity distributions of bat rays. The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.

Big Skate

Introduction

Big skates are found from Baja California to the Bering Sea (Miller and Lea 1972) but are uncommon south of Point Conception (Roedel and Ripley 1950). They have been collected from 3 to 110 m deep (Miller and Lea 1972). Big skates consume both crustaceans and fish (Hart 1973) and are an important commercial species along the California coast (Martin and Zorzi 1993).

Male big skates mature between 7 and 8 years at 1,000 to 1,100 mm TL, and females mature at about 12 years and 1,300 mm TL (Zeiner and Wolf 1993). They can reach 2,400 mm, but fish over 1,800 mm are rare (Miller and Lea 1972). The male to female ratio is 1:1 (Hitz 1964). Big skates lay horny egg cases that are up to 300 mm long (Hart 1973) and contain 1 to 8 eggs (Hitz 1964).

Methods

Otter trawl catches were used to describe abundance and distribution of big skates. Because relatively few big skates were collected, annual abundance indices were not calculated.

Results and Discussion

From 1980 to 1995, 318 big skates were collected. The highest catch was in 1987 and the lowest in 1995 (see Table 3). Catches were highest in spring and summer. Almost two-thirds of the big skates were collected in Central Bay channels. Based upon literature growth curves (Zeiner and Wolf 1993), few big skates collected during this survey were either mature (57) or age 0 (49), most appeared to be between 3 and 5 years old.

Most of the big skates were found in the cooler waters of the estuary at upper polyhaline to euhaline salinities (Figure 13). Their distribution appeared to be restricted upstream by low salinity and in South Bay by high temperature. Big skates were collected at a mean temperature of 14.3 °C and a mean salinity of 27.9‰.

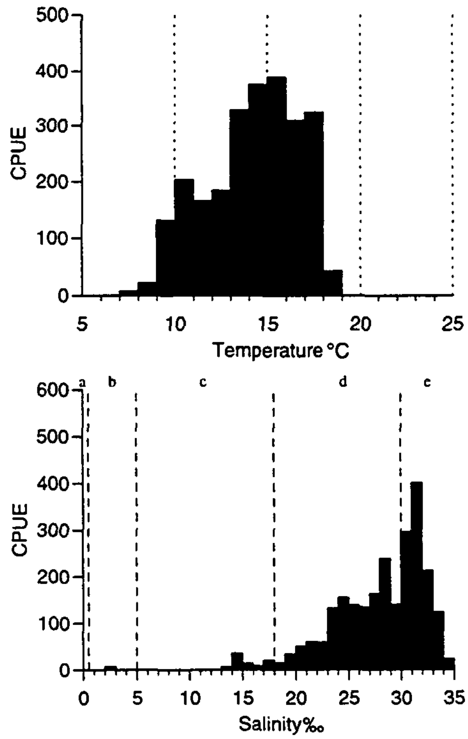

Figure 13 Temperature and salinity distributions of big skates. The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.

References

Ackerman, L.T. 1971. Contribution to the biology of the leopard shark, *Traikis semifasciatus* (Girard) in Elkhorn Slough, Monterey Bay, California. M.A. Thesis. California State University, Sacramento.

Baxter, R.L. 1980. Bat Ray *Myliobatis californica*. Inshore Fishes of California.Sacramento, California.

Compagno, L.J.V. 1984. Pages 251–655 *in*: FAO species catalogue. Volume 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2. Carcharhiniformes.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America from the Gulf of Alaska to Baja California. Houghton Mifflin Co., Boston, Massachusetts.

De Wit, L.A. 1975. Changes in the species composition of sharks in south San Francisco Bay. California Fish and Game 61:106–111.

Hart, J.L., editor. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180.

Herald, E.S. and W.E. Ripley. 1951. The relative abundance of sharks and bat stingrays in San Francisco Bay. California Fish and Game 37:315–329.

Hitz, C.R. 1964. Observations on egg cases of the big skate (*Raja binoculata* Girard) found in Oregon coastal waters. Journal of Fisheries Research Board of Canada 21:851–854.

Karl, S. R. 1979. Fish feeding habit studies from Tomales Bay, California. MS thesis. University of the Pacific, Stockton, California.

Karl, S. and S. Obrebski. 1976. The feeding biology of the bat ray, *Myliobatis californica* in Tomales Bay, California. Pages 181–186 *in*: C.A. Simenstad, S.J. Lipovsk, editors. Astoria, Oregon. Washington Sea Grant, Seattle, Washington.

Kusher, D.I., S.E. Smith, and G.M. Cailliet. 1992. Validated age and growth of the leopard shark, *Traikis semifasciata*, with comments on reproduction. Environmental Biology of Fishes 35:187–203.

Martin, L. and G.D. Zorzi. 1993. Status and review of the California skate fishery. National Oceanographic and Atmospheric Administration–National Marine Fisheries Service. Report 115.

Martin, L K. and G.M. Cailliet. 1988a. Aspects of the reproduction of the bat ray, *Myliobatis californica*, in central California. Copeia 3:754–762.

Martin, L.K. and G.M. Cailliet. 1988b. Age and growth determination of the bat ray, *Myliobatis californica* Gill, in central California. Copeia 3:763–773.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157.

Roedel, P.M. and W.E. Ripley. 1950. California sharks and rays. California Department of Fish and Game, Fish Bulletin 75.

Russo, R.A. 1975. Observations on the food habits of leopard sharks (*Triakis semifasciata*) and brown smoothhounds (*Mustelus henlei*). California Fish and Game 61:95–103.

Smith, S.E. 1984. Timing of vertebral-band deposition in tetracycline-injected leopard sharks. Transactions of the American Fisheries Society 113:308–313.

Smith, S.E. and N.J. Abramson. 1990. Leopard shark (*Triakis semifasciata*) distribution, mortality rate, yield, and stock replenishment estimates based on a tagging study in San Francisco Bay. Fishery Bulletin 88:371–381.

Talent, L.G. 1976. Food habits of the leopard shark, *Triakis semifasciata*, in Elkhorn Slough, Monterey Bay, California. California Fish and Game 62:286–298.

Talent, L.G. 1982. Food habits of the gray smoothhound, *Mustelus californicus*, the brown smoothhound, *Mustelus henlei*, the shovelnose guitarfish, *Rhinobatos productus*, and the bat ray, *Myliobatis californica* in Elkhorn Slough, California. California Fish and Game 68:224–234.

Talent, L.G. 1985. The occurrence, seasonal distribution, and reproductive condition of elasmobranch fishes in Elkhorn Slough, California. California Fish and Game 71:210–219.

Yudin, K.G. and G.M. Cailliet. 1990. Age and growth of the gray smoothhound, *Mustelus californicus*, and the brown smoothhound, *M. henlei*, sharks. American Elasmobranch Society Symposium Papers. Copeia 1:191–204.

Zeiner, S.J. and P. Wolf. 1993. Growth characteristics and estimates of age at maturity of two species of Skates (*Raja binoculata* and *Raja rhina*) from Monterey Bay, California. National Oceanographic and Atmospheric Administration–National Marine Fisheries Service. Report 115.