TRAP-CAUGHT SABLEFISH IN MONTEREY BAY, CALIFORNIA

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Abstract. During the course of this year-long study, 203 baited traps were set, resulting in the capture of 2632 sablefish, of which 1450 were tagged. An additional 1051 sablefish from other sources were sampled, making a total of 3683 sablefish analyzed. Catch rates at 50 fathoms (fm) were consistently low, and higher catch rates indicated that sablefish were most abundant at 300-750 fm. Sablefish showed a regular increase in size with depth, with the higher percentage of 'large' fish found at 500-750 fm. Seasonal variations were demonstrated at 100 fm by elevated catch rates and the presence of larger fish during the summer months, whereas little seasonality appeared in deeper waters. Squid proved to be a more effective bait than anchovy both in initial attractiveness and longevity. One and two-day soak times with squid bait yielded the best catches per trap, however 4-hr soak times yielded the best catch rates when standardized to a 48-hr period. Overall, female sablefish predominated in this study, with males most numerous among small fish. Sablefish in Monterey Bay spawned between November and February in waters deeper than 300 fm. Among fish of a given size, the more ripe individuals tended to be found in deeper waters. Preliminary tag returns indicated that sablefish in Monterey Bay are generally localized. Sablefish traps were very selective at depths from 300-750 fm, while at 50 fm, incidental species greatly outnumbered sablefish.

INTRODUCTION

Sablefish, *Anoplopoma fimbria*, support a small but important commercial fishery along the Pacific Coast of the United States and are marketed primarily as a fresh or smoked product. The larger fish (over seven pounds in the round) are usually smoked and sold as "smoked cod". The smaller fish are filleted and usually marketed locally as "butterfish". Other names include blackcod (the original name), candlefish, Alaska black cod, coal cod, blue cod, and deep-sea trout (Phillips 1958). Since 1916 when catch statistics were initiated in California, the catch has fluctuated from 83,626 pounds to a peak of 6.3 million pounds in 1945 (Parrish 1973). During this period longlines and trawls accounted for the majority of the

	DEPTH (FATHOMS)			
	100	300	500	≥600
Mean number of fish per trap	17.1± 5.3	13.1± 3.9	26.4± 6.0	20.8± 6.1
Mean percent small fish	74.5±10.5	47.2± 7.7	43.5± 7.6	5.9± 4.8
Mean percent medium fish	14.5± 7.3	21.8± 5.1	24.7± 3.9	27.1± 8.2
Mean percent large fish	4.9± 3.2	26.4± 7.3	31.8± 6.8	67.1± 5.4
Mean weight(lbs) of catch per trap	61.7±20.9	76.2±23.0	180.4±43.7	177.9±56.4
Mean percent small fish	65.4±11.1	33.2± 7.0	30.5± 8.3	3.0± 8.3
Mean percent medium fish	18.9± 8.0	22.0± 5.1	22.5± 4.5	19.6± 8.1
Medium percent large fish	9.6± 5.2	40.1± 8.1	46.3± 8.8	77.4± 6.9
Number of traps	33	43	31	8

Table 1. Mean number of fish and mean weight of catch per trap for one and two day sets. Numbers represent mean values ±the 95% confidence intervals for the mean. Mean percents were calculated from the percent of large, medium, and small fish for each trap.

sablefish harvested.

Trawl-caught landings of sablefish show little fluctuation and remain relatively stable, reflecting the trawling effort. This is because trawlers seek other species of fish and catch sablefish incidentally (Parrish 1973). Trawl-caught sablefish are usually less desirable to the fish buyer since the fish are smaller than longline-caught fish because most trawlers work in relatively shallow waters where small sablefish predominate (Parks 1973).

Sablefish have been shown to be highly attracted to odoriferous bait (Isaacs and Schick 1960). A funnelled trap with a baited cannister has been developed for use in catching sablefish (High 1971; Hipkins and Beardsley 1970; Hughes et al. 1970). With the development of these sablefish traps in the 1960's by the National Marine Fisheries Service, Seattle, many longline fishermen and fishermen new to sablefish fishing have been using the traps. However, this method had not been used in Monterey Bay prior to 1973. One of the advantages of traps is the labor saved over the longlining procedure. For example, Monterey longline boats would fish for one day and use the second day to rebait (James Hardwick, personal communication). Traps need very little manpower, and when properly set up, a fishing boat can operate with two people.

There is quite a body of literature dealing with sablefish natural history and fishery biology. Sablefish are in the family Anoplopomatidae along with only one other species, the skilfish, Erilepis zonifer (Hart 1973; Miller and Lea 1972). Sablefish occur in the eastern Pacific from Cedros Island, Baja California, to the Aleutian Islands and also from the Bering Sea to Japan (Hart 1973). Their depth distribution ranges from 0 to 833 fm (1524 m) (Miller and Lea 1972). The juveniles from age 0 to about age 1 are epipelagic. From about age 1 to age 2 juvenile sablefish can be either epipelagic or associated with the bottom at around 50 fm (100 m) depth (Kennedy and Smith 1972). Older sablefish are strongly demersal and are commonly found from 200 fm (366 m) to 450 fm (823 m) (Heyamoto and Alton 1965; Alverson et al. 1964).

The limited tagging and meristic counts of sablefish captured off California, Oregon, Washington, British Columbia, and Alaska indicate sablefish undergo limited intermixture and are segregated into localized stocks (Phillips 1969; Phillips et al. 1954).

The sablefish of Monterey Bay have been little studied. A Sea Grant funded study was undertaken to determine the feasibility of using traps to catch sablefish in Monterey Bay. Included in the objectives of this study were 1) to compare the catch rate and length frequencies (and therefore distribution) of sablefish with depth and season, 2) to compare the catch rates of different baits, 3) to determine sex ratios and the breeding season of sablefish, 4) to determine migratory patterns by tagging, and 5) to determine if other species are susceptible to trapping.

ACKNOWLEDGEMENTS

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BAIT	SOAK TIME			
	4 hr	1 day	2 day	≥3 day
SQUID				
No. fish/trap	14.7 ±17.1	23.3± 4.6	35.3± 18.4	7.7± 5.6
No. fish/hour	2.9± 2.9	1.0± 0.2	0.8± 0.4	0.1± 0.03
Catch(lbs)/trap	93.5± 95.5	132.5± 29.8	183.4±181.2	63.8± 75.7
Catch(lbs)/hour	21.7± 3.2	5.8± 1.3	4.0± 3.7	0.5± 0.5
No. of traps	3	56	4	3
ANCHOVY				
No. fish/trap	3.8± 3.6	13.2± 3.0	7.7± 21.3	5.5± 3.3
No. fish/hour	1.0± 0.9	0.6± 0.1	0.2± 0.4	0.1± 0.1
Catch(lbs)/trap	18.3± 18.6	70.5± 18.7	36.0±101.7	16.1± 8.0
Catch(lbs)/hour	4.6± 4.7	3.1± 0.8	0.8± 2.1	0.2± 0.1
No. of traps	19	36	3	4

Table 2. Catch rates with different baits and soak times for traps set in 100-500 fm. Numbers represent mean values ±the 95% confidence intervals for the mean.

Research Base, Seattle, Washington, were instrumental in providing information on the use of pot traps. The Rold Brothers, Moss Landing, California helped construct our traps and allowed us to sample their catch. Conrad Recksiek and James Hardwick reviewed the manuscript.

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MATERIALS AND METHODS

Sablefish were collected using traps, otter trawls, hook and line, and gill nets. Traps were used primarily. Other methods were utilized to capture fish not available to the traps. Commercial lampara net and purse seine catches of anchovy and squid were also sampled for small sablefish. Sablefish specimens were also obtained from the local commercial trap fishermen.

Our traps were based upon a design described by Hipkins and Beardsley (1970), and were constructed of 0.5 in (1.3 cm) reinforcing bar, welded together so they formed a rectangular frame box 2.5 ft x 2.5 ft (76.2 cm) x 6 ft (182.9 cm). Nylon netting, 3.5 in (8.9 cm) stretch mesh, was hung with nylon twine from the rectangular frame with a funnel made of the same material at one end. The netting on the door at the other end was hung with cotton twine so that it would serve as an escape panel in the event the trap was lost. The bait was held in a plastic gallon jar, perforated with 2 mm holes so that odors could diffuse out, yet not allow hagfishes or amphipods to enter and consume the bait. This bait container was suspended with rubber bands between two sides of the trap opposite the mouth of the funnel. Baits included market squid (Loligo opalescens), northern anchovy (Engraulis mordax), Pacific herring, and various demersal fishes. These various baits were initially tested for their effectiveness in attracting sablefish, but only squid and anchovy were used on a regular basis because of their availability and effectiveness.

Three traps were generally placed 60 fm (110 m) apart on a 0.5 in (1.3 cm) ground line that was tethered to a buoy line at one end. The buoy line was approximately 25% longer than the depth of the water and had a support buoy and a spar buoy with a radar reflector and red flag attached at the surface end.

Stations were located in the Monterey Submarine Canyon (Fig. 1), with stations A and B at 500 fm (915 m), C and D at 300 fm (549 m), E and F at 100 fm (183 m), and G and H at 50 fm (91 m) of water. These stations were chosen primarily for their depth and bottom topography. Occasional samples were taken at depths exceeding 500 fm but these depths were not sampled regularly. Sampling at the regular stations was conducted on a monthly basis from November, 1973 to November, 1974. Weather conditions occasionally prevented monthly samples at all depths.

Fish captured in the traps were either tagged and returned alive to the water or were collected and dissected. Fish to be tagged were immediately removed from the trap and placed in galvanized washtubs or plastic-lined boxes filled with running sea water. When catches were too large for the holding tanks, the remaining fish were kept in the trap and sprayed with sea water or the trap was lowered back into the water until the fish could all be tagged. Serially numbered internal anchor tags (Floy Tag and Manufacturing Company), having the address of the Moss Landing Marine Laboratories printed on them, were securely inserted on the left side of the fish, ventral and posterior to the origin of the first dorsal fin with a tagging gun (Floy FD-67) (Kennedy and Smith 1972). Prior to release, standard lengths were recorded and a scale sample was taken. Upon being returned to the water, the condition of the tagged fish was categorized as: good, fair, or poor.

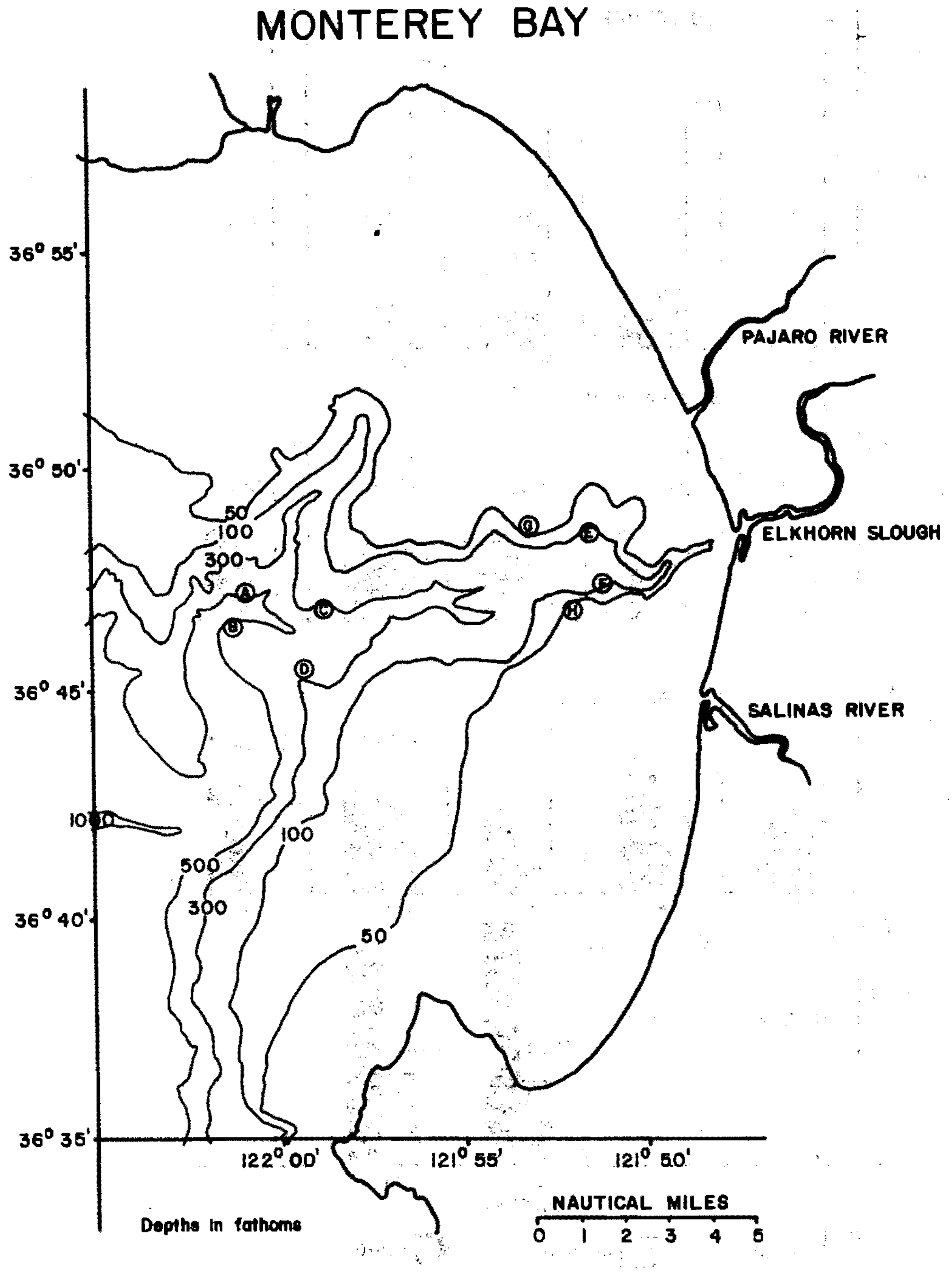

Figure 1. Monterey Bay, California and the Monterey Submarine Canyon with depth contours given in fathoms. Station locations are labelled A-H. Stations A and B are in 500 fathoms, C and D in 300 fms, E and F in 100 fms, and G and H in 50 fms.

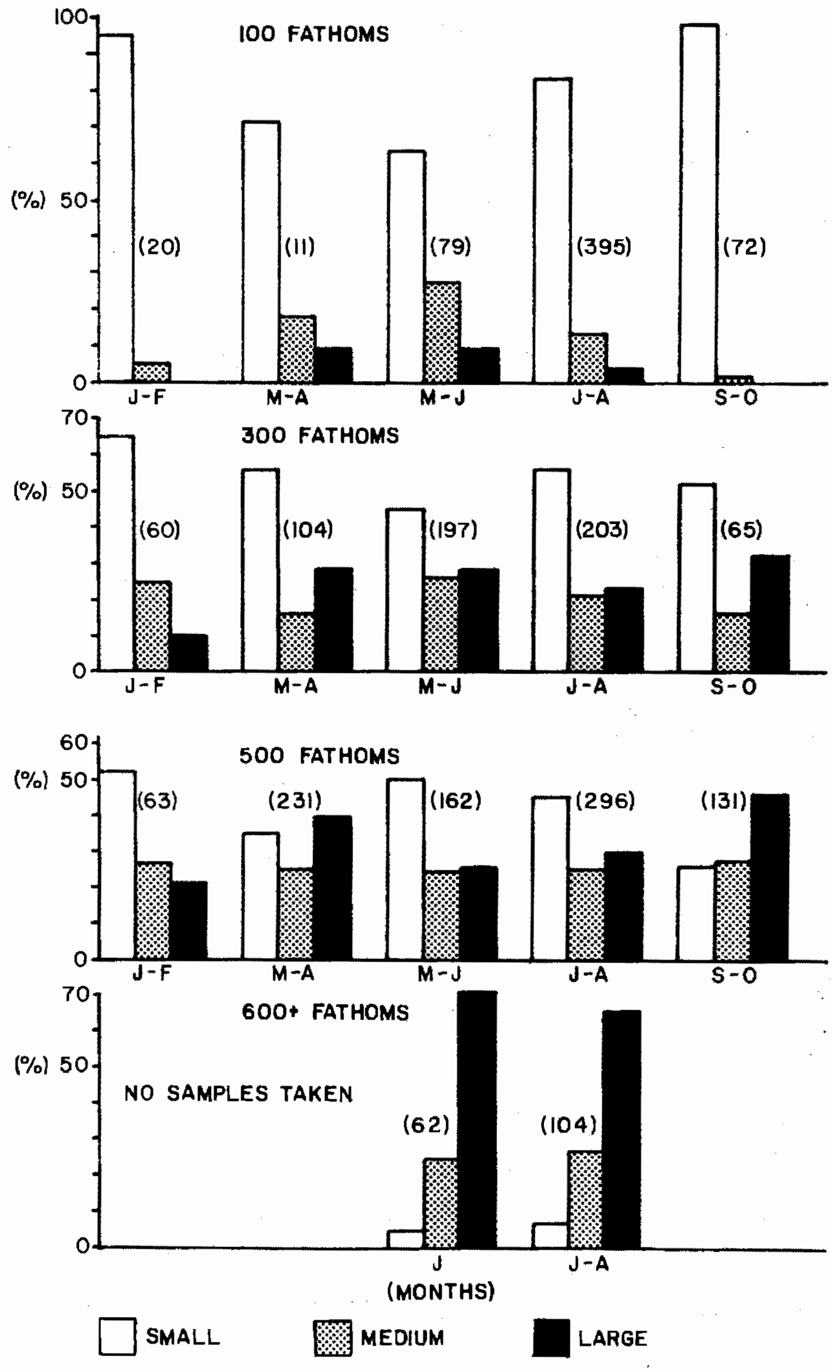

Figure 2. Seasonal variations in mean percent by number of large, medium, and small sablefish at four sampling depths. The number of fish for each bimonthly period are given in parentheses.

Sablefish collected were usually processed at sea. Measurement of standard length to the nearest 0.5 cm, weight to the nearest 0.5 lb and sex were recorded. The gonads, stomach, and intestines were removed and fixed in 10% formalin, and were later changed to 40% isopropyl alcohol. The gonads were analyzed for reproductive maturity and the gut retained for feeding habit studies. Otoliths and scales were taken for age determination. Other species caught in traps at the different depths were tabulated. In addition to size frequency distribution using 2 cm size intervals, sablefish from each trap were counted and sorted into the three size classes commonly used by sablefish buyers: 'small', less than 5 lb; 'medium', 5-7 lb; 'large', more than 7 lb. In tagging, where only the standard length was recorded, the weight of a fish was derived from an empirical regression equation ($W_{lb} = (0.00002)SL_{cm}^{3.08}$; $r = 0.959$) by the method of least squares. Percent composition by number of the three size classes of sablefish were calculated for different depths and seasons. Catch rates, in numbers per trap and weight of fish per trap, were calculated for different depths, seasons, soak times, and baits. Only intact fish were counted. Size frequencies were compared among depths and fish from all collecting methods. Gonad indices were calculated using the formula:

$$G.I. = \frac{\text{Weight of gonad (gm)}}{\text{Weight of fish (gm)}} \times 100.$$

Gonad indices were compared by depth and season for different size classes of sablefish. Tag returns were tabulated as they occurred. Size, weight, sex, and location data from the recaptures are still being generated.

RESULTS

During the course of this year-long study, 203 traps were set, resulting in the capture of 2632 sablefish. A total of 1450 of the 2632 trap-caught sablefish were tagged and released. In addition, 1051 sablefish from other sources were sampled, making a total of 3683 sablefish analyzed.

Catch rates at the two 50 fm stations (Fig. 1) were consistently low with only 27 fish captured out of 34 sets over the year (Table 5). Smaller fish were present but were not available to traps (Kennedy and Smith 1972), probably due to mesh size (Kennedy 1970), bait attractiveness, or feeding behavior. The mean number of fish per trap at the 100 fm stations was not significantly different from that at the 300 fm stations (Table 1), but there does appear to be a depression in the mean number of fish at 300 fm. Catch rates at 100 fm were highest during July and August averaging 24.8 and 28.8 fish per trap respectively. Depths from 500 and 600 fm proved to be the most productive, differing significantly ($0.01<P<0.05$) in mean number of fish per trap from the catch at the 100 and 300 fm stations (Table 1). By contrast, the mean weight of catch per trap increased steadily with depth from 100 to 500 fm (Table 1). At depths of 600-750 fm, where a limited number of sets were made, the mean weight of catch per trap was close to that at 500 fm even though the number of fish caught per trap was fewer. The 100 and 300 fm stations did not differ significantly in mean weight of catch per trap, but at the 500 fm stations, significantly greater weights of fish per trap occurred ($0.01<P<0.05$).

The proportion of sablefish in the three different market size classes varied with depth (Table 1). The mean percentage of 'small' fish by number (74.5%) at 100 fm differed significantly from that at 300 fm (47.2%). But the 300 and 500 fm stations had a similar proportion of 'small' fish. At 600 fm, 'small' fish occurred very rarely. Similar trends between depths occurred for weights of 'small' fish per trap. The proportion of 'medium' fish did not differ significantly by number or by weight at the four depths (Table 1), but there was a trend for 'medium' fish numerically to increase slightly with depth. 'Large' sablefish comprised a larger part of the

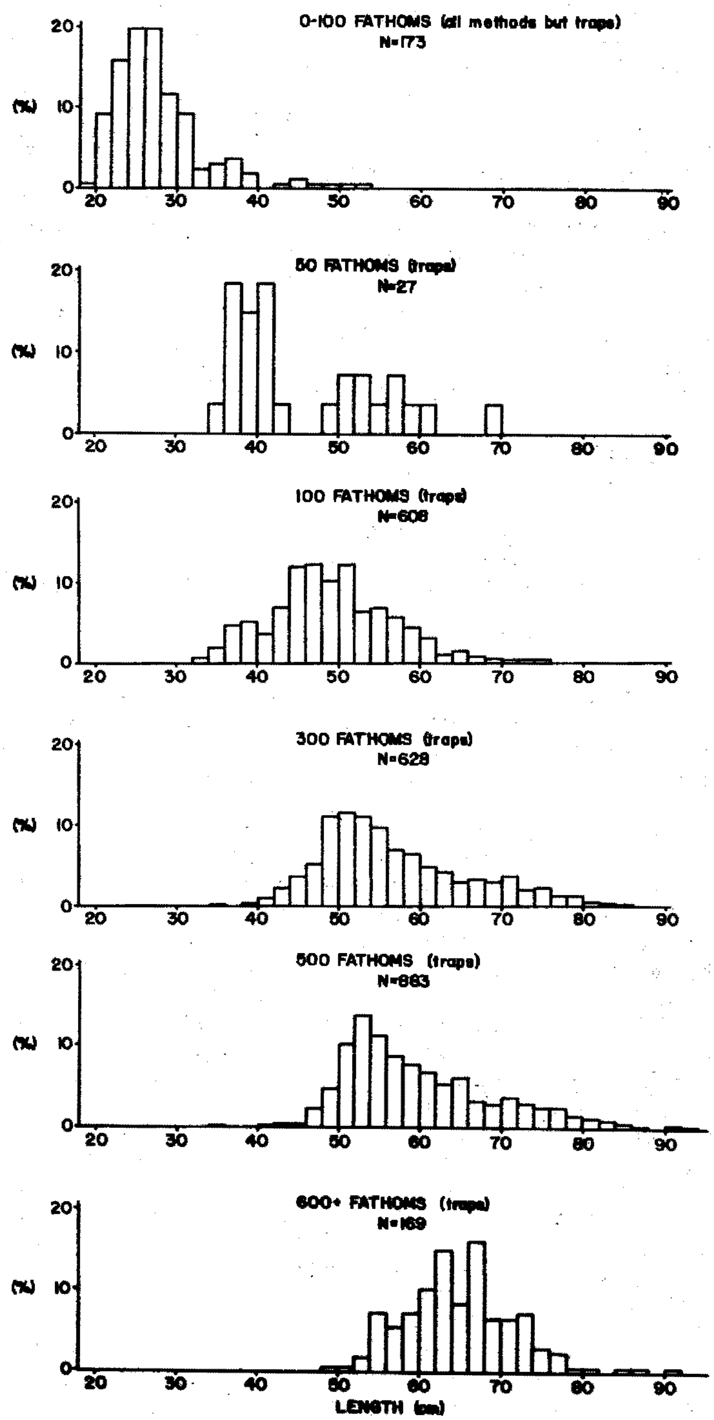

Figure 3. Percent length frequencies of sablefish by depth. For 0-100 fathoms, fish were caught with otter trawls, purse seines, gill nets, and hook and line. Fish from all other depths were caught with traps. N = the total number of fish measured for standard length to the nearest 2 cm at each depth.

DEPTH (FATHOMS)	SEX	FISH SIZE		
		Small	Medium	Large
0-100	M	0.10±0.04 N=77 n=76	0.50±0.00 N=1 n=1	N=0
	F	0.31±0.03 N=160 n=158	0.68±0.15 N=31 n=30	1.34±0.47 N=10 n=8
300	M	0.43±0.23 N=68 n=61	2.34±4.98 N=4 n=4	N=0
	F	0.63±0.17 N=82 n=71	1.03±0.28 N=62 n=56	2.14±0.56 N=85 n=75
≥500	M	0.72±0.27 N=52 n=49	1.23±1.21 N=10 n=10	0.37±0.00 N=1 n=1
	F	1.23±0.30 N=33 n=30	2.06±1.84 N=56 n=53	3.69±0.29 N=131 n=119

Table 3. Gonad indices as percent of body weight with fish size and depth of capture. Numbers represent mean gonad indices ±95% confidence intervals for the mean. N=total number of fish sexed; n=number of fish used to calculate the gonad indices.

population with increasing depth, both by number and weight (Table 1). The percentage of large fish changed significantly ($0.01<P<0.05$) between 100 and 300 fm and again between 500 and 600 fm. Few large sablefish were captured at 100 fm, whereas at 600 fm, 'large' sablefish dominated the catch and 'small' sablefish were scarce.

Seasonal variations in size class are most prominent at the 100 fm stations (Fig. 2), where 'small' fish constituted an overwhelming percentage of the catch. 'Large' fish were absent there from September through February and only a few large fish were present from March through August (Fig. 2). 'Medium' and 'large' fish were more numerous at the 100 fm stations during the summer months, while 'small' fish became correspondingly less so (Fig. 2).

The relative proportions of the three size classes of sablefish caught at 300 fm did not appear to be different from those at 500 fm. Catches at these two depths, however, differed greatly from the 100 fm catches in that 'large' fish were more abundant. Seasonal trends at the 300 fm and 500 fm stations are not obvious, but at 500 fm, 'large' fish made up the major part of the catch during September and October (Fig. 2). In general, similar proportions of 'large', 'medium', and 'small' fish occurred at 300 and 500 fm. The few samples taken in water deeper than 600 fm indicate that large fish predominated at those depths (Fig. 2).

Squid proved to be a more effective bait than northern anchovy for one and two day sets (Table 2). Squid caught significantly higher numbers of fish per trap and fish per hour and greater weights of fish per trap and fish per hour. More fish were caught per hour during the four hour sets and declined with longer soak times for both baits, but traps that were fishing for longer periods, such as one and two day sets, caught significantly more fish per trap (Table 2). Squid bait continued to attract more fish after two days, while northern anchovy apparently lost its effectiveness after two days, resulting in a decrease in fish per trap and in fish per hour (Table 2). After three days both baits seemed to lose their effectiveness and catch per trap and catch per hour declined. With soak times greater than three days, many sablefish died and were skeletonized by hagfish and amphipods. The results on baits and soak times are somewhat obscured by high variability as the confidence intervals exceeded the means in several cases. Much of this variability is due to small sample size (Table 2).

Length frequency histograms of captured sablefish show a regular increase in lengths with depth (Fig. 3). Mean standard lengths of sablefish differed significantly between all depths sampled except between 50 and 100 fm. Fish caught with surface gear such as lampara nets and purse seines ranged from 18 to 26 cm SL, while otter trawl-caught sablefish ranged from 21 to 50 cm SL (Fig. 3). Thus, these methods captured smaller fish (mean SL = 26.7 ± 0.9 cm). Fish smaller than 33 cm SL were not vulnerable to our traps. Small individuals were often gilled by the mesh. The bimodal distribution of the trap-caught fish from 50 fm reflects size differences between collection dates not shown in Figure 3. This histogram of fish caught in traps at 50 fm may not reflect the true size composition since sablefish are not abundant there and the sample size is small.

The sablefish from 100 fm had a mean size of 48.0 ± 0.6 cm SL and few fish at this depth were greater than 70 cm (Fig. 3). The 300 fm fish averaged 55.9 ± 0.7 cm SL and fish smaller than 40 cm SL were virtually absent from collections at this depth. Mesh size of the traps is probably not influencing the mean length at this depth. The fish from 500 fm exhibited a size distribution similar to the 300 fm fish but the mean size was significantly larger (58.9 ± 0.6 cm SL). Although the maximum size of the fish landed was about the same, fish from 600-750 fm averaged significantly larger (64.1 ± 1.0 cm SL) than those at all other depths (Fig. 3). No fish smaller than 48 cm SL were caught at or below 600 fm. One set at 1000 fm yielded four sablefish, which is deeper than previously reported.

The overall sex ratio for sablefish caught with all methods was one male to 3.64 females (22% male). The sex ratios were closest to unity among small sized sablefish but exhibited a striking predominance of females at all depths for the larger categories. The sex ratios for all depths combined were, for 'small' sablefish, 1:1.4 (42% male); for 'medium' sablefish, 1:9.9 (9% male); and for the 'large' sablefish, 1:226 (0.4% male) (Table 3). Only one male was captured in the 'large' category (more than 7 lb). Males outnumbered females only once at 500 fm in the 'small' category (Table 3).

Gonad indices (G.I.) indicated an increase in relative gonad size with both fish size and depth (Table 3) with only two exceptions. For 'medium' males at 300 fm (G.I. = 2.34), the value seems higher than might be expected, and for large males at 500 fm (G.I. = 0.37), the gonad index for the lone male appears low. Small sample size is the most likely cause of these irregularities.

Seasonal changes in gonad indices indicate that sablefish spawned from November through February in deep waters (Table 4). The gonad indices for both sexes regularly increased as the year progressed at both 300 and 500 fm stations, and were low in November-December (1973) at 300 fm and in January-February (1974) at 500 fm, indicating that most spawning had occurred. Gonad indices were low for both sexes in shallow waters (0-100 fm) and exhibited little noticeable seasonality.

Tagging results are preliminary, but indicate that most tagged sablefish remained in the Monterey Bay area. Five percent of the 1450 tagged and released sablefish have been recaptured, with 72 of the 73 returns coming from Monterey Bay waters. The remaining tag recovery was from an otter trawler off Brookings, Oregon, from 300 fm of water, the same depth from which it was originally captured. Seventy-one of the recaptured fish were from either commercial or scientific sablefish traps, while two sablefish were recovered from commercial drag boats. Some local migration was indicated since 65% of the fish were caught in shallower water than that from which they were tagged, 27% were recaptured at the same depth, and 8% were recaptured in deeper waters.

Sablefish traps were extremely selective at all depths except 50 fm, where the other species of fish were five times as abundant (Table 5). Of the species caught incidentally in shallow water, the Pacific hagfish *Eptatretus stoutii*, the Pacific sanddab *Citharichthys sordidus*, the canary rockfish *Sebastes pinniger*, and the lingcod *Ophiodon elongatus* were the most commonly encountered. If hagfish catches are not considered in 50 fm catches (since they were only caught in early model bait containers and are not adequately sampled since they are smaller than the mesh), there were still three times as many incidental fishes caught than sablefish. Excluding the 50 fm samples, only 16 species of fishes and 8 species of invertebrates were captured in sablefish traps, and the numbers of individuals of other species are greatly dominated by sablefish (2603 to 59). At these deeper stations (100, 300 and 500 fm), which are nearer the center of the depth distribution of sablefish, even fewer species were caught (Table 5). Notable among these were the rattails *Coryphaenoides acrolepis* and *C. pectoralis*, the black hagfish *Eptatretus deani*, and the finescale codling *Antimora microlepis*.

DISCUSSION

Catch rates and size composition of trap-caught sablefish are affected by many factors. We have chosen to evaluate those factors which were known to influence sablefish distribution, were likely to affect the commercial

DEPTH (FATHOMS)	SEX	Jan.-Feb.	Mar.-Apr.	May-June	July-Aug.	Sept.-Oct.	Nov.-Dec.
0-100	M	0.08±0.05 6	0.05±0.01 17	0.29±0.25 10	0.14±0.07 27	0.07±0.1 23	0.04±0.02* 4
	F	0.34±0.10 12	0.16±0.08 32	0.57±0.07 57	0.54±0.12 91	0.15±0.04 40	0.05±0.02* 15
300	M	0.11±0.02 7	0.22±0.20 25	0.34±0.24 12	0.73±0.53 18	1.76±1.87 8	0.06±0.02* 4
	F	1.16±0.24 15	0.98±0.15 64	0.98±0.17 54	1.16±0.41 31	2.24±1.68 12	1.77±0.76* 56
≥500	M	0.17±0.58 10	0.24±0.13 8	0.52±0.31 9	0.90±0.38 34	1.64±1.75 9	2.39±2.47 5
	F	1.40±0.91 19	1.41±0.55 20	2.01±0.42 106	2.30±0.27 115	3.69±0.72 63	4.05±1.00 60

Table 4. Mean gonad indices of sablefish captured in 1973-1974 by depth of capture and bimonthly intervals with 95% confidence intervals for the mean. The number beneath each mean is total number of individuals sexed. *The fish used in these categories were from the 1973 season.

Table 5. Fishes and Invertebrates Caught in Sablefish Traps

Species	Fathoms			
	50	100	300	500
FISHES				
Anoplopoma fimbria	27	619	875	1109
Antimora microlepis			1	6
Citharichthys sordidus	87	1		
Coryphaenoides acrolepis				11
Coryphaenoides pectoralis				1
Echinorhinus cookei			1	
Eopsetta jordani	1			
Eptatretus deani				17
Eptatretus stoutii	132		1	
Merluccius productus	2			
Microstomus pacificus			3	
Ophiodon elongatus	25	3	2	
Paraliparis sp.				1
Sebastes spp.	1		2	
Sebastes melanostomus			1	
Sebastes paucispinis		1		
Sebastes pinniger	28			
Sebastes rosenblatti		2		
Sebastolobus spp.			3	
Somniosus pacificus			1	
Squalus acanthias	1			
Apristurus brunneus (egg case)			1	
INVERTEBRATES				
Allocentrotus fragilis			2	
Anthomastus ritteri			2	
Asteronyx loveni			2	
Brisaster townsendi		1		
Cancer antennarius	1			
Cancer magister	4			
Cancer productus	43			
Chionoecetes tanneri				1
Holothuroids			7	
Pleurobranchaea californica	2			
Rathbunaster californicus			3	
Salps	1			
Stylatula elongata			2	
NUMBER OF TRAPS SET	34	44	77	48

catch, and were practical to measure during a resource study limited to one year in Monterey Bay. Thus, we concentrated on the effects of depth, bait, soak time, and season on catches of sablefish and incidental species.

From an economic point of view, fishing at depths of 500-600 fm would yield the highest weight of sablefish per trap. The catch from these depths would be more profitable since the catch rate is high and 'large' fish comprise the majority of the catch. A decision to fish this deep should be considered against other factors such as increased transit time, boat operating costs, retrieval time, and the flabby condition (and marketability) of some of the fish caught there (James Hardwick, personal communication).

In Monterey Bay, sablefish abundances peaked at 500-650 fm and were still high at their maximum reported depth (833 fm: Miller and Lea 1972). Heyamoto and Alton (1965), however, reported that maximum abundances of trawl-caught sablefish off Oregon were between 200 and 450 fm and that no sablefish were caught below 650 fm. Similar results were reported by Alverson et al. (1964). Trawl-caught sablefish are generally not as large as those caught in traps (Parks 1973; see also Fishery Market News Reports for 1973, U.S. Dept. Commerce, N.O.A.A., N.M.F.S.) and this may make their conclusions about depths of maximum abundance slightly misleading. Since traps catch larger sablefish and since larger sablefish live in deeper water (Heyamoto and Alton 1965; Phillips 1954; Kennedy and Pletcher 1968), our records of maximum abundance of sablefish are deeper than previously reported. It should be noted that the depression in our catch rates at 300 fm could be due to pressure from recent intense trap fishing and set line fishing that has been concentrated at that depth for many years (James Hardwick, personal communication). Phillips (1954) reported that longline-caught sablefish from 150-400 fm in Monterey Bay were smaller than those landed in Eureka or Fort Bragg. Since the Monterey Bay population of sablefish is near the southern limit of the sablefish range, Phillips (1954) proposed that they were smaller because they inhabited an area that was environmentally unfavorable. Apparently, sablefish in the Monterey Submarine Canyon live deeper than the northern fish and thus were not adequately sampled by the commercial fleet studied by Phillips (1954). It is also possible that size and depth distribution could be affected by canyon topography or oceanography.

Sablefish reportedly migrate offshore to deeper water during the winter months (Alverson et al. 1964; Heyamoto and Alton 1965). Our results appear to confirm this seasonal migration and show how this migration varies with size of sablefish. Our 100 fm stations showed increased catch rates during July and August along with the movement of larger fish into shallower depths as shown by the increase of the percent 'large' and 'medium' sablefish during the summer months. Unfortunately, we had no samples at 600-700 fm during January or February when 'large' sablefish were generally lacking at any of our regularly sampled depths. Since this is when sablefish are reported to live deeper, a high percentage of 'large' fish at around 600-750 fm would account for the dearth of large sablefish at the other stations, assuming the fish remain in the canyon.

Squid proved to be a more effective bait than anchovy both in initial effectiveness and longevity. Anchovy appeared to lose its effectiveness by the second day, while squid continued to attract and catch fish until the third day. Hughes et al. (1970) determined that a soak time of 12 hr caught more pounds per trap for a standardized 48-hr period than 24- or 48-hr soak times. When standardized to catch rate for a 48-hr period, our squid catch rate data for one- and two-day sets agrees closely with that reported using frozen herring by Hughes et al. (1970), but our anchovy catch rates were lower. Also, our standardized 4-hr soak times exhibited a much higher catch rate than that reported for 12-hr soak times by Hughes et al. (1970). Thus, if it were practical to lift a trap every 4 hr in a 48-hr period, the

12 liftings would catch more fish than 1 lifting every 48 hr. Hughes et al. (1970) reasoned that there might be a relatively low trap threshold density and a decreased efficiency of bait with longer fishing time. Our results agree, and it appears that relative rates of capture and escape change with increased soak time. As the bait becomes less attractive, the rate of capture is less than escape, resulting in a net decrease in fish captured. Thus, since squid retains its attractiveness longer than anchovy, the rate of escape is not higher than the rate of capture until after three days.

The overall sex ratio (78% female) is the same as that obtained by Parks (1973) for trap-caught sablefish off Oregon. Parks (1973) also found that trawl-caught sablefish had only 39% females and attributed this difference to the fact that larger fish, which are predominantly female (Edson 1954; Pruter 1954), can avoid the trawl and therefore the trawl captures smaller fish which are more often male than female. Our 'small' sablefish were 42% male, approximating the 1:1 ratio reported by Kennedy and Smith (1973) for small (maximum size = 48 cm) fish caught off Vancouver Island with hook and line. Only 0.4% of our 'large' sablefish were males, apparently because males do not get as large as females, as reported by Edson (1954) for sablefish off Alaska.

In agreement with published information, sablefish in Monterey Bay spawn in the winter months with peak spawning activity from November through February as shown by gonad indices of fish caught at 300 and 500 fm. Phillips (1954) noted spawning of California sablefish from December to April with peak activity occurring in January and February. Similar results were reported off Oregon and Washington: Thompson (1941) suggested from eggs in plankton samples that spawning started in February; Heyamoto and Alton (1965) noted spent and spawning individuals in March; Bell and Gharrett (1945) noted spawning in November and through February; while Bell and Pruter (1954) noted ripe individuals in November and spent females in January. Gonad indices also indicate that the more ripe fish are found in deeper waters since individuals of the same size have, on the average, a higher gonad index at greater depths. We have observed gravid females at our 300, 500, and deeper than 600 fm sampling depths.

Our preliminary sablefish tagging results indicate that sablefish in Monterey Bay are relatively parochial since they do not seem to migrate in great numbers from this area. This may reflect localized fishing effort rather than limited migratory patterns, but it does agree with other tagging studies. Phillips (1969), Kennedy and Smith (1972), and Holmberg and Jones (1954) have shown that sablefish stocks are generally of a local nature. However, some long-range migrations have occurred (Pasqualle 1964; Phillips 1969; Pattie 1970), and we have one tag return from Oregon.

Sablefish traps were considerably more selective at the 300 and 500 fm depths than at shallower depths. It appears that only a few species are susceptible to trapping (Parks 1973), either due to behavior or mesh size. Heyamoto and Alton (1965), using trawls off the mouth of the Columbia River, reported that sablefish comprised over 50% of the catch at 275-450 fm, while at about 50-150 fm, sablefish usually made up less than 10% of the catch by weight. Heimann (1963) sampled the trawl fishery in Monterey Bay and found that sablefish comprised 4.1% by weight of the commercial trawl catch at 130-200 fm but only 0.9-1.4% at depths from 30-130 fm. Hughes et al. (1970), from 222 trap sets in depths of 150-200 fm off Washington, reported catching only 4 species other than sablefish. Parks (1973) reported that 4 species in addition to sablefish were taken in traps at depths of 100 and 150 fm off Oregon, while at the 200 and 250 fm depths, sablefish was the only species captured. On the other hand, trawls near his traps captured 31 other species. Our trap catches reflect the decreased sablefish abundance at shallow depths and the dominance of sablefish at depths of 300 fm to 750 fm.

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