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SPORT CLAMMING IN HUMBOLDT BAY, CALIFORNIA DURING 2008: COMPARISONS WITH HISTORICAL SURVEY DATA

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A sport clam survey, conducted January through December 2008 in Humboldt Bay, California, was the continuation of a creel-type survey conducted by the California Department of Fish and Game from 1975 through 1989. Surveys were conducted on low tides in the south arm of Humboldt Bay. Data were collected on clammer effort and catch resulting in bootstrapped estimates of the number of clammer trips (clammer-days) per year, catch per unit effort, total catch by species, and spatial distribution of effort within the bay. The survey revealed an important shift in harvested clam species composition, a decrease in harvest level, and methods of harvest apparently unique to Humboldt Bay.

Keywords: clams, Humboldt Bay, historical survey, harvest estimates, bootstrap

INTRODUCTION

Humboldt Bay (Figure 1) is one of California's largest estuaries, second only to San Francisco Bay. Consisting of three sub-bays paralleling the coast, Humboldt Bay is 14 miles long and 4.5 miles wide at its widest point. The bay's 27.4 square miles encompass a diverse array of habitats including tidal flats, salt marsh, and eel grass (*Zostera marina*) beds (Initiative CMLPA 2010). Mapped eel grass beds within Humboldt Bay total 7.1 square miles, 40% of the known eel grass in California. South bay contains 78-95% of the total eelgrass biomass found in the Humboldt Bay (Harding and Butler 1979). As part of the Pacific Flyway, it provides essential habitat for migrating waterfowl and shore birds, and serves as an important nursery for fish and invertebrates (Barnhart et al. 1992). Arcata Bay, the northern arm, is known for economically important oyster aquaculture, producing 60% of oysters sold in California (Schlosser 2009).

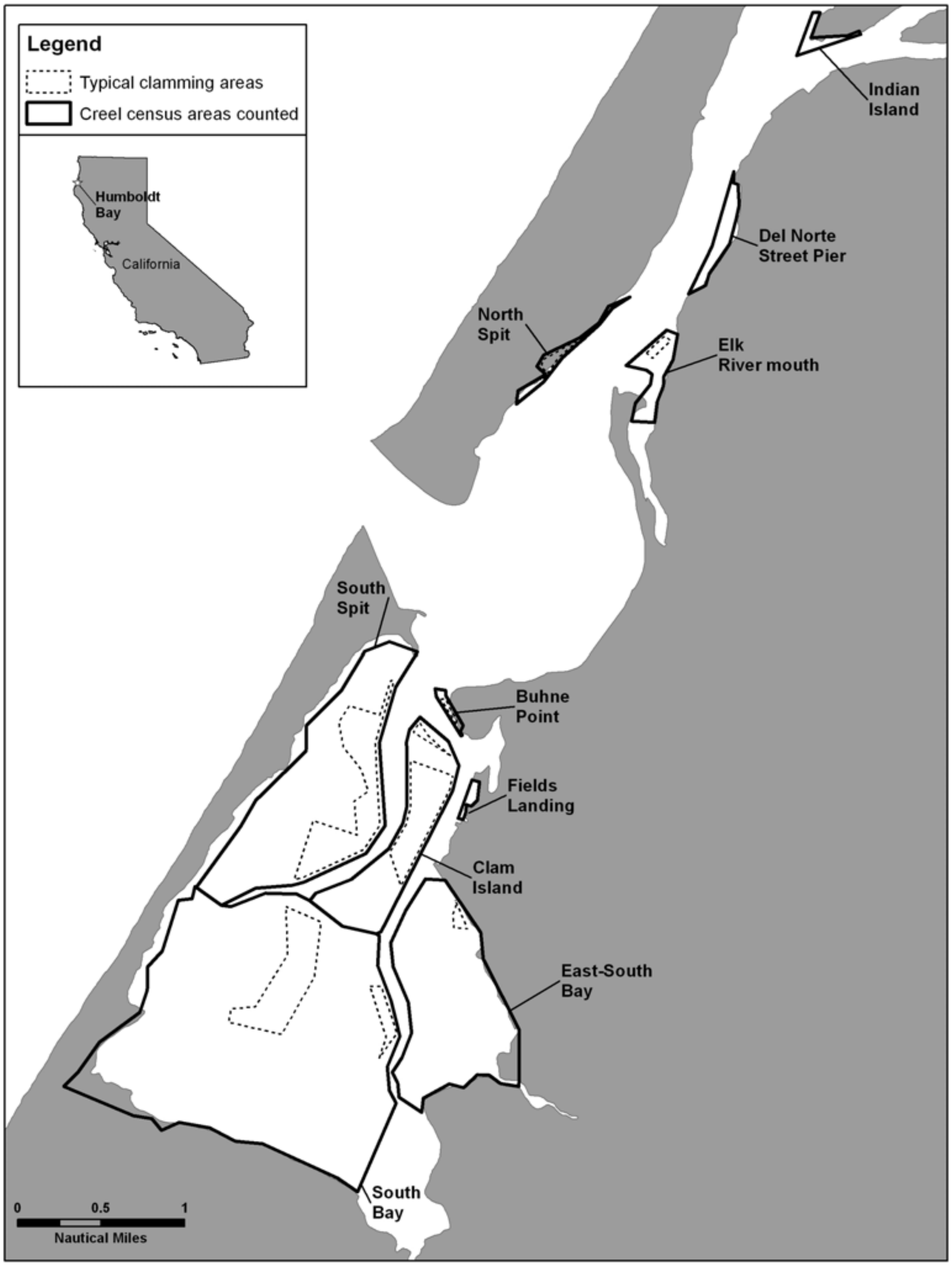

Figure 1. Clamming sampling areas in Humboldt Bay, Humboldt County, California, 1975, 1977-1989, and 2008.

Humboldt Bay provides an excellent opportunity for sport fishing for clams. Finding and digging clams on the bay requires no specialized equipment, although small boats are often utilized to get to prime clamming grounds. Unlike other shellfish harvesting opportunities, which are best during calm ocean conditions, bay clammers can be successful at a larger tidal range and can access tidal flats in foul weather. Among the species typically harvested are gaper clams (*Tresus* spp.), butter clams (*Saxidomus* spp.), Pacific littleneck clams (*Leukoma staminea*) and,occasionally, Pacific geoducks (*Panopea abrupta*).

There is a long history of Humboldt Bay supporting higher catch rates of clams, both sport and commercial, than elsewhere in California. During the 1960s and 1970s, concern about overfishing of clams led the California Department of Fish and Game (CDFG) to fund and conduct exploratory surveys of clammers in and around Humboldt Bay. Studies by Humboldt State University researchers showed poor recruitment among the popularly harvested gaper clams (Wendell et al. 1976). The information prompted a reduction in the gaper clam sport bag limit that has remained unchanged for over three decades. Even with this reduction, the Humboldt Bay regulations are generous. For any other location in California sport clammers are limited to ten gaper clams per day. Oregon sport fishers are limited to 12 gaper clams per day, while in Humboldt Bay sport fishers may take up to 25 gaper clams per day. For most other clam species the regulations are the same throughout the state. The California Fish and Game Code allows commercial clam harvest in Humboldt Bay, which must follow stringent public health regulations, but no landings have been reported since 1988.

From 1975 to 1989, CDFG conducted an annual creel census to gather information on recreational effort and catch (P.C. Collier, CDFG, unpublished data). After an 18 year hiatus, the CDFG resumed the creel census survey in 2008. The key findings of all complete survey years, including the 2008 resumption, are presented here.

METHODS

Modified Access Point Survey

The vast majority of clamming on Humboldt Bay occurs in the south bay, with some effort along the north bay channel near the bay entrance and near the mouth of Elk River. Clammers access the mud flats at a limited number of distinct access points, which allowed us to conduct a modified access point survey and eliminated the need for a roving creel survey (Pollock et al. 1994). The nature of clamming allowed several simplifications of the method, thus improving on the standard design used for most fishing surveys. The survey consisted of two parts, clammer counts and clammer interviews. Survey days were selected from a known number of clammer days, defined as days that have low tides less than or equal to 0.0 ft mean lower low water (MLLW) during daylight hours. Since clamming can only occur during a discrete time frame on each of those days, survey efficiency was maximized. In addition, the geography of the south bay provided several vantage points whereby creel samplers were able to conduct a nearly complete count of clammers during a short time period.

The study area was divided into ten sub-areas to improve harvest estimates (Figure 1). Using a modified bus-route survey technique (Pollock et al. 1994), the creel sampler followed a prescribed route and schedule to count clammers at the ten sub-locations over the course of one hour, ending the count when the tide was lowest. Counts were made by direct observation, and because clammers tend to spend the maximum amount of time on the clam beds, we could be fairly certain that each count represented the total number of clammers for that day. During previous surveys it was determined that weekend and very low tides had more effort, necessitating a stratified random sampling scheme. Stratification was first by MLLW tidal height: 0.0 ft to -0.9 ft and -1.0 ft or lower, and secondarily by day type: weekend and weekday.

All 2008 tides were divided into tide series, meaning a series of consecutive daylight tides less than or equal to 0.0 ft MLLW. Within each series, one day of each stratum present was randomly chosen for a count of clammers from the vantage points. Additionally, one day within the series was randomly chosen for interviews regardless of strata or selection for count. Randomization of the interview location was infeasible because effort was normally low or clustered. On the randomly selected interview day, the sampler took into account recent interview locations and access points being used that day to opportunistically choose the location. If there was very low or zero effort, the interview day was postponed until later in the series, preferably to a stratum with few interview days completed. An attempt was made to sample as many clammers as possible at the chosen location. Each sampled clammer's catch was identified to species, or genus if the clam could not be positively identified, and the shell length measured to the nearest mm.

Data Analysis

The bootstrap method (Efron 1981) was used to obtain confidence bounds around statistical estimates of clammers/day and clams/clammer. A combination of these two estimates, along with the total number of low tide days, yielded estimates of total clammers and total harvest by clam species. The bootstrap randomly selected *n* values, with replacement, from the survey samples. The mean of the bootstrapped values was obtained and the process repeated 1000 times for each estimate, using MS Excel software. The confidence bounds were calculated by sorting the bootstrapped values and taking the appropriate values for 95% confidence bounds.

For each sampling area, i, we counted clammers on sample days, and for each tidal stratum, j, we calculated the mean number of clammers on sampled days as clammers/day. This number was multiplied by the total days within each stratum, Nj, to estimate total number of clammers per stratum. Bootstrapping these values yielded an estimate of total clammers by area with confidence bounds. The totals for each area were summed to obtain 1000 bootstrapped estimates for all the areas. To obtain the estimated number of clammers, the 1000 bootstrapped numbers were sorted and the mean of the 500th and the 501st values yielded the estimated number of clammers. The 95% bounds were the 26th (lower bound) and the 975th (upper bound) rankings from the sorted file. The estimated number of clammers per area and tidal stratum was calculated as follows:

$$\hat{D}_{i,j} = N_j \frac{\sum_{k=1}^{n_{i,j}} d_{i,j,k}}{n_{i,j}}$$ number of clammers in area *i*, stratum *j*, where

$d_{i,j,k}$ = clammers in area *i*, stratum *j*, day *k*, and

$n_{i,j}$ = sample size (number of days sampled) in area i, stratum j.

The estimate of total clams harvested was obtained by multiplying each unsorted column of 1000 clammer bootstraps by the unsorted 1000 clams/clammer bootstrapped columns. Clams/clammer was the mean number of clams harvested per interviewed clammer, by area. The bootstrap was run using all interviewed clammers within each area. Since interviews were not obtained for all tidal strata, clams/clammer were calculated for each area while ignoring strata. For those species that were not always identified to species, a bootstrapped estimate was calculated for the genus. The estimated number of clams/clammer per area was calculated as follows and then multiplied by the estimated number of clammers by area to yield the total number of clams when summed over all areas:

$$\hat{R}_i = \frac{\sum_{k=1}^{v_i} c_{i,k}}{v_i}$$ clams/clammer for area i, where

$c_{i,k}$ = number of clams counted for area i, interview k, and

v_i = number of interviews for area i.

$$\hat{T}_i = \hat{D}_i \hat{R}_i$$ total number of clams in area i.

RESULTS

For all locations sampled in 2008, an estimated 1,294 clammer-days were expended during 2008. South Spit and Clam Island – both accessed almost exclusively by boat – were the most popular areas, seeing 453 and 365 clammer-days, respectively. Buhne Point and Elk River were other notable clamming areas, both easily accessed from shore (Table 1). An estimated 31,189 clams were taken by recreational fishers from nine sub-areas within Humboldt Bay. Since there was no effort recorded at the Del Norte Street Pier sub-area during the survey, it was not included in the analysis. Distribution of the take was uneven, with the highest number of clams taken from South Spit and Clam Island (10,914 and 8,831 clams, respectively). Very few clams were taken from Indian Island and Fields Landing

Table 1. Estimated number of clammer-days at nine sampled sites in Humboldt Bay, Humboldt County, California, 2008.

Clammer-Days	Sampling Location									
	East-South Bay	Fields Landing	Indian Island	Elk River	North Spit	Clam Island	Buhne Point	South Spit	South Bay	Total
Lower 95%	5	0	0	92	10	232	128	304	3	1,057
Mean	19	7	3	156	79	365	180	453	23	1,294
Upper 95%	38	21	8	228	174	534	243	622	48	1,558

(Table 2). Further, gaper clams were clearly favored by clam harvesters in 2008, making up > 84% of the total catch. We estimated there were 26,313 gaper clams harvested, followed by 4,465 butter clams; geoducks and littlenecks together made up 1.5% of the total harvest (Table 2). Over 80% of all gaper clams inspected had been removed from the shell, thereby confounding identification to species.

Table 2. Total clams harvested by species at nine sampled sites in Humboldt Bay, Humboldt County, California, 2008.

	Sampling Locations									
	East-South Bay	Fields Landing	Indian Island	Elk River	North Spit	Clam Island	Buhne Point	South Spit	South Bay	Total
Total Clams										
Lower 95%	114	0	0	2,232	232	5,637	3,124	7,401	76	25,273
Mean	450	171	65	3,764	1,888	8,831	4,338	10,914	547	31,189
Upper 95%	922	529	203	5,553	4,276	12,770	5,941	15,203	1,160	37,700
P. abrupta										
Lower 95%	1	0	0	16	2	37	20	49	1	153
Mean	4	2	1	36	18	85	43	105	5	307
Upper 95%	11	6	3	71	47	159	76	195	13	509
Tresus spp.										
Lower 95%	96	0	0	1,861	198	4,713	2,565	6,249	65	20,977
Mean	375	144	55	3,155	1,595	7,373	3,658	9,153	457	26,313
Upper 95%	768	450	172	4,669	3,517	10,986	5,022	12,748	977	31,806
Saxidomus spp.										
Lower 95%	15	0	0	216	32	528	271	617	11	2,024
Mean	62	22	8	524	265	1,229	618	1,547	75	4,465
Upper 95%	162	96	37	1,077	698	2,499	1,125	2,947	195	7,780
L. staminea										
Lower 95%	0	0	0	0	0	0	0	0	0	0
Mean	2	1	0	17	8	40	20	50	2	143
Upper 95%	7	4	1	49	32	117	55	132	9	381

The highest annual number of clammer-days during the period 1975-1989 was 6,639 in 1982, and the low of 2,440 came in 1989 (P. C. Collier, CDFG, unpublished data). The 1,294 clammer-days estimated for 2008 was a 70% decrease from the historic average of 4,365 clammer-days per year (Figure 2). Fluctuations in annual clam harvest correlated closely with clammer-days. The highest estimated annual catch was 188,000 clams in 1982, and the lowest was 72,000 clams in 1989. The total of 31,189 clams harvested in 2008 was a 75% decrease from the historic average of 127,500 clams per year (Figure 3).

The relative catch composition of gaper clams taken in 2008 was 84.4%, compared to the average of 45.5% in the earlier surveys. Also noteworthy was the dramatic decrease in the proportion of littleneck clams harvested, down from the historic average of 18.6% to 0.5% in 2008 (Table 3). However, the littleneck clam proportion of the annual catch did fluctuate markedly during the historic survey period. Geoduck clams made up 1% of the estimated harvest in 2008, but they were absent in all other survey years (Table 3).

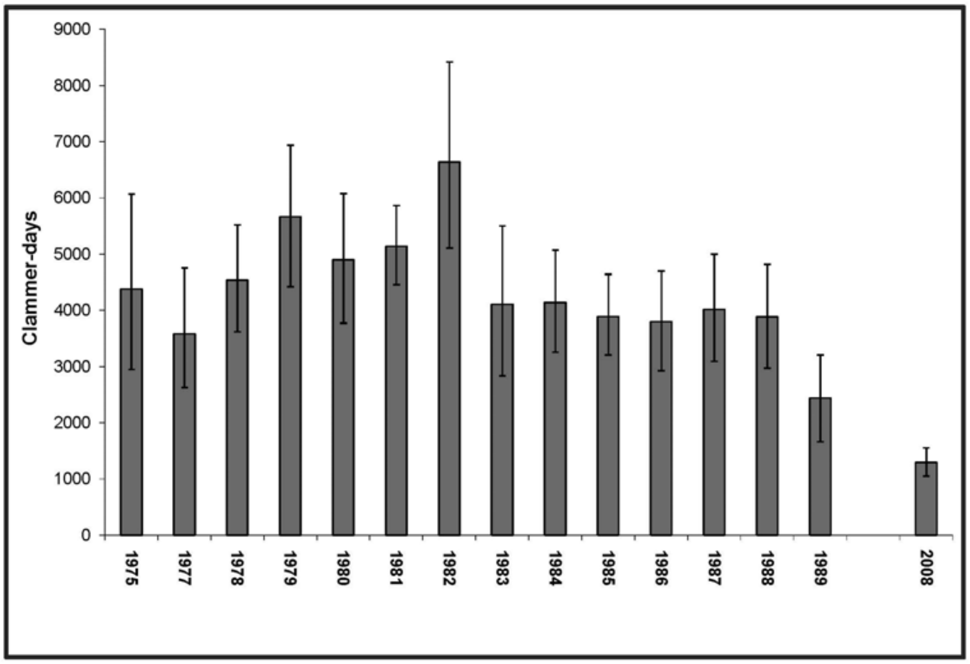

Figure 2. Estimated number of clammer-days per year and 95% confidence bounds in Humboldt Bay, Humboldt County, California, 1975, 1977-1989, and 2008.

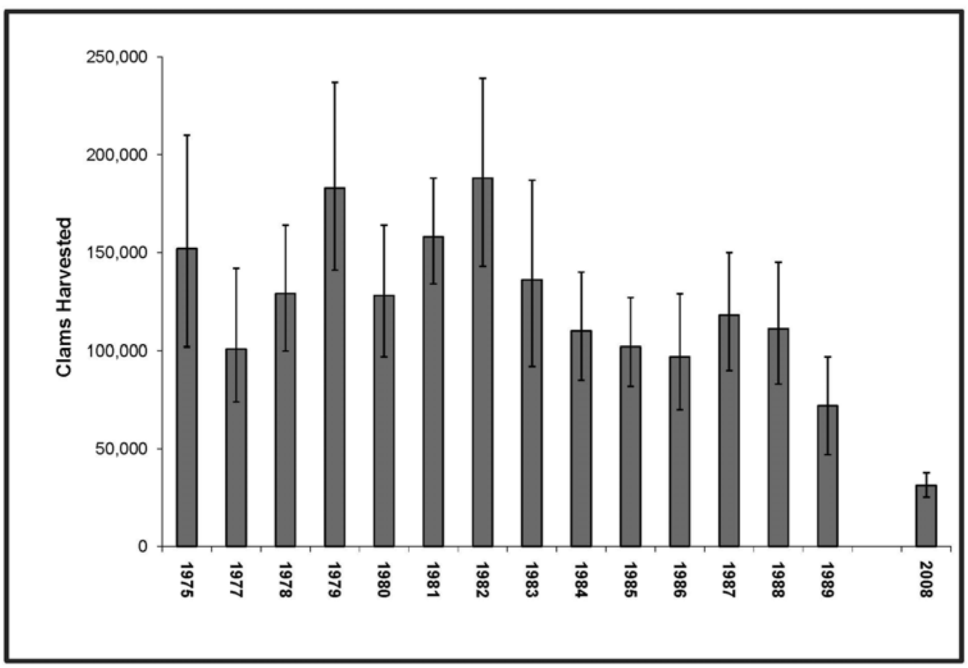

Figure 3. Estimated number of clams and 95% confidence bounds harvested annually from Humboldt Bay, Humboldt County, California, 1975, 1977-1989, and 2008.

Table 3. Clam catch (as percent composition), in Humboldt Bay, Humboldt County, California, 1975, 1977 – 1989, and 2008.

	Genera					
Year	*Tresus*	*Saxidomus*	*Leukoma*	*Clinocardium*	*Panopea*	Other
1975	72.2	18.8	8.9	0.2	0.0	0.0
1977	64.4	22.2	9.3	0.9	0.0	3.8
1978	59.4	33.8	6.2	0.5	0.0	0.1
1979	34.4	51.6	13.8	0.1	0.0	0.1
1980	53.4	35.0	8.2	3.4	0.0	0.0
1981	45.6	47.3	6.9	0.1	0.0	0.1
1982	38.4	42.3	11.1	7.9	0.0	0.2
1983	38.9	44.6	13.2	1.5	0.0	1.9
1984	47.0	36.9	10.5	0.5	0.0	5.1
1985	33.8	27.6	37.2	0.1	0.0	1.2
1986	28.5	37.8	32.7	0.4	0.0	0.7
1987	40.9	23.2	35.2	0.0	0.0	0.6
1988	43.4	26.0	28.9	0.1	0.0	1.6
1989	35.0	25.1	38.3	0.6	0.0	1.1
Mean[a]	45.4	33.7	18.6	1.2	0.0	1.2
2008	84.4	14.4	0.5	0.0	1.0	0.0

[a]1975-1989

DISCUSSION

Humboldt Bay contains a diverse array of substrate and soft-bottom habitat type, supporting a wide array of intertidal and subtidal clams (Tasto 1974, Hancock et al. 1979, Stout et al. 1986). Further, clam species are not uniformly distributed in the bay and often exhibit aggregated distributions. For example, gaper clam distribution has been described as high density clumps superimposed over a low density, random pattern (Wendell et al. 1976). Lower tides are popular with clammers for both the longer duration of exposed clam beds and a greater density of clams, the latter perhaps because lower intertidal areas are more frequently inundated, giving veligers (larval clams) more opportunity to settle (Wendell et al. 1976).

Six clam species made up most of the harvest: Washington and California butter clams, Pacific and fat gaper clams, Pacific littleneck clams and Pacific geoduck clams. Humboldt Bay is situated within the range overlap of two gaper clam and two butter clam species. The Pacific gaper (*Tresus nuttalli*) is wide ranging from Kodiak, Alaska to Baja California, Mexico. The fat gaper clam (*Tresus capax*) range also extends north to Alaska, and as far south as Oceano near San Luis Obispo, California, but is only occasionally found south of Humboldt Bay. The Washington butter clam (*Saxidomus gigantea*) is found north to Alaska and south to Capitola, near Santa Cruz, California. The California butter clam (*Saxidomus nuttallii*) ranges from Humboldt Bay on the north and extends south to Punta Rompiente, Baja California, Mexico. Pacific geoduck clams range from Kodiak, Alaska to Newport Bay, California. Pacific littleneck clams are even more wide ranging from the Aleutian Islands, Alaska to Bahia Santa Maria, Baja California, Mexico (Coan et al. 2000). Several species present in small numbers during the 1975 to 1989 surveys were absent from the 2008 survey, notably the Nuttall cockle (*Clinocardium nuttallii*), the rough piddock (*Zirfaea pilsbryi*), and clams of the genus *Macoma*. These results may simply represent a change in preference among harvesters, and do not necessarily indicate change in abundance.

Tomales Bay, Marin County, northern California, serves as an interesting comparison to Humboldt Bay. Just north of San Francisco Bay, Tomales Bay is approximately 12 miles long, narrow and relatively shallow, and historically known for its oyster and clam production. Containing over 700 acres of eel grass, it is also an important nursery for fish and invertebrates, and a staging area along the Pacific Flyway (Moore 2004). Clam populations there have been surveyed by the CDFG from the 1960s through the 1990s, with some of the highest catch and effort levels in the state. The most recent estimates of clammer effort in this more southerly bay during the nine-years from 1989 - 1997 show annual effort fluctuating between 13,400 and 34,800 clammer-days. Harvesters in Tomales Bay primarily pursued gaper clams, with an estimated annual harvest of 77,000 to 264,000 gaper clams during that period (T. Moore, CDFG, unpublished data). In contrast, Humboldt Bay clammer effort was much lower during both the most recent survey and during the earlier survey period (1975 to 1989), when the highest estimated level of annual effort was 6,640 clammer-days and yielded 188,000 clams in 1982. Additionally, the proportion of gaper clams harvested has been much lower in Humboldt Bay than Tomales Bay. For example, in 1982 only 38% of the total catch consisted of gaper clams, while 42% were butter clams.

The change in catch composition in Humboldt Bay was unexpected. The proportion of gaper clams harvested had increased while all other species, with the exception of geoducks, had decreased, and total catch was less varied (Table 3). The South East Asian immigrant proportion of the clammer demographic has increased over the past several decades, noteworthy only in that it may help to explain the observed shift in species preference, as gaper clams are popular in Asian cuisine. During the course of the 2008 survey, we noticed that particular demographic group digging often and targeting almost exclusively gaper clams. These subsistence-style clammers regularly broke the clam out of the shell as they dug it, a technique that was much less prevalent during prior creel sampling at Humboldt Bay and other locations in California, such as Tomales Bay and Bodega Bay, Sonoma County, as evidenced by the large numbers of gaper clams that were intact enough to be measured. There have been no reports of this technique currently being used at other popular clamming areas, such as Princeton Harbor, San Mateo County, and we believe it is a common practice only in Humboldt Bay. The lack of an intact shell, and sometimes siphon plates, on harvested gaper clams prevented both the positive identification to species and the gathering of length-frequency data, a problem both for managers and law enforcement personnel. However, because of the daily bag limit, strong digger preferences for larger clams, and high skill level, length frequency data gathered during the creel census is not representative of the clam population. Research sampling is the preferred method to get population data, and should be employed in this case (Pollock et al. 1994).

In the historic creel surveys, the fat gaper dominated the catch. Fishery independent surveys conducted in the late 1960s showed the Pacific gaper occurring at significantly lower densities than the fat gaper throughout south Humboldt Bay (Stout et al. 1986). Although inconclusive during 2008 because most harvested gapers were removed from the shell, creel samplers regularly noted a high proportion of gaper siphons having thick, leathery siphon plates, a characteristic of the Pacific gaper. Additionally, the 2008 creel survey and fishery-independent surveys conducted by the CDFG in 2008 and 2009 clearly showed the California butter clam to be the dominant butter clam. This was contrary to the 1986 survey of clam species composition by substrate type that concluded the Washington butter clam occurred in higher average density than the California butter clam (Stout et al. 1986). By substrate, Washington butter clams occurred at a higher frequency in sand while California butter clams occurred at a higher frequency in mud. Overall, fat gapers and Washington butter clams clearly dominated the sand and silty-sand habitats (Stout et al. 1986).

Humboldt Bay currently may contain fewer sandy substrates and more silt and mud; additionally, the proportion of gaper and butter clam species that are more common to the south of Humboldt Bay seems to have increased. We suggest that these apparent species shifts be further investigated and the potential causes, for example changes in Humboldt Bay habitat or global climate change, be explored in more detail.

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