CALIFORNIA FISH AND GAME

"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

VOLUME 78 WINTER 1992 NUMBER 1

California Fish and Game is published quarterly by the California Department of Fish and Game. It is a journal devoted to the conservation and understanding of fish and wildlife. If its contents are reproduced elsewhere, the authors and the California Department of Fish and Game would appreciate being acknowledged.

Subscriptions may be obtained at the rate of $10 per year by placing an order with the Editor, California Department of Fish and Game, 1416 Ninth Street, Sacramento. CA 95814. Checks or money orders in U.S. dollars should be made out to California Fish and Game. Inquiries regarding paid subscriptions should be directed to the Editor. Complimentary subscriptions are granted on an exchange basis.

Please direct correspondence to:

Dr. Eric R. Loft, Editor in Chief
California Fish and Game
1416 Ninth Street
Sacramento, California 95814

CALIFORNIA FISH AND GAME

VOLUME 78 WINTER 1992 NUMBER 1

Published Quarterly by

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
--LDA--

CONTENTS

ERRATUM

Bleich, V.C. and D. Racine. 1991. Mountain beaver (*Aplondontia rufa*) from Inyo County, California. Calif. Fish and Game 77(3):153-155.

The last sentence of paragraph one (page 153) should be corrected to read: The subspecies *phaea* and *nigra* are considered to be mammals of "special concern" in California (WIlliams 1986), and both are candidates for addition to the Federal list of endangered and threatened species (Steele 1989).

Calif. Fish and Game (78)1:1-10 1992

REVISITING OVERPOPULATED DEER RANGES IN THE UNITED STATES

PAUL R. KRAUSMAN, LYLE K. SOWLS[1], and BRUCE D. LEOPOLD[2]
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721

Leopold et al. (1947) conducted a survey of over-populated deer ranges in the United States and described approximately 100 herds that were over-populated. We identified deer experts in each state and asked a series of questions related to changes in their herds since 1947. Deer populations and their distribution have increased since 1947 and deer are in every state. Deer have effectively been controlled with hunting and habitat manipulation in many areas. Herds that are still overpopulated are not hunted, have an inadequate doe harvest, or inadequate harvest.

INTRODUCTION

In 1947 Leopold et al. (1947) conducted a survey of overpopulated deer (*Odocoileus* spp.) ranges in the United States. They compiled a country-wide map of deer problem areas for use in wildlife classes. They produced a map of over-populated ranges (Leopold et al. 1947:164) and described 99 problem areas throughout the United States. Overpopulated ranges were the result of individual and synergetic effects of buck laws, predator control, and over-large refuges. As of 1945 only 10% of the known problem areas were stabilized and Leopold et al. (1947) claimed "Most of the remedial reductions have been too late, too light, or too intermittent to accomplish their purpose."

Since the Leopold et al. (1947) study nearly a half century of research on deer has produced a wealth of information (summarized in Wallmo [1981] and Halls [1984]). However, we could not find an update on the herds Leopold et al. (1947) discussed. Leopold et al. (1947:162) hoped that the "imperfect history of the recent behavior of deer populations may convey the lesson that in managing overlarge herds, 'too little and too late' is the worst possible policy." To complete the picture for wildlife classes we were interested in the general changes that have occurred in deer management to minimize overpopulated ranges.

We corresponded with deer biologists in all states except Alaska and appreciate their responses to our questionnaires. Their responses are the basis of this work. This paper was presented at the Western States and Provinces Deer Workshop, 27-30 August 1991, Pacific Grove, California. R. C. Etchberger, M. C. Wallace, and W. B. Ballard reviewed the manuscript.

[1]Retired.

[2]Present address: Department of Wildlife and Fisheries, Mississippi State University, MS 39762-5917.

METHODS

We obtained data from a questionnaire sent in summer 1986 to deer biologists in each state. We located someone in each state familiar with the state's deer population and asked 4 questions:

1. What is the recent state wide status of your deer populations (mule deer [*Odocoileus hemionus* sp.], white-tailed deer [*O. virginianus* sp.], and/or Columbian black-tailed deer (*O. h. columbianus*]) compared to that reported by Leopold et al. (1947)?
2. Where in your state do you have irruptive areas, trouble areas, or chronic areas (if any)? Each type of area is defined by Leopold et al. (1947:163). On the enclosed map please outline the distributions of deer and irruptive areas, trouble areas, and chronic areas.
3. How has the status of deer changed in your state for the problem areas identified by Leopold et al. (1947)?
4. Briefly describe why your state wide deer population is in its present condition compared to the status reported by Leopold et al. (1947) (e.g., specific management, overgrazing, harvesting, predation, predator control).

RESULTS

We received complete responses from biologists in 47 states. Biologists in Utah and Washington did not respond, and we did not send a questionnaire to biologists in Alaska. We received specific comments about 76 of the 99 overpopulated ranges described by Leopold et al. (1947) and general comments about the increases that have occurred with most deer populations.

Nearly 100 deer ranges were over-populated in 1947 (Leopold et al. 1947). Nine of the 76 ranges reported to us were described as having densities higher than desired (Table 1). Only 1 area (Mt. Desert Island, Me., Table 1) was reported as similar to conditions reported by Leopold et al. (1947). Respondents stated that each of these 10 herds was above the desired levels due to limited, antlerless, or inadequate hunting. The other 66 herds compared were believed to be less than or equal to the desired management levels. California provides a good example.

Most deer herds in California (Table 1) are at or exceeding carrying capacity because females are not harvested and there has been a long-term decline in habitat quality. Most herds have densities less than desired but are around carrying capacity on a continuing basis.

Numerous reasons were provided for the change in the status of the other herds. The most common reason was related to management strategies that employed either adequate, antlerless, or buck only harvests; habitat improvement from reduction or removal of livestock and wildfire; and transplants. Other reasons provided included favorable climate, improved hunter access to areas, reduction of predation, disease eradication, supplemental feeding, immigration, reduced poaching, and improved public acceptance of deer as a consumable resource (Table 1).

Table 1. Status in 1980's of 76 over-populated ranges described by Leopold et al. (1947).

State and herd	1947 status	1980's status	Reason for change
Arizona			
Kaibab (north)	I[a]	≅K[b] with occasional overbrowsing	Reduction of livestock, Favorable climate
Kaibab (south)	C[c]	≅K with limited overbrowsing	Possible development of water
Woods Mt. mule deer	T[d]	≅K	
Bloody Basin	T	≅K	
Graham Mts.	I	≅K	
Tucson Mts.	T	≅K	
Arkansas			
Sycamore District Ozark Natl. For.	T	Moderate to low density	Habitat loss via advanced plant succession
California			
Interstate	I	Stable	Lack of disturbance and overgrazing
Humboldt Co.	T	≅K	Lack of disturbance
Glenn and Tehama co.	C	Stable to <K	Long-term decline in K
Tehama Co. (east)	T	Declining but ≅K	Overuse of summer range, lack of disturbance
Plumas and Lassen co.	I	Stable to declining but ≅K	Overgrazing and fire on winter ranges
Eldorado Co.	C	Declining but ≅K	>K and development on winter range
Yosemite	C	Increasing	Recent large wildfires
Inyo Co. (north)	T	Decline	Drought, K is variable
Inyo Co. (south)	C	Decline	Drought, K is variable
Sequoia and King's canyon	T	Decline	Predators and/or habitat changes
Riverside Co.	C	Decline	Fluctuating precipitation
Colorado			
Dinosaur Natl. Monument	I	Densities < long term objectives	Careful management, anterless harvest, limited supplemental feeding. Loss of habitat from towns, reservoirs, farms and mines.
Rocky Mtn. Natl. Park	C T	Densities > long term average	
Kanna Creek	I	Densities < long term average	
Gunnison Co.	I	Densities low	

Table 1. cont.

State and herd	1947 status	1980's status	Reason for change
Illinois			
Rockford	I	≅K	Transplants, controlled hunting
Horseshoe Lake Refuge	T	≅K	
Iowa			
Skunk River	T	≅K	Controlled harvest
Nishnabotna River	T	≅K	Controlled harvest
Des Moines River	T	≅K	Controlled harvest
Black Hawk County	T	≅K	Controlled harvest
Maine			
Mt. Desert Island	I	< K but similar to 1947	Lack of hunting
Massachusetts			
Nantucket Island	T	> K	Limited hunting
Michigan			
Upper Peninsula	I	Low densities	Winter habitat deteriorating, severe winter
Lower Peninsula	I	≅K	Antlerless hunting and heavy winter mortality
Lake County Area	I	High densities	Heavy winter loss
George Reserve	T	Controlled population	Hunting
Minnesota			
Red Lake Refuge	T	Stable to declining	Overharvest
Itasca State Park	C	Low density	Severe winter and either-sex hunting
State Croix State Park	I	Density fluctuates	Winter severity
Missouri			
St. Louis Game Park	T	K	Hunting
Montana			
Glacier Natl. Park	T	No problem	Improved deer/habitat relations
Six other winter ranges	T	No problem	Improved deer/habitat relations
Nebraska			
Bessey Division, Neb. Natl. For.	T	No problem	Controlled harvest

Table 1. cont.

State and herd	1947 status	1980's status	Reason for change
Nevada			
Santa Rosa	I	Increasing but < K	Range improvement
Kingston Canyon	I	Increasing but < K	Range improvement
Shell Creek	I	Increasing but < K	Range improvement
Reese River	I	Increasing but < K	Range improvement
Snake Division, Nev. Natl. For.	I	Increasing but < K	Range improvement
New Hampshire			
Coos County	No problem	Population declined	Winter habitat loss and overharvest of females
New Mexico			
Cuba	T	Deer populations are < K in N. M. although range is improving	Deer are in different stages of population cycle
Pecos River	T		
Gallinas District, Santa Fe Natl. For.	I		
Sandia Refuge, Cibola Natl. For.	I		
Magdalena Division, Cibola Natl. For.	C		
Black Canyon, Gila Natl. For.	C		
Jornado Range	I		
Sacramento Division, Lincoln Natl. For.	I		
New York			
Adirondacks	C	> K	Inadequate antlerless harvest and poor access to deer
Ontario and Stueben co.	T	≅K	
Allegany State Park	I	> K	Inadequate harvest
Bear Mt. State Park	C	> K	Inadequate harvest
Suffolk County, Long Island	C	≅K	Either sex hunting
Genesee County	T	< K	Hunting
North Carolina			
Pisgah Game Preserve	T	Low to moderate densities	Related to mast crop
North Dakota			
Upper and Lower Souris refuges	T	No change	Artificial feeding and inadequate harvest

Table 1. cont.

State and herd	1947 status	1980's status	Reason for change
Oklahoma			
Wichita Mountains Wildlife Refuge	T	Overpopulated	Inadequate harvest
Lake Murray State State Park	T	Overpopulated	Inadequate harvest
Oregon			
North Fork of John Day River	C	Static	Antlerless hunts
Murderer's Creek	T	< K	Antlerless hunts
Klamath-Deschutes Lake County	I	Stable	Antlerless hunts
Texas			
Edwards Plateau	T	> K	Large die off due to overgrazing aggravated by drought
Big Bend National Park	T	< K	
Vermont			
Essex County	C	≅K	Regulated antlerless hunts
Vermont Highlands	T	≅K	Regulated antlerless hunts
Windham County	I	≅K	Regulated antlerless hunts
Wisconsin			
North Wisc.	T	Stable	Antlerless hunts
Chambers Island	C	Stable	Natural succession
Camp McCoy, Necedah Refuge and Saddle Mound	I	Stable	Adequate harvest

[a]I = irruptive area or an area the deer population has damaged (Leopold et al. 1947:163).
[b]K = carrying capacity
[c]C = chronic area or a problem area of long standing usually in the post-irruptive stage (Leopold et al. 1947:163).
[d]T = trouble area or an area deer have recently exceeded K but to a lesser degree than I (Leopold et al. 1947:163).

When respondents described areas where deer herds were experiencing problems, the main sources were depleted habitat from natural succession, human use of deer habitat (e.g., town development and expansion, livestock operations, mining, and road construction), and an under-harvest of does. Other reasons included poaching, human harassment, increased elk (*Cervus elaphus*) numbers, overharvest, and severe winters (Table 1).

We were not able to obtain an updated map to compare with the map of overpopulated ranges presented by Leopold et al. (1947) because the terms they used (i.e., irruptive, chronic, and trouble) or the deer distribution provided were not accepted by most respondents. Present distribution maps, however, are available (Fig. 1 and 2). Also, many of the biologists from the Midwest pointed out that herds were often managed for an economic carrying capacity and not simply a biological carrying capacity. Many agencies take crop depredation into account when managing their herds.

DISCUSSION

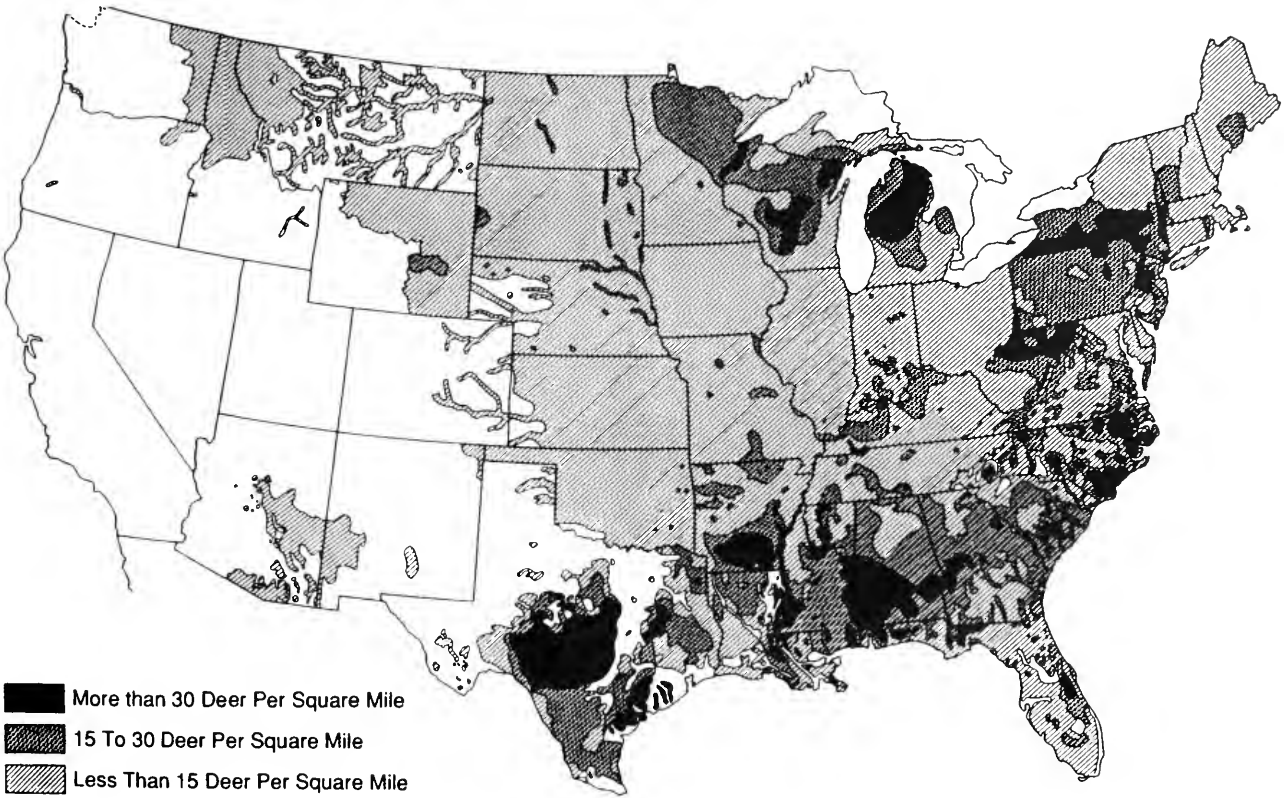
Survey studies of this nature should be interpreted conservatively. We did not visit all areas mentioned in the article and assume that the biologists we contacted had adequate and unbiased knowledge of the deer herds in their state. However, several general trends can be made from this survey. Overall, deer populations have increased throughout the United States since the Leopold et al. (1947) report and deer are in all 50 states. Most herds that were above carrying capacity in the 1940's have been effectively controlled by hunting and habitat manipulation. Those herds that continue to be above carrying capacity are at higher densities because of prohibition on firearms hunting, inadequate doe harvest, or inadequate harvest. Hunting is clearly an important tool in the management of deer populations in the United States.

The terms used by Leopold et al. (1947) (i.e., irruption, trouble area, chronic area) are not acceptable to many deer biologists today. Many respondents to the survey indicated that the terms used in the 1940's do not apply to contemporary management. Caughley (1981) argued that "overpopulation" can only be rigorously defined as too many animals.

Caughley (1981) further described 4 classes of "overpopulation": as when: (1) animals threaten human life or livelihood, (2) animals depress densities of favored species, (3) animals are too numerous for their own good, (4) and the system of plants and animals is not at equilibrium. The third class is an argument used as an ecological justification for sport hunting (Dasmann 1971, Caughley 1981) and implies populations must be managed constantly. However, Caughley (1981) argues that the classes 1, 2, and 3 involve value decisions and only class 4 is an ecological concept.

"The growth pattern typical of an ungulate population is an eruption, a crash, and then convergence to a steady density"(Caughley 1980). Many respondents expressed this attitude by stating the herds described by Leopold et al. (1947) in their state (e.g., N.M.) were not necessarily overpopulated, simply in different stages of a normal population cycle. The interpretation of carrying capacity and overpopulation certainly has changed in 40 years (Caughley 1980) and ultimately will influence deer management. We argue for scientific management that examines the equilibrium between deer and the energy components of their habitat.

Figure 1. Distribution of white-tailed deer in the United States, 1980 (Southeastern Cooperative Wildlife Disease Study 1982).



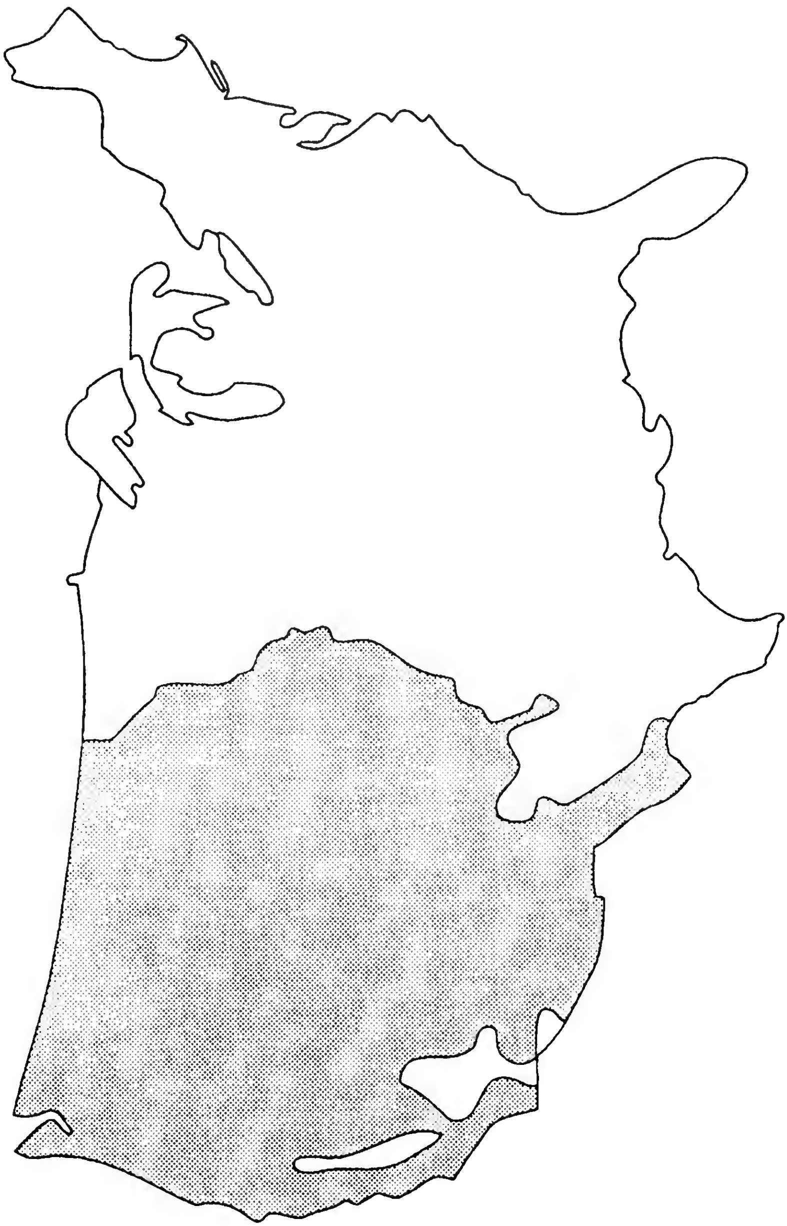


Figure 2. Distribution of mule deer in the United States, 1980 (Wallmo 1981:3).

LITERATURE CITED

Caughley, G. 1981. Overpopulation. Pages 7-19 *in* P. A. Jewell, S. Holt, and D. Hart, eds. Problems in management of locally abundant wild mammals.

______. 1980. What is this thing called carrying capacity. Pages 2-8 *in* M. S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior and management. Univ. Wyoming, Laramie.

Dasmann, W. 1971. If deer are to survive. Stackpole books, Harrisburg, Pa. 128pp.

Halls, L. K., ed. 1984. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pa. 870pp.

Leopold, A., L. K. Sowls, and D. L. Spencer. 1947. A survey of over-populated deer ranges in the United States. J. Wildl. Manage. 11:162-177.

Southeastern Cooperative Wildlife Disease Study. 1982. White-tailed deer populations 1982. A map prepared in cooperation with the Emergency Programs, Veterinary Services, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, through cooperative agreement 12-16-5-2230. Univ. Georgia, Athens. 1p.

Wallmo, O. C. 1981. Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln. 605pp.

Received: 30 August 1991
Accepted: 15 October 1991

Calif. Fish and Game (78)1:11-19 1992

THE PH AND ACID NEUTRALIZING CAPACITY OF PONDS CONTAINING *PSEUDACRIS REGILLA* LARVAE IN AN ALPINE BASIN OF THE SIERRA NEVADA

CHAD R. SOISETH
Department of Biology
University of California
Santa Barbara, CA 93106

Waters necessary for amphibian reproduction in the Sierra Nevada are sensitive to increases in atmospheric acid deposition but neither habitat pH nor acid tolerance have been determined for native amphibian species. The purposes of this study were (1) to determine the range of pH and acid neutralizing capacity (ANC) of 14 ponds in a high altitude (2,800 m elevation) watershed of the southern Sierra Nevada, (2) to evaluate whether pH and ANC influence the distribution of Pacific Treefrog (*Pseudacris* [= *Hyla*] *regilla*) larvae among ponds, and (3) to evaluate the susceptibility of *P. regilla* to current levels of pH and ANC. Ponds ranged in pH from 5.3 to 7.2 and in ANC from 0 to 132 ueq l^{-1}. No significant difference in pH or ANC was found for 9 ponds containing versus 5 ponds lacking *P. regilla* larvae. The presence or absence of larvae was independent of the duration of pond existence although ephemeral ponds exhibited significantly lower pH than permanent ponds. There was no evidence that acidification was affecting *P. regilla* in the Emerald Lake watershed of the southern Sierra Nevada.

INTRODUCTION

Sierra Nevada surface waters are sensitive to acid deposition because of their dilute chemistry (Melack *et al.* 1985), and acidic deposition has been reported in these waters (Dozier *et al.* 1987, Melack *et al.* 1982, Stohlgren and Parsons 1987). Episodic acidification in the Sierra occurs in alpine watersheds when solutes become concentrated during the initial phase of snowmelt and during intense summer rainstorms (Dozier *et al.* 1987, Melack *et al.* 1988).

Amphibian breeding waters are often weakly buffered and their chemistry is strongly influenced by snowmelt or rain inputs because watersheds are small and soils are poorly developed (Pough and Wilson 1977). Amphibians are vulnerable to acidification because reproduction and early development of many north temperate zone amphibians coincide with spring snowmelt (Pough and Wilson 1977). Mortality generally occurs below pH 5.0 and early developmental stages are most sensitive to low pH (Pierce 1985, Freda 1986). Embryos are less tolerant than larvae and tolerance increases as larvae grow (Pierce *et al.* 1984, Freda and Dunson 1985).

Interspecific (Gosner and Black 1957, Dale *et al.* 1985) and intraspecific (Pierce and Harvey 1987) variation in tolerance to acidification has been reported for many amphibians in the eastern United States. Tolerance limits are related to habitat pH (Pierce 1985, Freda 1986) yet basic information is lacking for amphibian species native to the Sierra Nevada. The purposes of this study were (1) to document the range of pH and acid neutralizing capacity (ANC) of amphibian habitat in a high elevation watershed in the southern Sierra Nevada, (2) to determine whether pH and ANC of pond habitats influence the distribution of amphibian larvae among ponds, and (3) to evaluate the susceptibility of amphibians contained in these ponds to current levels of pH and ANC.

STUDY AREA

Ponds were located in the Emerald Lake watershed, a north facing glacial cirque, in the upper Marble Fork basin of the Kaweah River drainage in Sequoia National Park (36°35' N, 118°40' W; elevation 2,760-3,160 m), California. The watershed is composed mainly of granitic bedrock with poorly developed, weakly buffered, acidic soils (Huntington and Akeson 1987, Lund *et al.* 1987). More than 90% of seasonal precipitation falls as snow with pH 5.2 to 5.5 (Dozier *et al.* 1989). Lakes in the area generally are ice-covered from November to mid May or late June and snowmelt usually occurs from April through mid July. Mean daily air temperatures range from 6 to 13°C during the summer and -4 to 4°C in winter. Lakes and streams in the area are weakly buffered and typical of most waters in the high Sierra (Melack *et al.* 1989). The ponds surveyed in this study ranged from approximately 25-300 m^2 in surface area and up to 2 m in depth. For additional detailed information on the study area see Tonnessen (1991).

METHODS

The Emerald Lake watershed was searched for ponds containing amphibians. All accessible ponds over a range of elevations (2,760-3,160 m) throughout the watershed were selected. Ten ponds were surveyed in 1985, plus 5 additional ponds in 1986 and 1987. The Pacific Treefrog (*Pseudacris* [= *Hyla*] *regilla*) was the only anuran occurring in the study area. The mountain yellow-legged frog (*Rana muscosa*), previously reported in the upper reaches of the Marble Fork drainage by Bradford (1984), was not observed during the current study. Ponds were visited at 2 to 4 week intervals with 1 to 5 visits to each pond, depending on the duration of pond existence, during the period of larval development (June-September). The presence or absence of larvae was noted on each sampling date. Ponds were categorized as either permanent or ephemeral, depending on the duration of existence, and as either containing or lacking larvae. Permanent ponds retained water over the summer (June-September) whereas ephemeral ponds dried by early to mid summer. Ponds containing larvae were defined as those which consistently held larvae on at least half of all visits over all years of the study. Ponds designated as lacking larvae were completely devoid of larvae throughout the study or contained 8 or fewer larvae on less than 25% of all visits. Two of the 5 ponds designated as lacking larvae occasionally contained low numbers of larvae. One of these 2 ponds contained 2 larvae on a single visit during 1987 while larvae were absent on 7 additional visits made to this pond over the 3 year study period. The other pond contained 8 larvae on one visit during 1985 and 2 larvae on one visit in 1987. Otherwise, larvae were absent during 7 additional visits made to this pond and from the 3 remaining ponds over the duration of the study. Ponds which consistently held larvae in successive years ($\geq$50% of all visits) were presumably important in contributing to local breeding populations, while the contribution of ponds occasionally containing a few larvae was probably negligible. The intention was to provide a range of pH and ANC for populations rather than individuals. Consequently, ponds that infrequently contained few larvae were designated as lacking larvae because they were more representative of ponds in this category than of ponds containing larvae.

Water samples were taken from 9 to 14 ponds between June and September of 1985 to 1987. Ponds were sampled once during July and August of 1985 and August and September of 1986. Sampling occurred at monthly intervals on 4 dates beginning in June of 1987. The same ponds were sampled in successive years and additional ponds were discovered and sampled in 1986 and 1987. Samples were collected 5-10 cm below the surface of each pond and stored in acid-washed, high-density polyethylene bottles. All samples were kept cool during transport to the laboratory. The pH of unfiltered samples was determined within 48 hours of collection using a Beckman model 40 pH meter and low ionic strength combination electrode. Unfiltered water samples were analyzed for acid neutralizing capacity (ANC) by Gran titration with 0.1 N HCl using the same apparatus (Wetzel and Likens 1991). ANC, currently used interchangeably with alkalinity, indicates the ability to neutralize strong acids and is a parameter commonly used to predict the response of surface waters to acidic inputs. ANC is the result of dissolved species (usually weak acid anions) that can accept and neutralize protons.

Seasonal mean pH and ANC values were determined for each pond during each year. Mean pH values were calculated by transforming pH values to hydrogen ion concentrations, averaging, and transforming back to pH. Because the data violated assumptions of normality, a Mann-Whitney *U* test (Sokal and Rohlf 1981) was used to test null hypotheses that ponds grouped according to presence of larvae or duration of existence did not differ in pH or ANC. Similarly, seasonal changes in pH and ANC of 5 permanent ponds sampled during both June and September of 1987 were tested. A *G*-test of independence (Sokal and Rohlf 1981) was used to determine whether a relationship existed between the duration of pond existence and presence or absence of *P. regilla* larvae.

RESULTS AND DISCUSSION

Presence and Relative Abundance of Larvae

P. regilla adults emerge during snowmelt (April through mid July) and mating occurs soon afterwards. Larvae were abundant by early July in 1985 and 1987 but late snowmelt and cooler temperatures during 1986 delayed reproduction and larvae were not observed until mid August. Larvae were observed on at least one occasion in 8 of 10 ponds in 1985 and 10 of 15 in 1986 and 1987. Most larvae metamorphosed between July and August during 1985 and 1987 while metamorphosis occurred between August and September in 1986. Although the abundance of *P. regilla* was not quantified, larval densities in ponds appeared similar during all years of the study.

Pond Chemistry, Duration and Distribution of Larvae

The pH and ANC of ponds containing *P. regilla* larvae ranged from 5.3 to 7.2 and from 0 to 132 ueq l^{-1}, respectively (Table 1). No significant difference in pH or ANC was observed between ponds lacking versus ponds containing *P. regilla* in each year of the study (Mann-Whitney U test, $P > 0.10$). These results suggest that biotic and/or abiotic factors other than pH and ANC alone currently influence the distribution of *P. regilla* among high elevation ponds in the Emerald Lake watershed. Similarly, 159 field sites in Nova Scotia were surveyed for 11 amphibian species and neither pH, alkalinity, or other ionic constituents influenced species distributions among 5 habitat types (Dale *et al.* 1985).

Ephemeral ponds were significantly lower in pH than permanent ponds (Mann-Whitney U test, $P < 0.05$) although pond types did not differ in ANC ($P > 0.05$)(Table 2). This was probably the result of the shorter existence of ephemeral ponds following initial snowmelt inputs and biotic and/or abiotic processes within the two pond types.

Ponds ranged slightly lower in pH and ANC during June compared with September of 1987 (Fig. 1) but apparent seasonal trends toward increasing pH and ANC in 5 permanent ponds were not significant (Mann-Whitney U test, $P > 0.10$).

Table 1. Comparison of pH and ANC of ponds containing versus lacking *P. regilla* larvae. Mean pH was based on seasonal averages using hydrogen ion concentration. Sample size (n) represents number of ponds.

Larval	pH			ANC (ueq l^{-1})			
presence	Median	$\bar{x}$	Range	Median	$\bar{x}$	Range	n
1985							
Larvae	6.0	5.8	5.3-6.9	--	--	--	6
No Larvae	6.6	6.6	6.4-7.0	--	--	--	3
1986							
Larvae	6.0	5.9	5.5-6.7	41	50	19-132	8
No Larvae	6.3	6.2	5.9-6.5	56	51	20-85	5
1987							
Larvae	6.1	5.9	5.4-7.2	35	50	0-130	9
No Larvae	6.3	6.2	5.7-6.8	69	63	20-92	5
All Years							
Larvae	6.1	5.9	5.3-7.2	40	50	0-132	9
No Larvae	6.3	6.2	5.7-7.0	64	59	20-92	5

Table 2. Comparison of pH and ANC of ponds categorized by duration of existence. Mean and standard deviation (s) were calculated using three-year means for each pond. Standard deviation of mean pH is expressed as hydrogen ion concentration ($[H^+] \times 10^{-6}$). Sample size (*n*) represents number of ponds. Asterisks denote a significant difference between groups (Mann-Whitney *U* test $P < 0.05$).

		pH				ANC ($\mu eq\ l^{-1}$)			
Pond Type		Median	$\bar{x}$	s	*n*	Median	$\bar{x}$	s	*n*
Ephemeral	*	6.4	5.8	1.05	10	47	46	24.6	9
Permanent	*	5.8	6.3	0.22	5	61	58	35.2	5

Although sample size was limited and few ponds existed for more than four weeks, little temporal change in pH and ANC was noted despite apparent evaporative losses and decreasing pond volume.

Eight of 10 ponds containing larvae were ephemeral while 2 of 5 ponds lacking larvae were ephemeral. Small sample size was problematic, but larval presence was independent of the duration of pond existence (*G* test, $P > 0.10$). Bradford (1989), in documenting the occurrence of fish and amphibian larvae in 67 high Sierra lakes and ponds, determined that *P. regilla* inhabited shallower waters than either *R. muscosa* or fish and these habitats frequently dried by late summer. Ephemeral ponds containing larvae in the Emerald Lake watershed generally existed until mid July or August (Fig. 1) and mass mortality due to desiccation was observed in two ponds during this period. Although larval presence was independent of pond duration in the current study, personal observations and Bradford (1989) suggest that this hypothesis requires further testing.

Susceptibility of *P. regilla* to Acidification

The acid tolerance of *P. regilla* is currently unknown but related species are relatively tolerant to acidification. The acid tolerance of most anurans in the eastern United States lies between pH 4.0 and 4.5 with tolerance limits dependent on habitat pH and developmental stage (Pierce 1985, Freda 1986). The lethal pH for *Pseudacris nigrita* and *Hyla crucifer* embryos, species related to *P. regilla* (Hedges 1986), occurs below 4.1 and 4.2, respectively (Gosner and Black 1957). In addition, Gosner and Black (1957) held *P. nigrita* larvae for 4 days at a pH of 3.8 to 3.9 with no adverse effects. Thus, these species appear relatively acid tolerant.

Pond pH below 5.0 was not detected in the current study and larval abundance in ponds containing *P. regilla* appeared similar during successive years. In addition, annual volume-weighted mean pH values of precipitation in the Sierra reportedly lie between 5.2 and 5.5 (Melack and Stoddard 1991). These data provide evidence that populations of *P. regilla* in the Emerald Lake watershed of the Sierra Nevada are tolerant of current pH levels. Moreover, if the tolerance of *P. regilla* parallels that of related eastern species, this species is likely to be relatively acid tolerant.

Despite the fact that *P. regilla* appears unaffected by current pH levels in the

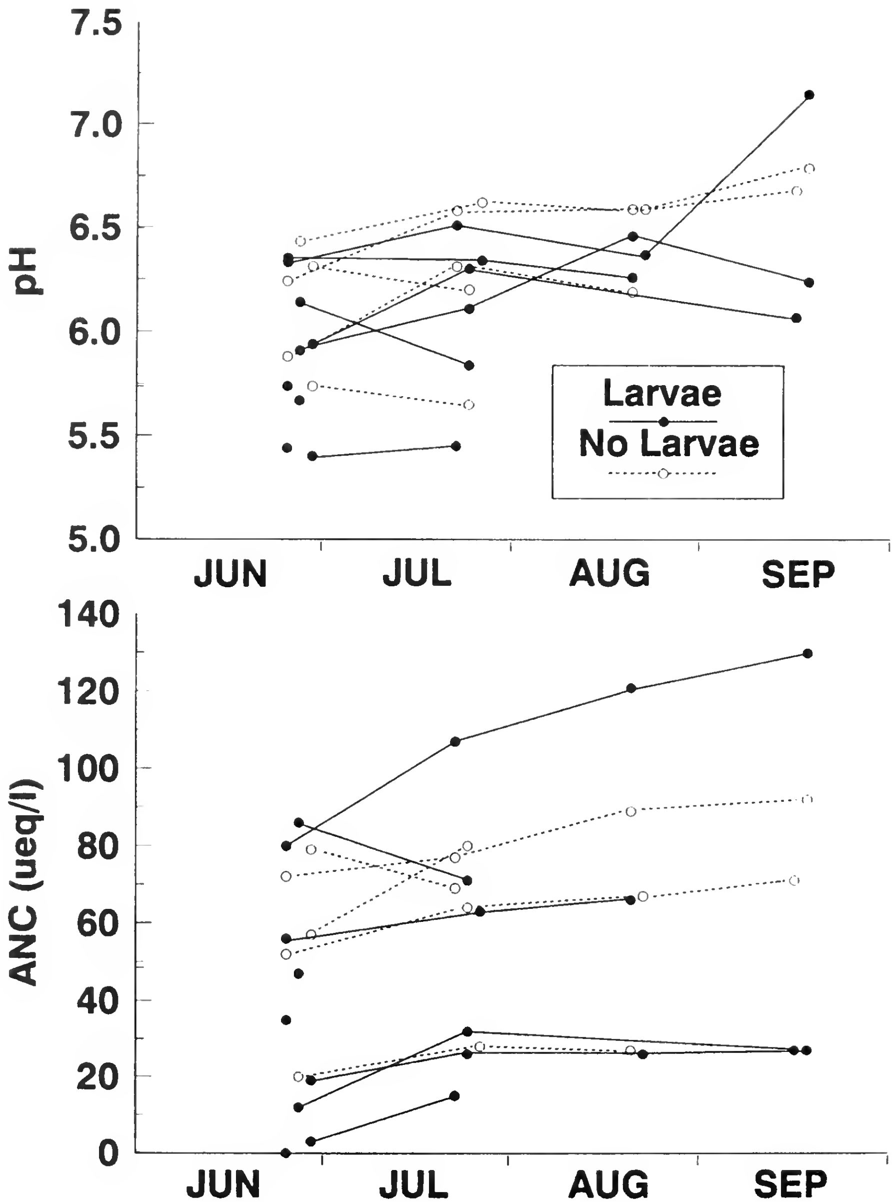


Figure 1. Temporal change in pH and ANC for ponds containing (closed circles) and lacking (open circles) *P. regilla* larvae during the summer of 1987. Ponds designated as permanent are those existing in September.

Sierra, their breeding habitat is sensitive to increased acidity. The range of ANC in waters containing *P. regilla* larvae is 0-130 ueq l^{-1}. Nine of 11 (82%) ponds sampled more than once in each year exhibited ANC below 90 ueq l^{-1}. Surface waters with ANC $\leq$ 200 ueq l^{-1} are defined as sensitive to acid precipitation by the EPA (Landers *et al.* 1987) and all of the ponds sampled in this study fell within this range. In addition, Dozier *et al.* (1989) determined that the acidity of Sierran snow can be magnified several fold in the initial fraction of snowmelt runoff. Episodic acidification of breeding habitat during snowmelt would most likely affect reproduction and early developmental stages of Sierran amphibians.

Because future emissions of compounds associated with acid deposition are likely to increase, toxic levels of acidification must be determined for sensitive developmental stages of Sierran amphibians. In addition, because amphibian species appear to be declining worldwide (Wyman 1990) and little information is currently available for local species, the abundance and distribution of amphibian populations throughout California should be documented and monitored.

CONCLUSIONS

The pH of ponds containing *P. regilla* larvae in the Emerald Lake watershed is not reduced to critical levels known to affect related eastern species. Ponds ranged in pH from 5.3 to 7.2 and in ANC from 0 to 132 ueq l^{-1}. Neither pH nor ANC were found to influence the distribution of *P. regilla* among ponds. Ephemeral ponds were significantly lower in pH than permanent ponds although the presence or absence of larvae was independent of the duration of pond existence. Despite the fact that *P. regilla* appears tolerant of current pH levels in breeding ponds of the Emerald Lake watershed, these habitats are sensitive to increased atmospheric acid deposition and the acid tolerance of Sierran amphibians must be determined.

ACKNOWLEDGMENTS

I wish to extend a special thanks to National Park Service personnel for their cooperation and support. I am grateful to S. Hamilton, S. Sippel, and J. Sickman at the University of California at Santa Barbara for analysis of water samples. Thanks to D. F. Bradford, A. Sarnelle, S. Hamilton and D. Showers for critical review of this manuscript. This work was partly supported by the National Park Service and by California Air Resources Board contracts A4-122-32 to S. D. Cooper and A6-184-32 to J. M. Melack, S. D. Cooper and T. M. Jenkins, Jr.

LITERATURE CITED

Bradford, D. F. 1984. Temperature modulation in a high-elevation amphibian, *Rana muscosa*. Copeia 1984:966-976.

_____. 1989. Allotopic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: implication of the negative effect of fish introductions. Copeia 1989:775-778.

Dale, J. M., B. Freedman, and J. Kerekes. 1985. Acidity and associated water chemistry of amphibian habitats in Nova Scotia. Can. J. Zool. 63:97-105.

Dozier, J., J. M. Melack, D. Marks, K. Elder, R. Kattelmann, and M. Williams. 1987. Snow deposition, melt, runoff and chemistry in a small alpine watershed, Emerald Lake Basin, Sequoia National Park. Final Report. California Air Resources Board. Contract A3-106-32. 156pp.

_____, _____, _____, _____, _____, _____. 1989. Snow deposition, melt, runoff and chemistry in a small alpine watershed, Emerald Lake Basin, Sequoia National Park. Final Report. California Air Resources Board. Contract A6-147-32. 268pp.

Freda, J. and W. A. Dunson. 1985. Field and laboratory studies of ion balance and growth rates of Ranid tadpoles chronically exposed to low pH. Copeia 1985:415-423.

_____. 1986. The influence of acidic pond water on amphibians: a review. Water, Air and Soil Pollution 30:439-450.

Gosner, K. L. and I. H. Black. 1957. The effects of acidity on the development and hatching of New Jersey frogs. Ecology 38:256-262.

Hedges, S. B. 1986. An electrophoretic analysis of holarctic hylid frog evolution. Syst. Zool. 35:1-21.

Huntington, G. L., and M. A. Akeson. 1987. Pedologic investigations in support of acid rain studies, Sequoia National Park, California. Dep. Land, Air and Water Res. Univ. of California, Davis.

Landers, D. H., J. M. Eilers, D. F. Brakke, W. S. Overton, P. E. Kellar, M. E. Silverstein, R. D. Schonbrod, R. E. Crowe, R. A. Linthurst, J. M. Omernik, S. A. Teague, and E. P. Meier. 1987. Western lake survey phase I. Characteristics of lakes in the Western United States. Volume I: population descriptions and physico-chemical relationships. EPA/600/3-86/054a. U.S. Environ. Prot. Agency, Washington, D.C. 149pp.

Lund, L. J., A. D. Brown, M. A. Leuking, S. C. Nodvin, A. L. Page, and G. Sposito. 1987. Soil processes at Emerald Lake. Final Report. Calif. Air Res. Board. Contract A3-105-32. 114pp.

Melack, J. M., S. D. Cooper, T. M. Jenkins, L. Barmuta, S. Hamilton, K. Kratz, J. Sickman, and C. Soiseth. 1989. Chemical and biological characteristics of Emerald Lake and the streams in its watershed, and the responses of the lake and streams to acidic deposition. Final Report. Calif. Air Res. Board. Contract A6-184-32. 465pp.

_____, and J. L. Stoddard. 1991. Sierra Nevada, California. Pages 503-537 *in* D. F. Charles, (ed.) Acidic deposition and aquatic ecosystems: regional case studies. Springer-Verlag, New York.

_____, _____, and D. R. Dawson. 1982. Acid precipitation and buffer capacity of lakes in the Sierra Nevada, California. Pages 465-471 *in* J. A. Johnson and R. A. Clarke, (eds.), International Symposium on Hydrometeorology. American Water Resources Association, Bethesda, Maryland.

_____, _____, and C. A. Ochs. 1985. Major ion chemistry and sensitivity to acid precipitation of Sierra Nevada lakes. Water Resources Research 21: 27-32.

_____, M. W. Williams, and J. O. Sickman. 1988. Episodic acidification during snowmelt in waters of the Sierra Nevada, California. Pages 426-436 *in* I. G. Poppoff, C. R. Goldman, S. L. Loeb and L. B. Leopold (eds.), International Mountain Watershed Symposium. Tahoe Resource Conservation District, South Lake Tahoe, California.

Pierce, B. A., J. B. Hoskins, and E. Epstein. 1984. Acid tolerance in Connecticut Wood Frogs (*Rana sylvatica*). J. Herpetol. 18:159-167.

_____. 1985. Acid tolerance in amphibians. Bioscience 35:239-243.

_____, and J. M. Harvey. 1987. Geographic variation in acid tolerance of Connecticut Wood frogs. Copeia 1987:94-103.

Pough, F. H. and R. E. Wilson. 1977. Acid precipitation and reproductive success of *Ambystoma* salamanders. Water, Air and Soil Pollution 7:307-316.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. 2nd ed. W. H. Freeman & Co., San Francisco, California. 859pp.

Stohlgren, T. J. and D. J. Parsons. 1987. Variation of wet deposition chemistry in Sequoia National Park, California. Atmospheric Environment, 21:1369-1374.

Tonnessen, K. A. 1991. The Emerald Lake watershed study: introduction and site description. Water Resources Research 27:1537-1539.

Wetzel, R. G. and G. E. Likens. 1991. Limnological analyses. 2nd ed. Springer-Verlag, New York. 391pp.

Wyman, R. L. 1990. What's happening to the amphibians? Conserv. Biology 4:350-352.

Received: 24 July 1991
Accepted: 13 February 1992

Calif. Fish and Game (78)1:20-44 1992

THE EVOLUTION OF CALIFORNIA'S HERRING ROE FISHERY: CATCH ALLOCATION, LIMITED ENTRY, AND CONFLICT RESOLUTION

JEROME D. SPRATT
California Department of Fish and Game
Marine Resources Division
2201 Garden Road
Monterey, California 93940

California's Pacific herring (*Clupea pallasi*) roe fishery began in 1973. A formal limited entry program was adopted in 1977 and the number of herring permits issued for the major fishing areas of San Francisco and Tomales Bays peaked at 471 permits in the 1982-83 season. In 1989, the Legislature adopted a policy to allow the sale of permits. The majority of herring permits are issued for San Francisco Bay. San Francisco Bay herring quotas are allocated approximately 33% to round haul (purse seine and lampara nets) vessels and 67% to gill net vessels. All round haul vessels are on individual vessel quotas that have lessened competition among round haul vessels. In addition, round haul vessels may not fish in waters of San Francisco Bay less than 11m deep until gill net quotas have been taken. Congestion in the San Francisco Bay gill net fishery was alleviated when the gill net fleet was divided into platoons that fish at alternate times. San Francisco Bay is surrounded by a metropolitan area, and many fishing areas have been closed due to conflicts with recreational users and noise pollution near private residences. A test boat system that controls the opening and closing of the round haul fishery and limits catch-and-release practices was implemented in 1991. In conjunction with the test boat system, an important pre-spawn staging area of San Francisco Bay was closed to gill net fishing in 1991. Congestion and socioeconomic issues were less of a problem in Tomales Bay due to the fewer number of permits and the rural nature of the surrounding communities.

INTRODUCTION

California's Pacific herring (*Clupea pallasi*) fishery developed in 1973 when Japan began importing herring roe from the west coast of North America. Catches peaked in the 1981-82 season at 11,321 tons (Table 1). When the Japanese herring market developed, the status of California's herring stocks was largely unknown.

This report deals primarily with the San Francisco Bay fishery, but the development of the Tomales Bay herring fishery was also included (Fig. 1). The early stages of the fisheries in Humboldt Bay and Crescent City Harbor are mentioned, but the development of these minor fisheries was not followed because congestion and gear conflicts have not been a problem in these areas.

Table 1. California Herring Roe Fishery Quotas and Catch in Tons by Area from 1972-73 to 1990-91.

	San Francisco Bay		Tomales Bay		Humboldt Bay		Crescent City	
Season	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch
1972-73	1,500	436	750	598	—	0	—	12
1973-74	500	1,938	450	521	20	2	—	59
1974-75	600	514	500	518	20	0	—	13
1975-76	3,050	1,719	625	144	20	11	—	0
1976-77	4,000	4,201	1,175	606	50	21	—	0
1977-78	5,000	4,987	1,175	716	50	12	30	13
1978-79	5,000	4,121	1,200	448	50	49	30	12
1979-80	6,000	6,430	1,200	603	50	49	30	26
1980-81	7,250	5,826	1,200	448	50	43	30	6
1981-82	10,000	10,415	1,200	851	50	51	30	4
1982-83	10,399	9,695	1,000	822	60	25	30	9
1983-84	10,399	2,838[a]	1,000	110[a]	60	55	30	16
1984-85	6,500	7,740	1,000	430	60	59	30	35
1985-86	7,530	7,278	1,000	771	60	59	30	30
1986-87	7,530	8,098[b]	1,000	867	60	71	30	0
1987-88	8,500	8,741[b]	750	750	60	31	30	50
1988-89	9,500	9,736[b]	750	213	60	44	30	30
1989-90	9,057	8,962[b]	-	-	60	61	30	33
1990-91	8,858	7,741[b]	-	-	60	63	30	36

[a]El Nino affected the fishery. Spawning biomass declined, and due to poor quality roe, the fishery was closed prematurely.
[b]Herring only, roe on kelp is not included.

CONTROLLED EXPANSION OF THE FISHERY

In 1973, the best available information on the status of California's herring stocks was 20 years old, and the California Department of Fish and Game (DFG) began annual herring population assessments in Tomales and San Francisco bays (Table 2). While the herring population was being evaluated, the California State Legislature (CSL) chose a cautious management approach, setting conservative catch quotas for the first two herring seasons. The CSL controlled herring quotas for the first three seasons, but ultimately gave management authority to the Fish and Game Commission (FGC).

1972-73 Season. As the first herring season approached, the specter of a large unrestricted fishery motivated a concerned state senator from the San Francisco Bay area to introduce emergency legislation, which expired 60 days after enactment, giving the CSL temporary control over the herring fishery. The fishery was already underway when the Governor signed the bill on January 17, 1973. Temporary catch quotas were set at 750 tons in Tomales Bay and 1,500 tons in San Francisco Bay.

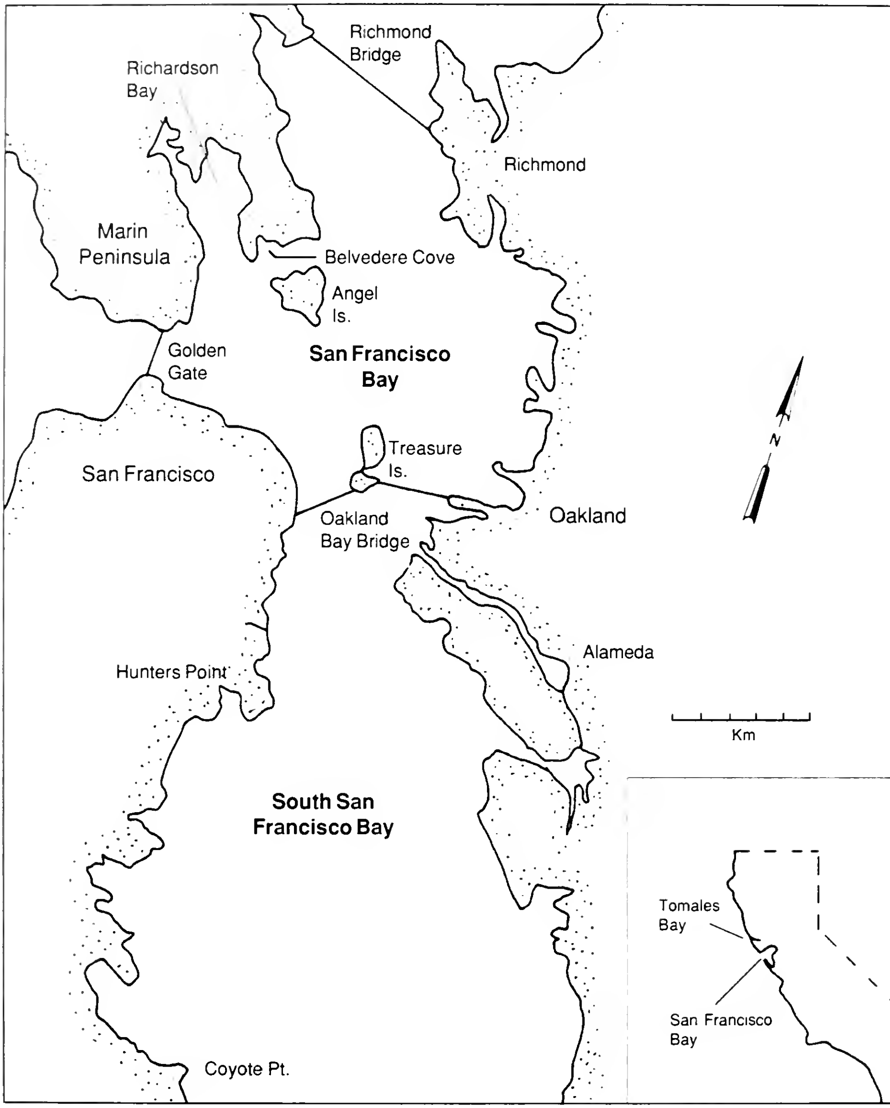


Figure 1. San Francisco Bay, California and proximity to Tomales Bay.

There were no limitations on the number of fishermen who could participate in the fishery and 17 vessels were active during the season (Tables 3 and 4).

1973-74 Season. The CSL passed new legislation prior to the 1973-74 herring season that gave the FGC management authority over the herring fishery. Quotas were fixed for two years at 500 tons (Table 3) and 450 tons (Table 4) in San Francisco and Tomales Bays, respectively. Because of the limited fishing area in San Francisco

Table 2. Pacific herring biomass estimates in tons from spawning-ground surveys in San Francisco and Tomales bays, California.

Season	San Francisco Bay	Tomales Bay	Season	San Francisco Bay	Tomales Bay
1973-74	6,200	6,600	1982-83	59,200	11,000
1974-75	27,200	4,700	1983-84	40,800	1,200
1975-76	27,100	7,900	1984-85	46,900	6,600
1976-77	26,900	5,100	1985-86	49,100	1,200
1977-78	8,700	22,200	1986-87	56,800	5,800
1978-79	36,700	—	1987-88	68,900	2,100
1979-80	53,000	6,000	1988-89	66,000	167
1980-81	65,400	5,600	1989-90	64,500	345
1981-82	99,600	7,100	1990-91	51,000	779

and Tomales Bays and a concern for the safety of other users of bay waters, the CSL also gave the FGC authority to limit the number of herring permits.

The FGC issued 17 permits for the 1973-74 season, equal to the number of vessels that participated during the first season. Permit applicants were required to have a vessel and gear capable of taking herring. The number of qualified applicants exceeded the number of available permits, and a drawing (lottery) was held. Applicants could apply separately for both bays but could only be drawn for one. The Tomales Bay drawing was held first, and if drawn for Tomales Bay, the applicant was not eligible for the San Francisco Bay drawing. A bait herring fishery existed in San Francisco Bay before the roe fishery began. Six of the San Francisco Bay herring permits were for bait only and not subject to the quota. Issuing unrestricted bait permits proved to be a mistake. Herring quotas were exceeded in both bays because of uncontrolled landings by bait permit holders who were not subject to the 450 and 500 ton quotas established for the roe fishery. The "bait" herring probably entered the roe market.

The CSL expanded the herring fishery regulations to include Humboldt Bay in the 1973-74 season, establishing a modest quota of 20 tons (Table 1). In addition, a two year study was initiated to determine the status of the Humboldt Bay herring population (Rabin and Barnhart 1986).

1974-75 Season. The FGC included bait herring in new quotas, effectively closing the bait loophole. The lottery was continued and for the first time, permits were issued to drift gillnetters in both bays. Prior to this, the herring fishery was composed entirely of round haul (purse seine and lampara) vessels.

Fish and Game Commission Control

The CSL granted permanent management authority of the herring fishery in San Francisco and Tomales Bays to the FGC in 1975. Herring research during the 1973-74 and 1974-75 seasons in San Francisco and Tomales Bays provided new data on which to base management decisions (Spratt 1976), and an orderly expansion of the herring fishery began.

1975-76 Season. Based on herring biomass estimates from the 1974-75 season (Table 2), the FGC increased the roe herring quotas to 3,000 tons in San Francisco Bay and 600 tons in Tomales Bay. The lottery was retained and a total of 57 permits were drawn for San Francisco and Tomales Bays (Table 3 and 4).

In addition, the FGC approved 10 special permits for San Francisco Bay and five for Tomales Bay. Special permits were for bait or fresh fish market uses and were issued on a first-come first-serve basis. Applicants drawn in the roe herring lottery could not apply for special permits. In an effort to bring as many new vessels as possible into the fishery, each applicant that applied for both bays was required to do so with a different vessel. No more than one application could be submitted per vessel.

In 1976, Humboldt Bay and Crescent City Harbor were included under FGC authority when the CSL gave the FGC control of herring in all ocean waters. A 50 ton herring quota with six permits was established for Humboldt Bay. In 1977, the number of Humboldt Bay permits was reduced to four, and in 1983 the Humboldt Bay quota was increased to 60 tons. There have been no further changes in regulations for Humboldt Bay.

1976-77 Season. The San Francisco Bay herring quota increased to 4,000 tons as a result of greater spawning escapement in the 1975-76 season. The Tomales Bay quota was increased to 825 tons. A separate quota of 350 tons was established for the new Bodega Bay area fishery, where 477 tons of herring were caught in the 1975-76 season.

The first major increase in the number of herring roe permits occurred this season. Due to a higher quota and increased interest in the fishery, the FGC decided to discontinue the lottery and issue herring permits to all qualified applicants. To be eligible for a San Francisco Bay herring roe permit the applicant must have met the following conditions: 1) possessed a valid California commercial fishing license, 2) owned or operated a vessel currently registered with the DFG, and 3) the vessel had to be capable of handling the gear specified in the application. A total of 165 gill net, 39 purse seine, and 27 lampara permits were issued. The legalization of set gill nets in 1977, as opposed to drift gill nets, made gill net gear more desirable and resulted in the increase in gill net permits issued (Table 3).

In Tomales Bay, the lottery was retained and seven gill net, five round haul, and five beach net permits (formerly special permits) were issued. This is the last season that round haul permits were issued for Tomales Bay. An additional 24 gill net permits were issued for Bodega Bay (Table 4). The Tomales and Bodega Bay roe permits were issued for either Tomales or Bodega Bay, permittees could not fish in both areas.

1977-78 Season. The 1976-77 San Francisco Bay herring biomass increased to an estimated 26,900 tons, justifying another quota increase to 5,000 tons for the 1977-78 season. The Tomales-Bodega Bay quota remained at 1,175 tons. Rather than create a windfall for existing permittees, the FGC decided to issue additional herring

Table 3. Number of herring roe permits and quota allocation in tons by season for San Francisco Bay, California.

Season	Gear	Number permits	Quota allocation	
1972-73	Round haul	12	not allocated	
	Total	12	1,500	
1973-74	Round haul	12	not allocated	
	Total	12	600	
1974-75	Round haul	10	150	ton maximum limit
	Gill net	2		all vessels
	Total	12	500	
1975-76	Round haul	24	100	per vessel
	Gillnet	24	25	per vessel
	Special	10	5	per vessel
	Total	48	3,050	
1976-77	Lampara	27	1,500	
	Purse seine	39	1,500	
	Gill net	165	1,000	
	Fresh fish	3	15	5 tons per vessel
	Total	234	4,000	
1977-78	Lampara	29	1,500	
	Purse seine	30	1,500	
	Gill net	226	2,000	
	Fresh fish	5	25	5 tons per vessel
	Total	290	5,025	
1978-79	Lampara	31	1,500	
	Purse Seine	27	1,500	
	Even gill net	110	1,000	
	Odd gill net	110	1,000	
	Fresh fish	10	20	2 tons per vessel
	Total	288	5,020	
1979-80	Lampara	27	1,500	
	Purse seine	27	1,500	
	Even gill net	109	1,500	
	Odd gill net	109	1,500	
	Fresh fish	10	20	500 lb trip limit
	Total	282	6,020	
1980-81	Lampara	24	1,500	
	Purse seine	29	1,500	
	Even gill net	112	1,500	
	Odd gill net	111	1,500	
	X gill net	100	1,250	
	Total	376	7,250	
1981-82	Lampara	27	2,185	
	Purse seine	24	1,875	
	Even gill net	116	2,070	
	Odd gillnet	116	2,145	
	X gill net	100	1,725	
	Total	383	10,000	
1982-83	Lampara	21	1,792	
	Purse seine	22	1,719	
	Even gill net	126	2,166	
	Odd gill net	134	2,400	
	X gill net	127	2,322	
	Total	430	10,399	

1983-84	Lampara	21	2,260	
	Purse seine	22	1,875	
	Even gill net	127	2,088	
	Odd gill net	135	2,088	
	X gill net	125	2,088	
	Total	430	10,399	
1984-85	Lampara	21	1,131	
	Purse seine	22	1,079	
	Even gill net	126	1,408	
	Odd gill net	128	1,485	
	X gill net	120	1,397	
	Total	418	6,500	
1985-86	Lampara	21	1,260	
	Purse seine	22	1,320	
	Even gill net	128	1,683	
	Odd gill net	129	1,683	
	X gill net	116	1,584	
	Total	416	7,530	
1986-87	Lampara	21	1,260	
	Purse seine	21	1,260	
	Even gill net	128	1,683	
	Odd gill net	127	1,683	
	X gill net	116	1,584	
	Roe-on-kelp	1	60	7.5 tons of product
	Total	414	7,530	
1987-88	Lampara	21	1,422	
	Purse seine	21	1,422	
	Even gill net	128	1,900	
	Odd gill net	127	1,900	
	X gill net	116	1,788	
	Roe-on-kelp	1	68	15 tons of product
	Total	414	8,500	
1988-89	Lampara	9	681	
	Purse seine	31	2,346	
	Even gill net	127	2,089	
	Odd gill net	128	2,123	
	X gill net	117	1,999	
	Roe-on-kelp	5	262	59 tons of product
	Allotment A & B	2[a]	-	5 tons of product
	Total	419	9,500	
1989-90	Lampara	3	228	
	Purse seine	33	2,508	
	Even gill net	126	2,144	
	Odd gill net	128	2,178	
	X gill net	115	1,940	
	Roe-on-kelp	8	492	110 tons of product
	Total	413	9,500	
1990-91	Roundhaul	34	2,584	
	Even gill net	127	2,142	
	Odd gill net	130	2,192	
	X gill net	115	1,940	
	Roe-on-kelp	10	642	144 tons of product
	Total	416	9,500	

[a]Two of the roe-on-kelp permittees were the successful bidders for allotments (A and B).

Table 4. The number of herring roe permits and quota allocation in tons by season for Tomales Bay, California.

Season	Gear	Number permits	Quota allocation	
1972-73	Round haul	5	—	
	Total	5	750	
1973-74	Round haul	5	—	
	Total	5		
1974-75	Round haul	4	150	ton maximum
	Gill net	1		per vessel
	Total	5	500	
1975-76	Round haul	5	100	tons per vessel
	Gill net	4	25	tons per vessel
	Special	5	5	tons per vessel
	Total	14	625	
1976-77	Round haul	5	550	
	Tomales gill net	7	250	
	Bodega gill net	24	350	
	Beach net	5	5	tons per vessel
	Total	41	1,175	
1977-78	Tomales gill net	33	600	includes beach nets
	Beach net	5	—	
	Bodega gill net	30	575	
	Fresh Fish	5	10	2 tons per vessel
	Total	73	1,185	
1978-79	Tomales platoon	34	600	includes beach nets
	Bodega platoon	33	600	
	Beach net	2	—	
	Fresh fish	5	10	2 tons per vessel
	Total	74	1,210	
1979-80	Tomales platoon	35	600	
	Bodega platoon	34	600	
	Fresh fish	5	10	2 tons per vessel
	Total	74	1,210	
1980-81	Tomales platoon	35	600	
	Bodega platoon	35	600	
	Total	70	1,200	
1981-82	Tomales platoon	24	600	
	Bodega platoon	32	600	
	Total	56	1,200	
1982-83	Gill net	41	1,000[a]	
1983-84	Gill net	40	1,000	
1984-85	Gill net	40	1,000	
1985-86	Gill net	40	1,000	
1986-87	Gill net	40	1,000	
1987-88	Gill net	40	750	
1988-89	Gill net	40	750	
1989-90	Gill net	40	0	
1990-91	Gill net	40	0	

[a]Quotas have not been allocated since the 1982-83 season when all gillnetters were combined into one group.

roe permits based on qualifying points earned over the previous 10 years. Points were earned as follows: 1) one point for each year the applicant held a California commercial fishing license, 2) ten points for those applicants that participated in each of the previous three California herring seasons as a crew member, boat owner, or operator, 3) seven points for those applicants that participated in two of the previous three seasons, and 4) five points for those applicants that participated in at least one of the previous three seasons.

The maximum number of points possible was 20, and all applicants with 19 or 20 points were issued permits. All of the new permits issued were for gill nets (Table 3 and 4). In addition, round haul permittees were allowed to exchange their permits for gill net permits.

In 1977, the FGC established a 30 ton herring quota for Crescent City Harbor, with four permits. Since the 1983-84 season only three permits have been issued annually. There have been no further changes in regulations for Crescent City Harbor.

1978-79 Season. No new San Francisco Bay permits were issued for the 1978-79 season. In Tomales Bay, two permittees did not reapply and the FGC issued three new permits. Permits for Tomales and Bodega Bays were also combined into one permit area.

1979-80 Season. The 1979-80 herring quota was increased to 6,000 tons, but no new permits were issued. The FGC began the phase-out of round haul permits, by deciding that no new round haul permits would be issued in the future for San Francisco Bay.

Due to the success of the fishery, more fishermen wanted permits and the legality of limited entry was being questioned. In response to the pressure to increase the number of permits,the State Attorney General required the FGC to develop a plan that would allow for new entrants into the fishery. The FGC's plan established qualification criteria for new entrants but called for no new gill net permits to be issued for the Tomales-Bodega Bay area until the total number of permits fell below 69, and no new gill net permits to be issued for San Francisco Bay until the 1980-81 season. If there were more applicants than the number of permits available, a lottery would be held. Preferential status would be given in the lottery using the same system of qualifying points as used in the 1977-78 season. Entry into the fishery remained closed, but the means of issuing new permits was established.

1980-81 Season. The 1979-80 San Francisco Bay herring biomass estimate increased to 53,000 tons, justifying higher herring quotas for the 1980-81 season. The FGC took this opportunity to again increase the number of roe permits, rather than create a windfall for existing permittees.

Due to congestion on the fishing grounds, the FGC opened an experimental December fishery in San Francisco Bay. The regular San Francisco Bay herring season opened the first week of January, and the new experimental December fishery was set for a three week period beginning November 30, 1980. Herring fishing in December was considered an experiment because it was unknown if herring captured so early in the spawning season would be acceptable for the roe market. One hundred new roe permits were issued, with the entire 1,250 ton quota increase allotted to the December fishery. A further restriction on the new fishery called for its suspension and a corresponding quota reduction if the San Francisco Bay herring biomass dropped below 36,000 tons.

In Tomales Bay, one permittee did not reapply. The number of roe permits dropped below 69, and the FGC issued two new roe permits for the 1980-81 season (Table 4).

1981-82 Season. No new permits were issued for the 1981-82 season, but Tomales Bay permittees were allowed to transfer to San Francisco Bay to alleviate overcrowding in Tomales Bay. Quota changes in San Francisco Bay, beginning with the 1981-82 season, were made by gear type and were percentage adjustments based on the change in the overall quota (see section on allocation). The Pacific Fishery Management Council (PFMC) recommended that the maximum harvest rate of herring not exceed 20% of the available biomass (PFMC 1982). California has generally been more conservative in setting herring quotas.

1982-83 Season. As in 1981-82, permittees from Tomales Bay were again given the opportunity to transfer their permits to San Francisco Bay; consequently the number of Tomales Bay permits declined to 41. The transfer of permits to San Francisco Bay, coupled with the FGC decision to issue more December gill net permits created 430 San Francisco Bay herring permits for the 1982-83 season. The total number of herring permits peaked at 471 for the San Francisco and Tomales Bay herring fisheries in the 1982-83 season.

1983-84 Through 1988-89 Season. The FGC maintained a policy of not issuing new herring permits, with the exception of the 1986-87 season, when nine December permittees did not reapply and five new permits were issued. The actual number of active permits varied each year because permit holders could be inactive for a herring season due to medical or other valid reasons. When they returned to the fishery after a year of absence it gave the impression that a new permit was issued, when in fact, that was not the case. This happened in the 1988-89 season when there was a net increase of three roe permits.

1989-90 through 1990-91. The fishery has remained lucrative and there is an ever growing number of fishermen with 20 qualifying points that are eligible to obtain a herring permit. In addition, there are more permit holders nearing retirement age. Because of these two factors, the CSL approved the sale of herring permits. Previously, under specified circumstances (death, incapacity, or retirement of the permittee), permits could only be transferred to partners, heirs, or siblings. Although the total number of permits was still limited, they assumed a monetary value and could be sold.

The CSL set the following guidelines for the sale of permits. Permits must be sold to individuals with 20 qualifying points as stated previously, and a list of qualified buyers would be supplied to a permittee wishing to sell a permit. The seller must notify all qualified buyers by certified mail of his or her intent to transfer the permit. After 60 days the DFG can certify the transfer to a qualified applicant upon payment of a $5,000 transfer fee paid to the State. San Francisco Bay gillnet permits for the 1990-91 season were valued at approximately $60,000.

The transferability of permits represented a significant change in the permit distribution system. Permits now have a value, and the mechanism for issuing new permits by lottery to qualified point holders no longer appears valid. Legislation will probably be required to change the system.

QUOTA ALLOCATION

California's two major herring spawning areas of Tomales and San Francisco Bays are within 50 miles of each other (Fig. 1), and are managed on the assumption that they contain separate spawning stocks. The Departments herring biomass estimates are determined annually for both bays by conducting spawning-ground and/or hydroacoustic surveys (Spratt 1991, Wendell and Oda 1990). Herring catch quotas are generally set at about 15% of the annual biomass estimates from each bay. Area quotas are not allocated, rather, they are set independently and fluctuate based on annual herring biomass estimates in each bay.

Tomales Bay

Allocation of the quota has not been a major issue in Tomales Bay because the fishery is small compared to San Francisco Bay with fewer boats and smaller fishing grounds. Under CSL control, Tomales Bay herring were caught by round haul vessels. In the 1974-75 season only five permits were issued for the relatively small quota of 500 tons. However, there was concern that one large vessel could dominate the fishery. Therefore, no permittee was allowed to take more than 150 tons. This represented the first step toward catch allocation.

In the 1975-76 season, the Tomales Bay fishery expanded and the 600 ton quota was allocated to each vessel on an individual basis. Round haul vessels received 100 tons each and gill net vessels 25 tons each. Round haul vessels were allocated a higher quota because of the larger crews and higher operating costs.

Individual vessel quotas were eliminated for the 1976-77 season in favor of group or gear quotas. Most of the quota increase in the 1976-77 season went to new gill net permittees. A separate quota of 350 tons was established for 24 new Bodega Bay permittees. The seven Tomales Bay gillnetters received 250 tons while the five vessel round haul quota was increased to 550 tons. The FGC changed the 25 ton special bait and fresh fish allocation to a gear allocation for beach nets.

In the 1977-78 season, largely due to public sentiment, round haul vessels were permanently prohibited from participating in the Tomales Bay fishery. The total quota of 1,175 tons was allocated evenly between Bodega Bay and Tomales Bay. The 25 ton beach net allocation was included in the Tomales Bay quota, but a 10 ton fresh fish allocation was retained with five 2 ton permits.

The Tomales and Bodega Bay quotas were combined for 1978-79 season and increased to 1,200 tons. Because 69 permits would cause congestion on the fishing grounds, former Bodega and Tomales Bay permittees were split into two platoons and allowed to fish alternate weeks during the season. Each platoon was allocated 600 tons. The platoon system and fishing alternate weeks was not successful in Tomales Bay, because one platoon tended to catch most of the herring, causing ill will between the two platoons.

In the 1980-81 season, separation of the Tomales Bay gill net platoons was modified to provide for an equitable catch. The first platoon was required to stop fishing when 100 tons were taken. The second platoon then fished until an additional 100 tons were taken, at which time the first platoon started fishing again, and so on until the quotas were met. Also, the fresh fish allocation was modified so that they could not be taken during the herring roe fishery season.

The platoon system used to allocate the Tomales Bay catch was unsuccessful because Tomales Bay is small, overcrowding was a serious problem, and there were simply too many vessels. In order to minimize this problem, the number of Tomales Bay permits had to be reduced. The FGC created a two-year window of opportunity for Tomales Bay permittees to transfer to the San Francisco Bay herring fishery. The intent was to reduce the number of Tomales Bay permits and combine the remaining permittees into one group for the 1982-83 season. The 41 permittees that chose to stay in Tomales Bay fished under a reduced quota of 1,000 tons in the 1983-84 season.

The number of herring permits issued for Tomales Bay has been 40 since the 1982-83 season. Tomales Bay catch quotas have fluctuated based on biomass estimates. Vessel quota allocation has not been reconsidered because most permittees are against allocation and prefer the competitive nature of the present fishery which rewards luck and hard work with the best catches.

The Tomales Bay permittees are organized and have regular meetings to discuss issues and to resolve their socioeconomic problems. With only 40 herring permits in Tomales Bay, allocation was eliminated seven years ago and probably will not be reinstated.

San Francisco Bay

The San Francisco Bay herring fishery is larger and far more congested than the Tomales Bay fishery. Allocation of quotas, catch, gear, and fishing time will continue to be a part of the San Francisco Bay herring fishery.

The San Francisco Bay herring fleet was composed almost entirely of round haul vessels during the first three seasons (1972-73 through 1974-75). Only 12 permits were issued for each of the first three seasons, but there was intense competition between vessels. The FGC perceived that larger vessels had an unfair advantage and imposed a maximum boat allocation of 150 tons for the 1974-75 season.

The fishery expanded in the 1975-76 season and the FGC retained the concept of vessel allocation. The 3,000 ton roe herring quota was divided as follows: round haul vessels - 2,400 tons with equal vessel allocations of 100 tons; gill net vessels - 600 tons with equal vessel allocations of 25 tons. In addition, the 10 special bait or fresh fish permits were issued with a separate quota of 50 tons and equal vessel allocations of 5 tons.

In 1976-77, the San Francisco Bay herring fishery was opened to all qualified applicants. The round haul vessel allocation was increased to 3,000 tons but divided equally between purse seine (1,500 tons) and lampara vessels (1,500 tons). The 165 gill net vessels received a 1,000 ton allocation. A 15 ton allocation of herring for the fresh fish market was retained. Individual vessel allocations that guarantee a permittee a specific share of the quota were eliminated this season.

In the 1977-78 season, the San Francisco Bay herring quota was increased to 5,000 tons with the entire increase of 1,000 tons allocated to gill net vessels. The number of gill net permits issued increased to 226 and congestion on the fishing grounds and at off-loading points around the bay became a serious problem.

In the 1978-79 season, the FGC adopted further regulations that set the stage for seasons to come. Congestion in the fishery was alleviated by dividing the 220 gill net permittees into two platoons; each platoon was allocated a 1,000 ton quota. In addition, a 20 ton trip limit was established for all vessels.

The 1979-80 season quota was increased to 6,000 tons and the 1,000 ton increase was again allocated to gill net permittees. Congestion on the fishing grounds was reduced, but dockside congestion during unloading operations continued. The fresh fish allocation was modified so that a permittee had to possess a valid market order for herring, not to exceed 500 pounds per day. The fresh fish season was also closed during the roe fishery. Before this action, herring caught under fresh fish market permits may have entered the roe market. The herring population biomass estimates continued to increase and peaked at nearly 100,000 tons in 1981-82. As the quotas increased, pressure to expand the fishery by adding new permits also increased, and the legality of the limited entry policy was being questioned.

In response to the pressure to issue more permits, the FGC provided for 100 new gill net permits for the 1980-81 season and established a third platoon and a 3-week December or "X" season (see section on the "X"platoon). The quota increase of 1,250 tons in the 1980-81 season was allocated entirely to the "X" fishery. There was also a provision that, if the San Francisco Bay biomass ever fell below the 1979 level of 36,000 tons, the "X" season and its permits would be suspended for that season. Herring quotas continued to increase and reached 10,000 tons in the 1981-82 season. The three gill net platoons were allocated 60% and round haul vessels 40% of the quota. "ODD","EVEN", "X", purse seine, and lampara quotas were allocated based on the number of expected permits in each platoon or gear type. Quotas are set in advance of the season, and the number of expected permits often differed from the number actually issued. For example, the total gill net quota was divided by the total number of expected gill net permits to obtain the average quota per vessel. The quota allocation to the "ODD" gill net platoon was the number of expected permits in that platoon multiplied by the average gill net quota per vessel. The same system was used with round haul vessels.

The average per vessel quota was multiplied by the number of lampara permits expected to be issued to determine the lampara allocation. In the case of round haul vessels, this was carried one step further and the average quota per vessel became a catch limit or vessel allocation. In the 1981-82 season the round haul vessel quota was 78 tons. All herring landed in excess of a vessel's individual quota was forfeited to the DFG.

From 1982-83 through 1990-91, the FGC policy of allocating the quota 67%/33% between gill net and round haul vessels has worked well, as has the method of dividing up gear quotas between groups of permittees based on average vessel quotas.

Roe-On-Kelp Fishery

Roe-on-kelp harvesting by the open pound method (pounds are 18.3x12.2 m floating rafts) was first allowed in the San Francisco Bay fishery in the 1986-87 season. This method, commonly used in Canada, involves hanging giant kelp (*Macrosystis pyrifera*) from rafts, waiting until herring spawn on the kelp, then harvesting the product. Prior to this time, herring eggs on naturally growing vegetation were harvested.

In the 1988-89 season the roe-on-kelp fishery expanded from one to five permits. The FGC, still trying to reduce the overall number of vessels in the fishery, made the new permits available to existing round haul and gill net herring permittees willing to transfer to the new fishery. Three round haul and two gill net permittees transferred. These were gear transfers, not new permits.

The roe-on-kelp allocation to each permittee was the equivalent of each permittee's share of the herring quota in whole fish. A total of 262 tons of whole herring was transferred to the roe-on-kelp fishery (Table 3). The equivalent roe-on-kelp quota was 59 tons of product (conversion factor = 0.2237); 4 tons for each gill net transfer and 17 tons for each round haul transfer.

In addition, since 1965, two allotments (A and B) have been issued annually in San Francisco Bay for the harvest of 5 tons of herring roe on seaweed that grows naturally in the bay. Allotments were awarded by sealed bid, with the two highest bidders receiving the allotments. The bid price was a royalty per ton, paid to the DFG. In 1989, the development of the open pound or raft method has resulted in the conversion of these two allotments of 2.5 tons each to the open pound method. Two of the five gear transferees were also the successful bidders for the allotments. The total open pound quota was 64 tons in the 1988-89 season.

The royalty per ton that roe-on-kelp permittees must pay the DFG has been a source of controversy since the fishery has changed from a harvest that used divers to an open raft method. Royalties were high, over $2,500 per ton when a competitive bid process was used to award permits. Roe-on-kelp fishermen successfully argued that the bidding process had driven the royalty too high, and the FGC set a new royalty fee of $500 per ton for the 1989-90 and subsequent seasons.

In the 1990-91 season the FGC expanded the roe-on-kelp fishery from five to ten permits. The total quota was 144 tons of product, or the equivalent of 642 tons of whole herring.

SOCIOECONOMIC ISSUES

All herring roe fisheries, from California to Alaska, have over-crowded fishing grounds and intense fishing activity during spawning runs. The San Francisco Bay herring fishery adds another element because it takes place in the center of a large metropolitan area. Problems associated with the fishing industry are highly visible to any interested or concerned citizen. While only San Francisco Bay was discussed here, most of the issues also apply to Tomales Bay.

Recreational Conflicts

Weekend Closures. Sailing, fishing, and other recreational activities may conflict with commercial herring fishing operations. While these recreational activities can take place during the week, most occurs during weekends. The potential conflict with recreational users of the bay was minimized by closing the herring roe fishery from noon Friday to sunset Sunday.

Public piers. No herring net may be set or operated within 300 feet of public piers. This decision was also the result of conflicts between recreational fishing and commercial fishing activities.

Area Closures

There are a variety of reasons why herring fishing is restricted to certain areas; most closures are a direct result of the highly populated San Francisco Bay area.

Military Bases. U. S. Naval installations at Treasure Island, Hunter's Point, and Alameda (Fig. 1) have restricted areas around the bases. Civilian activities and herring fishing operations are prohibited near these installations.

Noise Pollution. Herring fishing is a noisy business. The sound of net floats banging on gunwales, vessel engines, deck speakers, the whine of hydraulic motors, and barking sea lions can build to a very annoying level at night. Because of these factors, Belvedere Cove (Fig. 1), an affluent area of waterfront homes and a prime fishing area, was closed to herring fishing in the 1980-81 season. Noise is also a problem in the Sausalito area and along the San Francisco waterfront (Fig. 1), but these areas remain open to herring fishing.

Since the 1986-87 season, the unloading of herring has been prohibited between 10 P.M. and 6 A.M., because of noise associated with the pumping of herring during the unloading procedure at dockside.

Marinas. Herring nets have been set across marina entrances blocking vessel traffic and creating potential safety hazards. This activity has resulted in many small area closures near marinas throughout the bay.

Ecological Reserves. During the 1970s, Richardson Bay near Sausalito was the primary herring spawning area in San Francisco Bay (Spratt 1981). Richardson Bay (Fig. 1) is an ecological reserve and has never been open to herring fishing. In December 1981, a large winter storm occurred just after a major herring spawn in

Richardson Bay. Spawn-laden vegetation (*Gracilaria* sp.) was torn loose from the soft mud bottom of the bay by wind-driven waves. Vegetation densities did not recover and have remained low into the early 1990s. Consequently, herring have abandoned Richardson Bay in favor of the waterfront pier pilings in the City of San Francisco.

Gear Conflicts

Round Haul vs. Gill Net. Most of San Francisco Bay has been closed to encircling nets (purse seine, lampara, and beach nets) for many years to prevent the take of salmon, striped bass, sturgeon, and shad. From 1972-73 through 1978-79, round haul vessels were restricted to an area near the entrance to San Francisco Bay (Fig. 2a). Bait nets, a small lampara type net without purse rings and made of standard No. 9 seine twine or lighter, have always been allowed for use throughout San Francisco Bay for bait purposes.

In 1979, the FGC ruled that lampara nets used in the herring fishery qualified as bait nets. The size of the lampara or bait net was not an issue. Lamparas were used to take herring in central San Francisco Bay in the 1979-80 season, beginning a 10 year period that gradually opened more of San Francisco Bay to round haul gear. A further precaution intended to prevent the take of sport species by round haul vessels requires that a rigid metal grate of parallel bars, no more than 3 inches apart be placed over the hatch while loading fish into the hold. Any large fish (sturgeon or striped bass) would be deflected onto the deck, rather than fall into the hold, and returned to the water unharmed.

In the 1979-80 season the lampara fishing area was expanded to include the east side of the bay between the Richmond-San Rafael Bridge and the Oakland Bay Bridge (Fig. 2b), but they were allowed to fish only after gill net quotas were taken. This action was necessary because set gill nets and round haul gear may conflict, particularly when spawning is underway or when herring are concentrated in small areas of the bay. Subsequently, in the 1984-85 season, lamparas were allowed to fish while the gill net fishery was in progress. However, lamparas were restricted by the following new regulations: 1) daytime fishing only, 2) prohibited from fishing in waters less than 11 m deep, and 3) the east bay between Richmond and Oakland was closed (Fig. 2b).

In the 1985-86 season, areas open to lampara nets was expanded to include the area south of the Oakland Bay Bridge in waters greater than 11 m deep during daylight hours (Fig. 2c). Night- time fishing was allowed only after the gill net quotas were taken. During this time, purse seiners continued to be restricted to the original area near the entrance of the Bay. The incidental take of sport species by lamparas did not prove to be a serious problem. On the rare occasion when a protected species was taken, the metal grate over the hatch allowed the fish to be returned to the bay quickly. Finally, prior to the 1988-89 season purse seine restrictions were removed and they were included with lamparas (i.e., round haul gear). The only restriction remaining was the 11 m depth prohibition until the gill net quotas were taken (Fig. 2d).

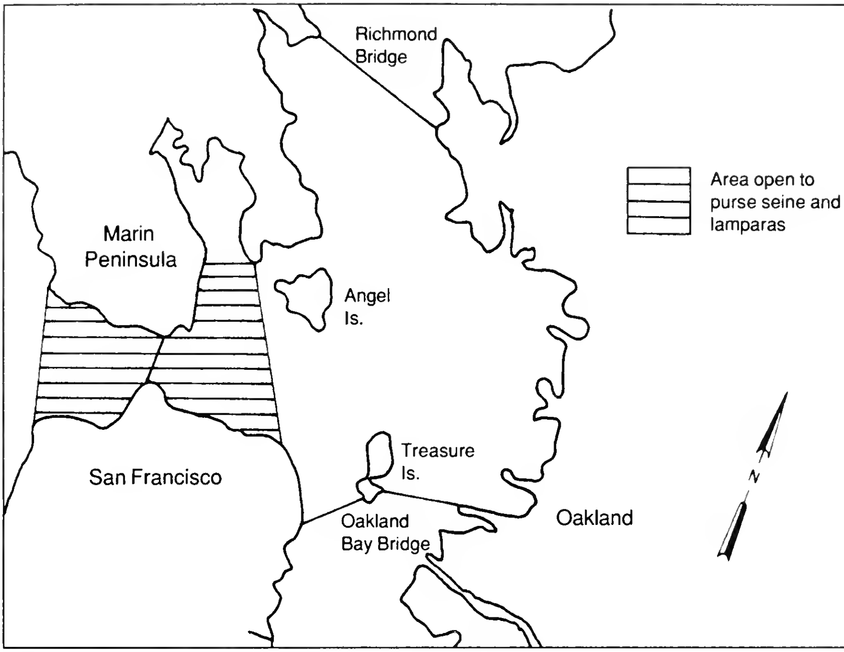


Figure 2a. Area of San Francisco Bay open to purse seine and lampara gear from the 1972-73 to 1978-79 seasons.

This change resulted in many lampara vessels changing to modified purse seine nets (Table 3), and by the 1990-91 season only a few lampara nets remained in the fishery.

Transfer of Herring Between Vessels. The transfer of herring between vessels or permittees is prohibited. This prevents groups of vessels from fishing together, where one large vessel could make a large catch and transfer herring to smaller vessels. It also prevents the transfer of herring between round haul and gill net vessels. The transfer of herring would circumvent the purpose of separate gear quotas and vessel allocations.

Open Pound vs. Gill Net. In the roe-on-kelp fishery, pounds or rafts with kelp hanging from them are deployed in an area where herring are expected to spawn. The rafts are difficult to maneuver and for best results must be moved as the spawning herring school moves. Gill nets set near roe-on-kelp rafts often prevent movement of the rafts. This conflict has not been resolved and may prevent further expansion of the roe-on-kelp fishery. This method of fishing has become popular and there were 10 permits available in the 1990-91 season, with each permittee allowed two rafts.

Gill Net Closure. There is a large area in the central part of south San Francisco Bay between the Bay Bridge and Hunter's Point, where herring hold (i.e., congregate) prior to spawning (Fig. 3). Beginning with the 1991-92 season, this area will be closed to gill nets. This is the first major area or depth restriction placed on gill net gear.

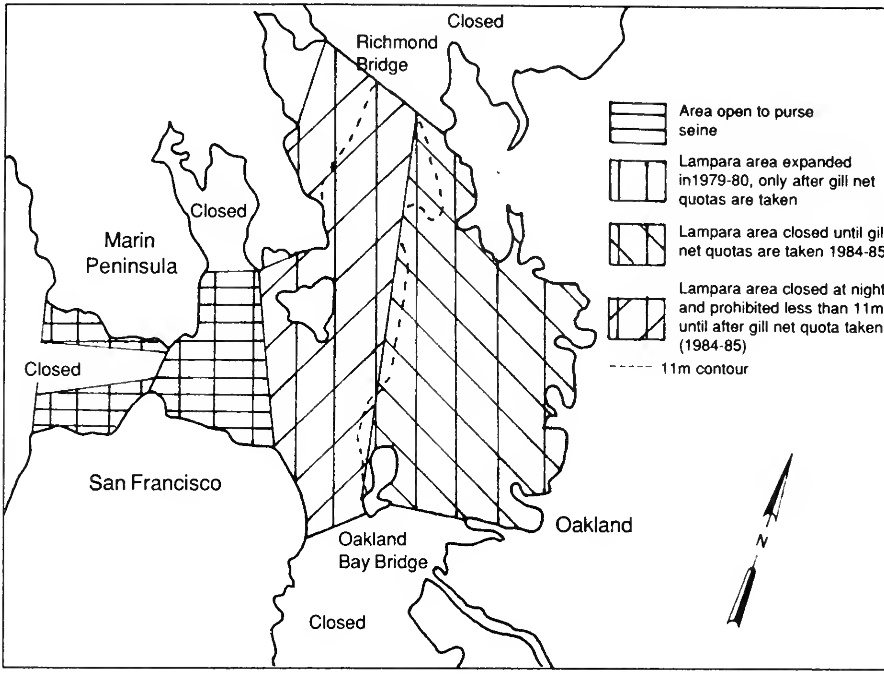


Figure 2b. Areas of San Francisco Bay open to purse seine and lampara gear from the 1979-80 to 1984-85 seasons.

Gill net fishing activity can trigger herring to spawn prematurely in deep water or on herring nets. Such spawning may affect the survival of herring eggs and subsequent year class strength. These spawns are not included in spawn escapement estimates, thus affecting biomass estimates and catch quotas. The FGC felt that this action was in the best interest of the fishery. A test boat program, described later, also placed restrictions on round haul vessels fishing in the same holding area.

Congestion

Congestion on the fishing grounds and at dockside during unloading operations is a serious problem. It has been compounded by the two different gear types used in the fishery and the need to unload quickly and return to the fishing grounds before a spawning run ends. Limited entry controlled the number of herring permits, but many new problems surfaced that have precipitated the following regulations.

Gear Limits. Purse seines and lampara nets are limited to a maximum length of 240 fm (439 m) with no depth restriction. In San Francisco Bay gill net permittees are limited to 2 shackles of 65 fm (119 m) each. In Tomales Bay the gill net limit is 195 fm (357 m).

Assigned Fishing Days. Purse seine vessels were allowed to fish only Monday, Tuesday, and Thursday in the 1977-78 season. In the 1978-79 season, lamparas were

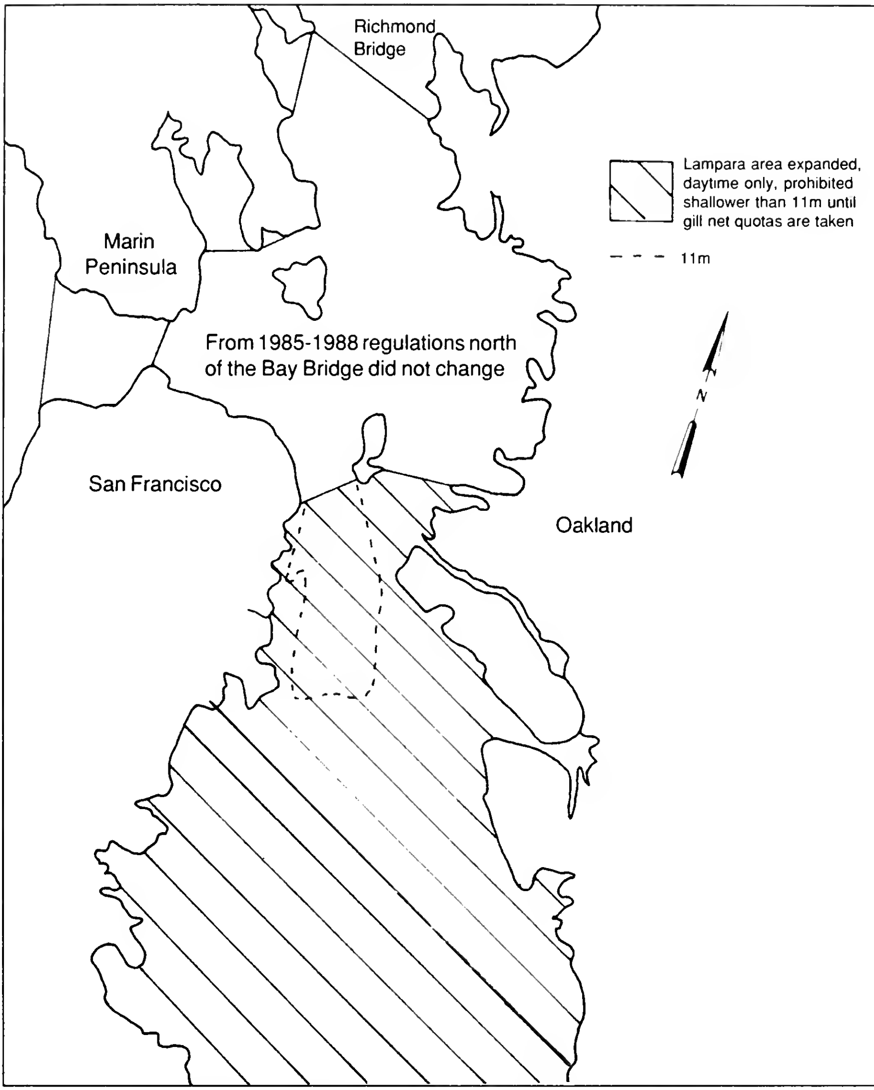


Figure 2c. Areas of San Francisco Bay open to purse seine and lampara gear from the 1985-86 to 1987-88 seasons.

included and all round haul vessels were allowed to fish only Monday through Thursday. These measures were largely ineffective, resulting in large catches on days when fishing was allowed. Consequently, in the 1979-80 season round haul vessels were allowed to resume fishing from sunset Sunday to noon Friday.

Daily Landing Limits And Trip Limits. Daily landing limits of 40 tons and trip limits of 20 tons were in force from 1976-77 until the 1981-82 season when the number of permits expanded. The intent was to control congestion at dockside during peak unloading times. It was not effective. A round haul vessel could still take

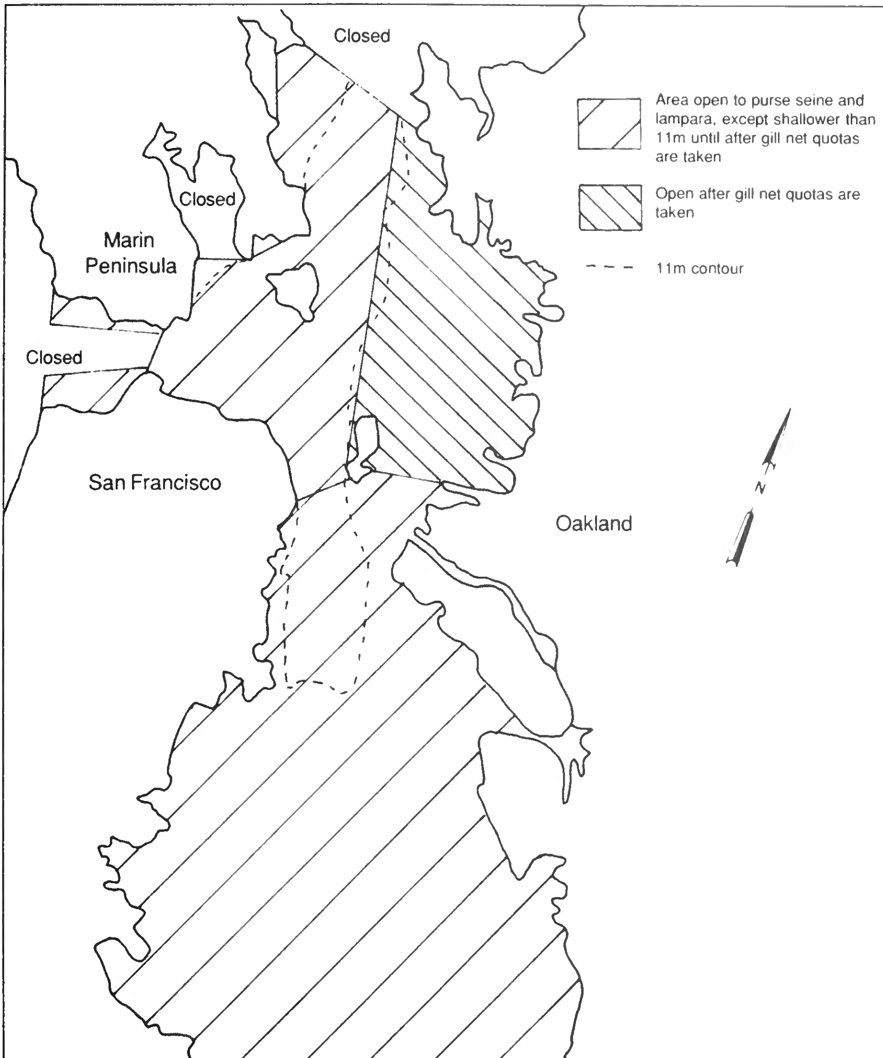


Figure 2d. Areas of San Francisco Bay open to purse seine and lampara gear in the 1988-89 season.

considerable time to unload their catch while smaller gill net vessels waited. Consequently, such restrictions were subsequently repealed.

Platoon System. Congestion on the fishing grounds and at dockside was not solved, but greatly reduced when the gill net vessels were divided into equal sized platoons of 110 permittees prior to the 1978-79 season. Gillnetters were divided based on their permit numbers, and assigned to the "EVEN" or "ODD" platoon. The quota was also divided equally and the platoons fished alternate weeks during the

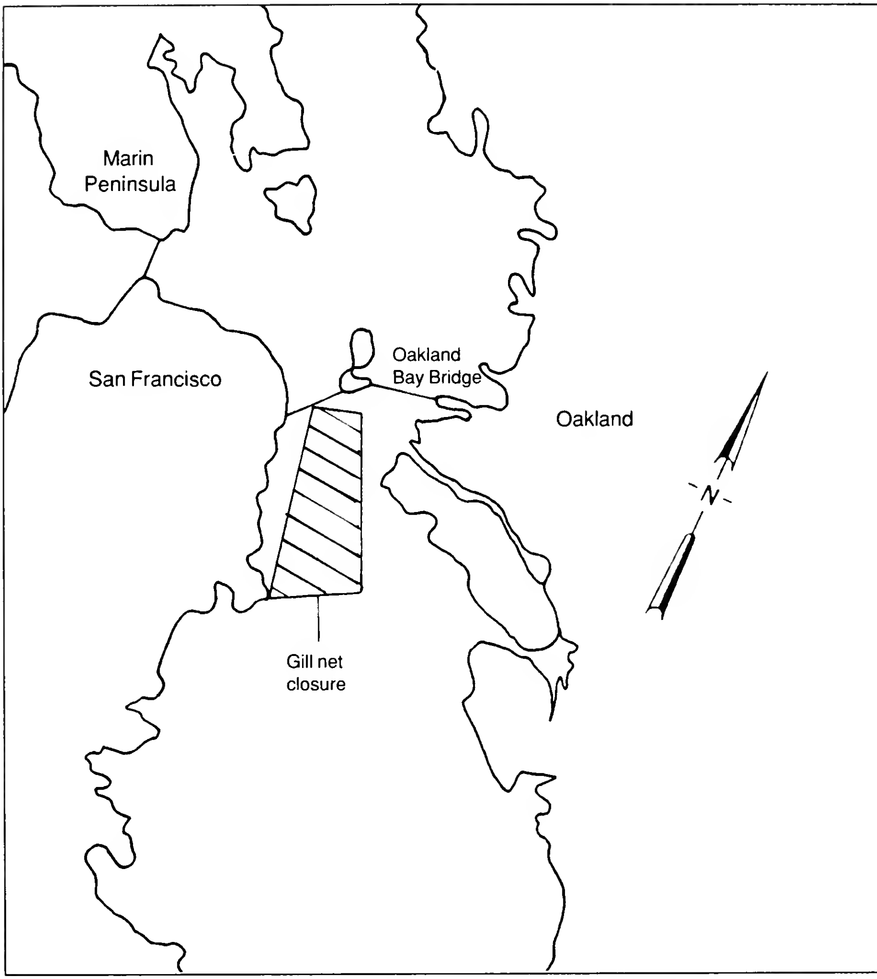


Figure 3. Herring holding area closed to gillnetters in the 1991-92 season.

season. If one platoon caught its share of the quota the alternate platoon was allowed to fish until the remaining gill net quota was taken. In addition, the platoons rotated each year; i.e. the platoon that started first one season would start second the following season.

The "X" Platoon. The San Francisco Bay platoon system worked so well that the FGC established a third "X" platoon when the fleet was expanded prior to the 1980-81 season (Table 3). The third platoon, composed of 100 additional gill net permits, did not add to the congestion because they were given a separate three week fishing season in December. Because of the short December season, if they did not catch their quota the "X" platoon was also allowed to fish after the "ODD" and "EVEN" platoons finished. In 1991, after 11 seasons, the FGC ruled that the December herring fishery was no longer considered an experimental fishery. The platoon's name was changed from "XH" to "DH"; all other regulations pertaining to the "DH" platoon remain unchanged.

Round Haul Vessel Quotas. Individual vessel quotas have been part of the round haul fishery since the 1974-75 season. In the 1981-82 season the total round haul quota of 4060 tons was divided equally among 51 permittees and became a vessel allocation or limit. This action eased the competition between round haul vessels and greatly reduced congestion at dockside because the need to bring in large loads of herring was eliminated.

Test Boat System. The allocation of individual quotas to round haul vessels in San Francisco Bay increased the quality of the catch. Round haul fishermen may be more selective in the herring that they keep because herring may by caught, held in the net, and tested for roe content. If roe content is low, herring may be released alive. However, there were concerns about vessel quotas and their effect on the fishery. Some fishermen are too selective early in the season, and release herring that are not quite good enough with the hope of catching better fish later in the season. This results in the failure of many round haul vessels to catch their individual quotas and needlessly extends the season into February and March.

Another concern is that the testing and releasing of herring by round haul vessels may be harmful to the resource. This practice has been part of the fishery from the beginning, but the extent that testing and releasing increases fishing mortality has not been determined. However, round haul vessel quotas have resulted in an increase in testing and releasing by the fleet. Because of the potential harmful effects of catch and release practices, this problem was addressed during 1988.

The idea of a test boat program that would control the opening of the round haul fishery had been considered for several years. During the late 1980's, the DFG proposed that the industry develop their own voluntary test boat program. This seemed reasonable because they were the ones that stood to gain from increasing the quality of the catch, while reducing the unfavorable practice of catching and releasing herring. After three years, the industry had not developed a successful test boat plan.

In 1991, the time for a test boat system had arrived. The DFG, drawing from information gained during three years of discussions and meetings with fishermen and buyers, proposed an official DFG herring test boat system for the 1991-92 season. The major provisions of the 1991-92 test boat system are as follows:

1. The test boat system shall be in effect during January and until February 15, 1992.
2. All round haul permittees must participate.
3. Four (4) vessels will be drawn for each Test Boat Fishing Period (TBFP). A random drawing will determine the order of participation.
4. A test boat may operate in any area of San Francisco Bay legally open to round haul vessels.
5. After each spawn the Department shall determine the date, day, and time at which the TBFP will start.

6. A test boat may retain on board the catch from only one set during the TBFP until the fishery is declared open by an official Coast Guard announcement.
7. The TBFP will end and fishing will be open to all roundhaul permittees when all of the following conditions have been met: a) At least two (2) test boats have taken and retained a load of herring with a roe content of 9% or more, and b) each roe content of 9% or more has been verified by one of the herring buyers or his representative, and c) each buyer has notified the Coast Guard that a test boat has retained a load of herring with a roe content of 9% or more, and d) the buyer has identified himself by name of speaker, company, and vessel, and e) the Coast Guard has announced the opening of the fishery on VHF Channel 16.
8. During any open fishing period, no roundhaul vessel shall release any fish once a set has been made.
9. If the daily roe content of landings drops below 9%, as determined from fish receipts, the Department will announce the end of the open fishing period and the beginning of the next TBFP.

PROBLEMS ASSOCIATED WITH ALLOCATION

Allocations are made on paper, may be difficult to implement, there are no guarantees, and the smallest allocation unit must be large enough to provide adequate economic return to the fishermen. In short, allocation of catch, fishing time, and areas results in a highly structured fishery that becomes dependent on predictable and dependable behavior of the target species.

An unexpected change in the behavior of the target species may prevent catch allocations from being taken and may cause economic hardship. An example is the Tomales Bay fishery which is now closed. The decline in biomass of herring has been attributed to the five year California drought, which is believed to have caused a change in the distribution of Tomales Bay herring. The movement of herring places an extreme economic hardship on the 40 Tomales Bay permittees, who may not legally fish for herring in other areas. Individual vessel allocations may also increase wastage of fish, due to illegal discarding of poor quality catches. Allocations also increase the incentive to under-report catches.

Insuring compliance with vessel allocation, area closures, and time closures adds to the workload of management and enforcement personnel, particularly when there is a several hundred vessel fleet.

There will probably be quota shortfalls because individual vessel allocations will not make good fishermen out of poor fishermen. Many vessels may not catch their allocations due to mechanical breakdowns. These factors will extend the fishing season and add to industry and management costs.

DISCUSSION

There were few changes in the herring regulations from 1982-83 through 1990-91. Changes that were made primarily dealt with socioeconomic issues. The basic concepts of limited entry, quota allocation, and the platoon system remained unchanged.

The 1991-92 season will see the implementation of the test boat program and closure of deep water herring holding areas to the use of gill nets south in San Francisco Bay, the latest significant changes in herring regulations. These new regulation changes will be evaluated during the 1991-92 season.

The gill net fishery regulations in San Francisco Bay are working; however the issue of individual vessel quotas is continually brought up. The gill net fleet of San Francisco Bay is a composite of new state-of-the-art fast aluminum bow-pickers and 50 year old conventional, slow wooden vessels. Platoon quotas are taken rapidly and older vessels have difficulty competing with the newer modern vessels. Because of competition, the concept of individual gill net vessel quotas guaranteeing a specified catch is appealing to many fishermen. However, the gillnetters of San Francisco Bay are split over this issue, and the FGC will probably not consider adopting this regulation until a majority of the fishermen favor individual boat quotas.

The San Francisco Bay round haul vs. gill net gear conflict has been minimized. Until the gill net quotas are taken, round haul vessels may not fish shallower than 11 m. This in effect gives gillnetters exclusive access to shallow herring spawning areas until their quotas are taken. After the gill net quotas are filled round haul vessels may fish in all areas of the bay open to herring fishing.

The limited entry plan for the herring fishery that was adopted by the FGC essentially closed the fishery to new entrants. Only five new permits have been issued since 1983 because the number of herring permits have not declined below the level that would allow new permits to be issued. Transferring permits to heirs or partners was allowed, and tended to stabilize the number of permits.

The herring fishery is lucrative, and many of the permittees have been in the fishery since the beginning and are nearing retirement age. There are a large number of fishermen interested in obtaining a herring permit. Because of these factors, the limited entry regulations were modified in 1988. The number of permits remain limited, but they may now be sold. Consequently, the system is permanently changed and its unlikely that herring permits will ever again be issued by lottery, they will simply be sold.

CONCLUSION

When the DFG determined the status of the herring resource in San Francisco Bay and recommended quota increases, expansion of the fishery was inevitable. Most of the regulation changes were the result of the increased quotas for this lucrative fishery. Management of the herring roe fishery has gone through a long trial and error process. Regulations evolved and annual changes in regulations were necessary as the new fishery developed.

Management concepts new to commercial fishing in California were introduced. Limited entry, the lottery, vessel quotas, quota allocation by gear, assigned fishing areas by gear, the platoon system, and test boat program were all controversial management methods. Some are still controversial, but these regulations have proven effective in solving socioeconomic conflicts in a congested fishery.

LITERATURE CITED

PFMC. 1982. Pacific Herring Fishery Management Plan (DRAFT). Pacific Fishery Management Council, Portland, Oregon. 131pp.

Rabin, D.J., and R.A. Barnhart. 1986. Population characteristics of Pacific herring (*Clupea harengus pallasi*) in Humboldt Bay, California. Calif. Fish Game 72:4-16.

Spratt, J. D. 1976. The Pacific herring resource of Tomales and San Francisco Bays: its size and structure. Calif. Fish and Game, Mar. Res. Tech. Rep. 33:1-44.

______. 1981. The status of the Pacific herring, *Clupea harengus pallasi*, resource in California 1972 to 1980. Calif. Fish and Game, Fish Bull. 171:1-107.

______. 1991. Biomass estimates of Pacific herring, *Clupea pallasi*, in California from the 1990-91 spawning-ground surveys. Calif. Fish and Game, Mar. Res. Admin. Rep. 91-14:1-41.

Wendell, F., and K. T. Oda. 1990. Pacific herring, *Clupea pallasi*, studies in San Francisco and Tomales Bays, April 1989 to March 1990. Calif. Fish and Game, Mar. Res. Admin. Rep. 90-14:1-55.

Received: 20 September 1991
Accepted: 19 December 1991

92 82806

INSTRUCTIONS FOR CONTRIBUTORS

EDITORIAL POLICY

California Fish and Game is a technical, professional, and educational journal devoted to the conservation and understanding of fish, wildlife, and native communities. Original manuscripts submitted for consideration should deal with California flora or fauna, or provide information of direct interest and benefit to California researchers and managers.

MANUSCRIPTS: Refer to the CBE Style Manual (5th Edition) and a recent issue of *California Fish and Game* for general guidance in preparing manuscripts. Specific guidelines are available from the Editor in Chief.

COPY: Use good quality 215 x 280 mm (8.5 x 11 in.) paper. Double-space throughout with 3-cm margins. Do not hyphenate at the right margin, or right-justify text. Authors should submit three good copies of their manuscript, including tables and figures to the Editor in Chief. If written on a micro-computer, a 5.25 or 3.5 in. diskette of the manuscript in word processor and ASCII file format will be desired with the final accepted version of the manuscript.

CITATIONS: All citations should follow the name-and-year system. See a recent issue of *California Fish and Game* for format of citations and Literature Cited. Use initials for given names in Literature Cited.

ABSTRACTS: Every article, except notes, must be introduced by an abstract. Abstracts should be about 1 typed line per typed page of text. In one paragraph describe the problem studied, most important findings, and their implications.

TABLES: Start each table on a separate page and double-space throughout. Identify footnotes with roman letters.

FIGURES: Consider proportions of figures in relation to the page size of *California Fish and Game*. Figures and line-drawings should be of high-quality with clear, well-defined lines and lettering. Lettering style should be the same throughout. The original or copy of each figure submitted must be no larger than 215 x 280 mm (8.5 x 11 in.). Figures must be readable when reduced to finished size. The usable printed page is 117 x 191 mm (4.6 x 7.5 in.). Figures, including captions cannot exceed these limits. Photographs of high-quality with strong contrasts are accepted and should be submitted on glossy paper. Type figure captions on a separate page, not on the figure page. On the back and top of each figure or photograph, lightly write the figure number and senior author's last name.

PAGE CHARGES AND REPRINTS: All authors will be charged $35 per printed page and will be billed before publication of the manuscript. Reprints may be ordered through the editor at the time the galley proof is submitted. Authors will receive a reprint charge form along with the galley proof.

Editor, ***CALIFORNIA FISH AND GAME***
California Department of Fish and Game
1416 Ninth St., Sacramento, CA 95814