CALIFORNIA
FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

CALIFORNIA FISH AND GAME

CONTENTS

MOVEMENT AND DISPERSION OF RED ABALONE, *HALIOTIS RUFESCENS,* IN NORTHERN CALIFORNIA

JERALD S. AULT
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

and

JOHN D. DEMARTINI
Department of Biological Sciences
Humboldt State University
Arcata, CA 95521

Tagging of red abalone in Northern California over an 11 year period showed that movement and dispersal occurred at high frequency. The high incidence of movement contributed to continuous population flux. However, not all tagged abalone were observed to have moved. Some abalone exhibited no apparent movement for short periods of time, and occasionally maintained the same site for prolonged periods. Red abalone densities apparently remained constant through time even though much emigration and immigration occurred. Adults tended to reposition on scars, regardless if the scars were previously theirs. Stimuli for movement may have been food supply, although physical disturbance was identified in prompting movement.

INTRODUCTION

Red abalone, *Haliotis rufescens,* are widely distributed along the coast of California and support important commercial and sport fisheries. During the past two decades, red abalone stocks have declined in abundance throughout major portions of their range. Declines are attributed to possible overexploitation, habitat degradation, and increasing sea otter predation in the traditionally productive abalone beds off central California (Leighton et al. 1981, Ault 1985a).

Studies providing insight into the spatial and temporal mechanisms that influence rates of repopulation are fundamental to the evaluation of haliotid population dynamics (Hancock 1979, Clavier and Olivier 1984). Worldwide, several species of abalone are known to move frequently, and some species for considerable distances (Newman 1966, Poore 1972, Shepherd 1973). The published literature on red abalone implies that very little movement or dispersion occurs (Bonnot 1948, Cox 1960, 1962, Hines and Pearse 1982).

An extensive tagging program of subtidal abalone in Northern California was undertaken to assess growth, general distribution along the coast, food supply, movement, and to identify predators and competitors. Ault (1985a) provides a synopsis of these findings. This report deals with movement and presents both qualitative and quantitative evidence for movements and dispersion by individual red abalone.

STUDY SITE

This study was conducted at Point Cabrillo Marine Ecological Reserve, Fort Bragg, California (Figure 1). The reserve is closed to commercial and sport take

of red abalone. The coastline at Point Cabrillo is highly exposed. Wave action has eroded the marine terrace such that the coastline is very irregular and bordered by reefs (Figure 2). Thus, the study site contained various degrees of exposure and depths resulting in a spectrum of habitats utilized by different size classes of red abalone.
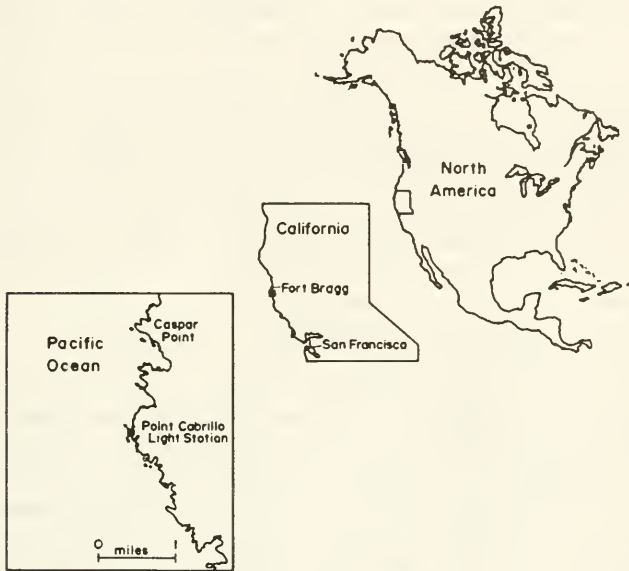

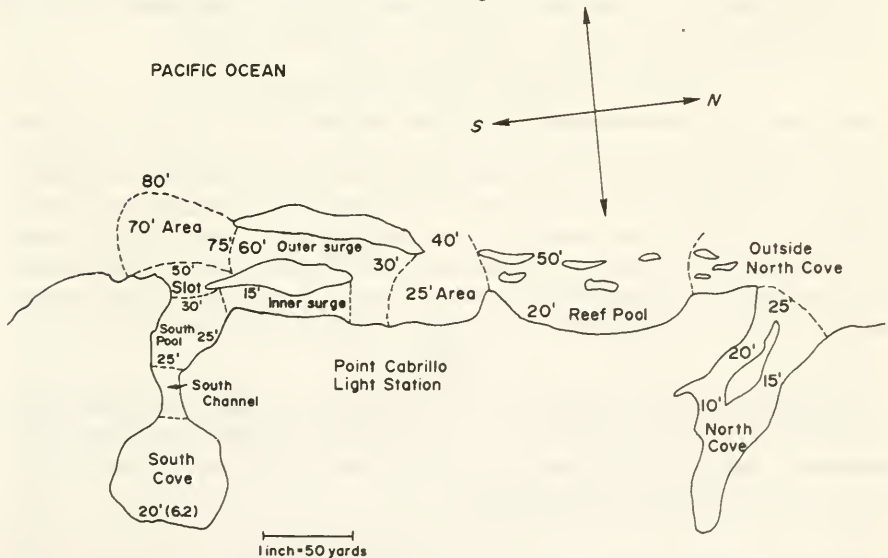FIGURE 1.   Location of Point Cabrillo marine ecological reserve.

FIGURE 2.   Depiction of the eleven tag and release zones developed for studying red abalone movements at Point Cabrillo marine ecological reserve. Depths indicated are in feet.

METHODS

Longterm Movements

The study began in January, 1971, and continued until 1975. Over this period 3,877 red abalone were tagged by scuba divers. Periodic observations continued through June, 1982. We divided the subtidal waters and seabed constituting the Reserve into eleven well-defined zones (c.f. Figure 2). During the course of each tagging session, within each study zone, most available red abalone greater than 50 mm long were collected. Shorter specimens were generally not taken, because tagging them fractured the shell between respiratory pores. Abalone were removed by a metal bar or a lever, placed in a mesh bag and taken to shore. Each abalone collected was measured for shell length and width in millimeters, weighed in grams, sexed if possible, and a numbered metal tag attached to stainless steel wire was wound through two respiratory pores. While tagging, depending upon prevalent weather conditions, care was taken to keep only a few abalones out of the water at any time, minimizing shock and exposure. All tagged abalone were free of deep cuts. Abalone were returned to the area of collection. Caution was taken to place animals in crevices, on developed "scars" (a clean area of rock approximately the size of their foot and usually devoid of macrobiota), or under secure boulders. Subsequent observations and collections of tagged abalone were made by divers at time intervals of varying length (usually 4 weeks) over the 11 year study. During these surveys the tag number and the location were recorded. An abalone was classified to have "moved" only if it was captured in a zone other than it's release area. The location noted was the midpoint of the zone for the dive. Distances moved were determined by calculating a minimum least-linear distance between midpoints of the zones. The null hypothesis that $P\{X=x \mid Y=y\}$ is equal to $P\{X=x\}$ was tested at the $\alpha = 0.05$ level throughout using row by column and multiway tests of independence following methods presented in Snedecor and Cochran (1980).

Nocturnal and Short-term Movements

From July 22, 1974, to September 9, 1974, monitorings of nocturnal and short-term movements were conducted at three specific sites (i) South Channel, (ii) Slot, and (iii) Outer Surge Channel with depths from 25–35', 40–50', and 55–65', respectively (Figure 2). Early in the morning of the first day of study from 20 to 26 abalone ranging in size from 170 to 200 mm long were tagged *in situ* at each site. The position that day of each specimen was mapped. Divers returned daily to determine the total number of abalone at a particular location, the number tagged, the numbers that had moved, and an estimate of the movement.

Model

For the apparent loss of tagged abalone at a given site, a model was developed to quantify observed dispersion rates of red abalone at the three short-term movement study sites. The fraction of tagged abalone present in a search of an entire zone at time t was expressed as:

$$T_t = T_o e - ut + \xi$$

where, T_o = initial number of abalone tagged and released at a site.
T_t = number of tagged abalone resighted at time t.
u = coefficient of loss ($u = M + d$).

M = instantaneous rate of natural mortality.

d = instantaneous rate of dispersion.

t = time elapsed post tagging.

. ξ = error term associated with nonidentification and tag loss.

For the duration of the short-term study (45 days), it was assumed that losses due to natural mortality and to tagging mortality were zero (i.e., M = 0) ; thus the coefficient of loss reduced to:

$$u = M + d = d$$

where d is the modeled dispersion rate.

The observed rate of loss to the tagged population would then be strictly due to dispersion. It was also assumed that there was no active predation on tagged abalone, or that if predation did occur, then it affected both the tagged and untagged populations at equivalent rates. The model was fitted to data utilizing nonlinear least squares regression by the methods suggested in Draper and Smith (1981) using an algorithm by Marquardt (1963).

RESULTS

Qualitative Assessments of Movements

Information attesting to movements involved some unmarked specimens. Obviously, seeing animals moving is satisfactory evidence that movements occur. We noted that different size classes usually occupied different habitats. Diurnally, juveniles preferred the dark undersides of boulders and the recesses of crevices. Specimens < 50 mm long were found diurnally under boulders having a clean veneer of crustose coralline algae on the boulder's undersides. No small abalone were found under boulders bearing sediments or colonial invertebrates like sponges and bryozoans. At Point Cabrillo, boulders occurred in waters < 8m deep. Specimens between about 50 mm and 100 mm long commonly occurred diurnally in crevices and under large boulders. Specimens approaching or exceeding sport legal size ($\geq$ 178 mm long) were generally exposed but also utilized large crevices and undersides of large boulders. Suitable habitat was found between 5–20 m (16–65 ft) deep. Exposed specimens were generally attached to scars. Scars are produced by abalone occupying a site for prolonged periods, resulting in the death of the covering macrobiota. Scars, in varying stages of formation, were noted many times, but scars were particularly prevalent during the summer. Rocky surfaces predisposed to scar formation were those bearing colonies of the polychaete worm *Dodecaceria concharum*. Diurnally, exposed specimens were rarely observed moving. In a few instances movement was associated with the twenty-rayed star *Pycnopodia helianthoides* making contact with exposed abalone. We observed this sea star at times eating red abalone within the study area. Large abalone were also observed traversing sand. This fact may possibly indicate a means for repopulation of rocks lacking juvenile habitat, but possessing habitat for adults.

Disturbance of boulders serving as abalone habitat caused the immediate movement of juveniles and adults. When boulders are being rolled or disturbed, abalone will drop from the boulder to prevent crushing. Circumstantial evidence suggests that, in the winter, movement may be prompted by rock and boulder habitat being displaced by heavy storm seas. Following periods of heavy seas we

observed large boulders having been rolled, and some bore many unoccupied scars. During these periods many abalone were found attached, but not to scars. After periods of high seas, broken shells, of those abalone presumably crushed, were found strewn along the bottom. Some abalone bore evidence of broken shell repair.

Further evidence for movement is the fact that red abalone size classes were stratified according to habitats. The degree to which adults were exposed varied seasonally. More empty scars were noted during the winter, a period charac- terized by heavy seas, an extreme paucity of food, and the lack of cryptic cover provided by the low and attached algae. Occasionally abalone were found with their shells covered by the biota typical of another depth or specific microhabitat. Most frequently the shells of these mobile specimens were covered by the coral- line alga, *Calliarthron tuberculosum*, characteristic of exposed and well lighted areas found 8 m deep or less (Abbott and Hollenberg 1976). Some extant ab- alone shells bearing *C. tuberculosum* were found as deep as 25 m; *C. tuberculosum* does not survive at such depth. Specimens bearing the alga at vary- ing stages of degeneration indicated that these specimens had been present at these greater depths for periods ranging from days to probably weeks.

Nocturnal and Short Period Movements

During the afternoon of the first day of the short term movement study we re- turned to each specific study site and observed that no specimens had moved. However, upon returning the following morning we noted that a number of the specimens had moved, and some were on the scars previously occupied by other abalone. In some cases vacant scars were noted which had been occupied the day before (Table 1). Evidently movement was nocturnal and specimens tended to home back to scars, but not necessarily the one they previously oc- cupied. Distances traversed by individual abalone ranged from 1.0 to 6.0 m per day. Some tagged abalone moved *at least* eight times during the course of our 45- day investigation, although some specimens apparently did not move to new lo- cations at all. In a few cases tagged abalone apparently occupied the same scar for weeks. In numerous cases abalone moved, and were either not observed again, or were subsequently observed in the study area or the near vicinity at ir- regular intervals. Movements were probably greater than we resolved by mea- surement (Table 2). Over the period that the diurnal investigation was con- ducted, a general pattern of diffusion of the tagged population was indicated at all depths and locations studied (Figure 3). Modeled dispersion rates were great- est in South channel ($u_{sc} = 9.39 \times 10^{-2}$) which was the shallowest and most dynamic area studied, and least ($u_{os} = 2.61 \times 10^{-2}$) in the Outer Surge Chan- nel, the deepest and presumably most stable area with respect to physical dy- namics. Factor(s) inducing movement were not completely ascertained. How- ever, areas of strong current and greater sea exposure apparently create more dynamic and fluctuating environments and may hence prompt a greater inci- dence of movement in and out of these locations. Deeper water sites were gen- erally more stable with respect to currents, but not necessarily to food supply. Movements of red abalone both horizontally and vertically along the seabed were common at all depths.

TABLE 1: Numbers of Tagged Abalone Present Relative to the Number of Tagged in a Given Area for the Three Short-Term Movement Study Sites at Point Cabrillo.

LOCATION: DEPTH:	SOUTH CHANNEL 25'				SLOT 45'				OUTER SURGE CHANNEL 60'			
DAYS POST TAG	TOTAL # OF ABALONES IN AREA	# OF TAGGED ABALONE IN AREA	VACANT SCARS	DAYS POST TAG	TOTAL # OF ABALONES IN AREA	# OF TAGGED ABALONE IN AREA	VACANT SCARS	DAYS POST TAG	TOTAL # OF ABALONES IN AREA	# OF TAGGED ABALONE IN AREA	VACANT SCARS
0	26	20		0	43	23	1	0	33	26	1
1	19	15		1	34	17	1	1	42	20	3
2	26	12	1	2	32	20	2	2	48	25	11
3	16	9		3	40	23	3	3	40	20	9
4	12	11	2	4	13	13	2	4	27	18	8
14	10	8		14	21	9	1	14	37	17	6
15	9	5		15	19	6	4	15	40	13	6
16	5	5		16	15	6	3	16	34	15	7
19	6	6		17	14	7	1	17	34	16	4
22	6	5		18	12	8	2	18	32	18	2
45	7	7		19	12	8		19	33	16	9
				22	18	7	2	22	32	16	1
				45	17	7		45		14	
Observation Dates	n = 11				n = 13				n = 13		
Dispersion Rate From Model:	$\mu_{SC} = 9.3856 \times 10^{-2}$				$\mu_{S} = 6.6527 \times 10^{-2}$				$\mu_{OS} = 2.6125 \times 10^{-2}$		

TABLE 2: Range of Diurnal Movements and the Total Number of Known Movements Per Individual Specimen for the 45 Day Study on Short-Term Movements for Three Sites at Point Cabrillo.

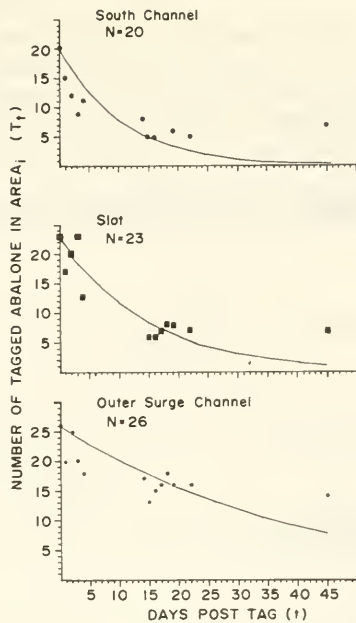| LOCATION	RANGE OF DISTANCES MOVED (METERS/DAY)	NUMBER OF DIVER OBSERVATION DATES	FREQUENCY DISTRIBUTION OF THE MINIMUM NUMBER OF MOVES OBSERVED PER INDIVIDUAL TAGGED SPECIMEN DURING THE 45 DAY STUDY									
			0	1	2	3	4	5	6	7	8	
X South Channel	2.5–5.75	11	1	0	8	7	3	0	1	0	0	20
X Slot	1.6–6.0	13	2	2	4	8	4	1	1	0	1	23
Outer Surge	2.0–4.0	13	6	5	7	3	4	0	1	0	0	26

X - Stronger water movement occurs commonly

FIGURE 3.   Dispersion model curves fitted for the three short-term movement study sites at Point Cabrillo reserve.

Long-term Movements

A total of 3,877 red abalone was tagged and released in the 11 zones of the study area. A frequency distribution of the total numbers of abalones tagged and released by 5 mm size classes is shown (Figure 4). Tagged specimens ranged from 20 to 230 mm long, and except for abalone < 100 mm long, included a fair representation of the population size structure. The mode of the sampled distribution occurred at 110 mm shell length. Difficulty in sighting abalone smaller than 100 mm long resulted in less tagging of these animals. The distribution of sizes tagged in most areas was broad (Figure 5), although actual sample sizes by zone varied considerably. Approximately 4% of the total abalone tagged and released over the 4-yr tagging period were mortalities subsequently collected moribund (Figure 6). Some of these were collected as tagged shells only. Total mortalities recovered relative to the total numbers tagged showed two discrete groups of recoveries; (i) those $\leq$ 150 mm in shell length $X_9^2 = 7.77$, n.s.), and (ii) those > 150 mm ($X_5^2 = 3.31$, n.s.), suggesting differential mortality. Those $\leq$ 50 mm and > 210 mm were discounted because of the small sample sizes in these size intervals. These patterns were interesting because the recovery of mortalities suggests that abalone > 150 mm shell length had a mortality rate 1.42 times greater than abalone $\leq$ 150 mm (17.9% vs. 7.4% respectively). Two possible reasons for the division in mortality rates were that: (1) the rate was actually higher in abalone > 150 mm, or that (2) probably more likely, the shells of abalone > 150 mm were more easily located by divers, and for specimens $\leq$ 150 mm their shells could much more easily be overlooked or lost, crushed by rolling boulders, eaten or otherwise destroyed. Additionally, the frequency of multiple

resightings for abalone > 150 mm was higher and thus may have contributed to the higher mortality observed in larger animals. In general, we believe that tagging had a negligible effect on survival or behavior because most shell margins of those animals recovered showed evidence of new growth. For this reason we believe that mortality rates associated with tagging were low and probably equivalent across all size classes.
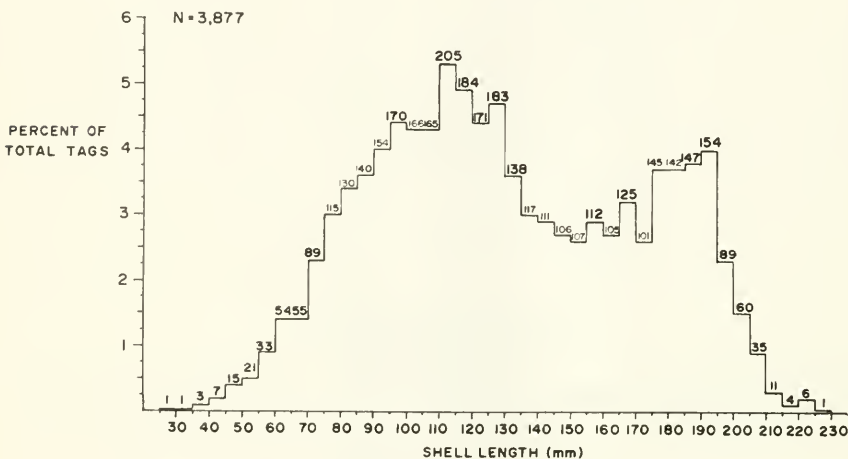

FIGURE 4.   Frequency distribution by 5 mm size classes for total number of red abalone tagged and released for all zones combined.

From the 3,877 abalone tagged and released in our study, 2,247 (58%) were either resighted or recovered at least one time. A total of 4,302 individual resightings of tagged abalone was recorded. Some specimens were resighted only once, while others were resighted several times and thus confirmed differential resighting rates among size classes ($X_{11}^2 = 74.03$, $p < .001$). Abalone > 110 mm long had the highest frequency of resighting (c.f. Figure 5). The greatest fraction of recaptures for all tagged size classes occurred during the first year after tagging; subsequently, resighting rates declined exponentially for abalone placed in all study zones (Table 3). Approximately 42% of the tagged abalone were never resighted after their release. For those abalone resighted, their recovery suggested statistical homogeneity of four contiguous groupings of size classes: (i) 31–70 mm ($X_3^2 = 0.53$, n.s.); (ii) 71–110 ($X_3^2 = 6.23$, n.s.); (iii) 111–160 mm ($X_4^2 = 7.42$, n.s.); and (iv) 161–230 mm ($X_6^2 = 7.47$, n.s.); however, these groupings were significantly different from each other ($X_{11}^2 = 34.03$, $p < .001$). The probability of resighting an abalone at least one time after tagging was: for abalone 161–230 mm, 67.4% of total tagged; for abalone 111–159 mm, 58.9%; for abalone 71–110 mm, 51.6%; and for abalone 31–70 mm, 32.6%, respectively. This may explain the disparity in recovery of shells of the various moribund size classes. If the resighting rates of tagged dead abalone are roughly proportional to those of live tagged abalone then these statistics bear out differential resighting frequencies of the size classes. Assuming that natural mortality affected the
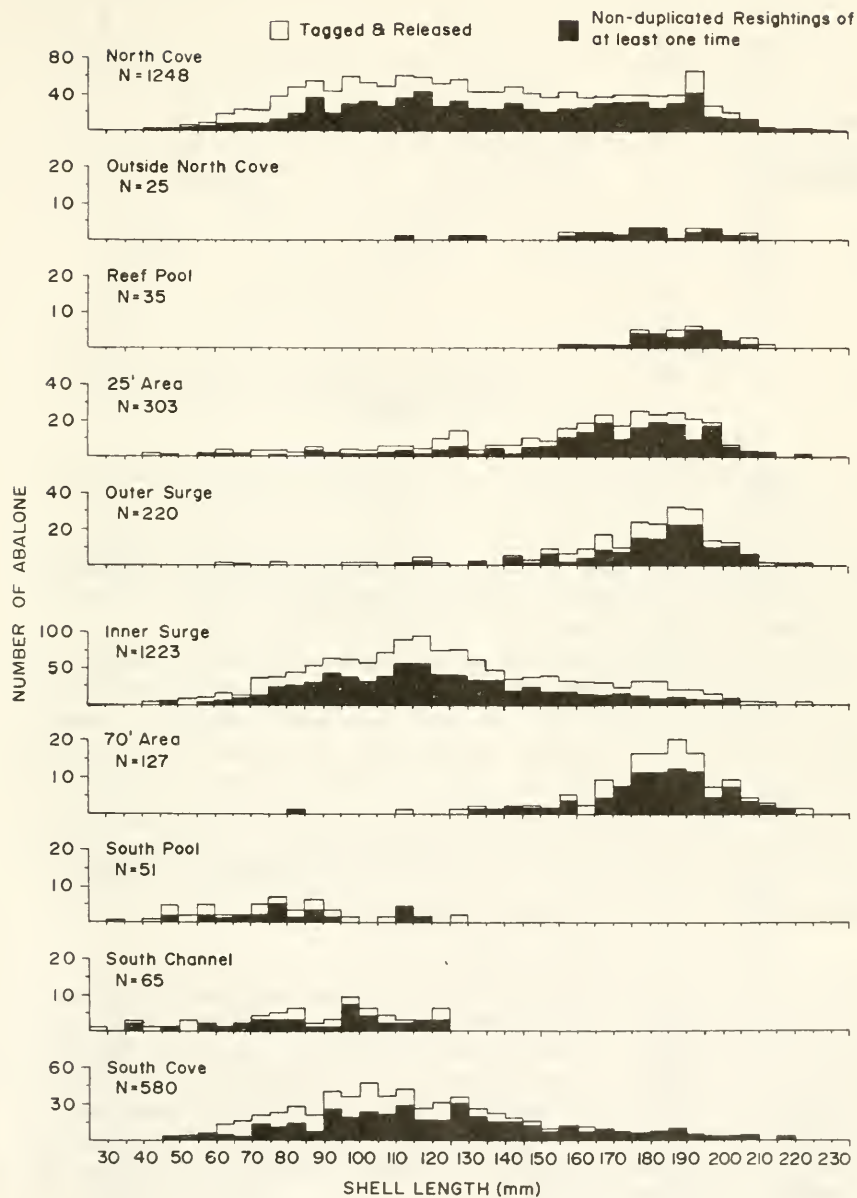
FIGURE 5. Size frequency distribution of tagged and released abalone (open area); and subsequent non-duplicated resightings of those specimens of at least one time by release zone.
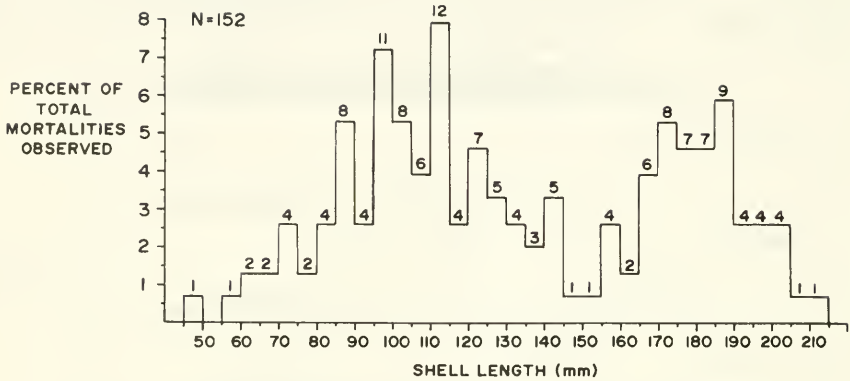
FIGURE 6.   Frequency distribution by 5 mm size classes of tagged red abalone recovered as mortalities for all zones combined.

resighted and non-resighted groups equally (not a robust assumption), then non-resighted group mortality was 110 abalone. This leaves some 1,520 tagged abalone in an undetermined status after their release. The disappearance of these tagged abalone may be attributed to the following factors:

1. The fraction of tagged population loss due to natural mortality was higher than that estimated by the recovery of shells with tags attached (i.e., some of these empty shells, particularly those of the small size classes, went unrecovered).
2. Some tag loss could be attributed to weakening of the wire securing the tag to an abalone through breaks or corrosion, or fracturing shells < 100 mm.
3. All tagged abalone in a particular zone were not recovered. The paucity of recoveries could have been influenced seasonally by heavy algal growth, and intra-annually by the inherently cryptic nature of juveniles and subadults.
4. Tagged abalone emigrated from the study area.

Rate of Movements

About 11 percent of the tagged abalone that were resighted at least once moved out of their release zone. Abalone in some zones exhibited a wider range of movement than others (Table 4). Median distance moved was 87 m for resighted abalone (Figure 7). Movements out of the respective release zones varied temporally. The trend for movement was from shallow to deep water in the summer, and from deep to shallow water in winter. Movements were extensive for all size classes. Distances of movement varied from 1m to over 150 m per month per individual (Table 5).

Evidently large distances were traversed by some red abalone. There were 29 records of abalone which had each travelled > 350m along the seabed off Point Cabrillo over periods ranging from 3 to 61 months. Larger abalone apparently tended to move more frequently and further (Figure 8). Two abalone, observed 3 months after tagging, had moved distances greater than 0.5 km least-linear dis-

TABLE 3: Non-Duplicated Resightings of Tagged Specimens From the Initial Tag & Releases Remaining in Designated Release Area by Years Post-Release.

TAGGING AREA	NUMBER TAGGED INITIALLY	NUMBERS OF INITIAL TAGGED SPECIMENS PRESENT IN AREA BY YEARS POST TAG & RELEASE								
		1	2	3	4	5	6	7	8	11
North Cove	1,248	709	186	99	44	28	8	0	3	0
Outside North Cove	25	21	2	1	0	0	0	0	0	0
Reef Pool	35	32	4	5	0	0	0	0	0	3
25' Area	303	239	45	61	40	2	0	0	0	3
Outer Surge	220	174	64	51	50	5	2	24	1	3
Inner Surge	1,223	475	169	65	60	10	0	0	0	1
70' Area	127	97	47	32	6	8	2	0	0	0
South Pool	51	38	2	2	0	0	0	0	0	0
South Channel	65	65	3	2	1	0	0	0	0	0
South Cove	580	273	114	17	23	7	16	0	0	0
Σ	3,877	2,123	636	335	224	60	26	24	4	7

TABLE 4: Number of Red Abalone Known to Have Moved Out of Their Respective Designated Release Area and the Percentages of Total Abalone Tagged & Released by Site.

	NORTH COVE	OUTSIDE NORTH COVE	REEF POOL	25' AREA	OUTER SURGE	INNER SURGE	70' AREA	SOUTH POOL	SOUTH CHANNEL	SOUTH COVE	TOTAL
Number of Specimens Known Moving Out of Release Zone	70	12	8	86	51	36	45	5	25	86	424
Percent of Total Tags Released	5.6	48.0	22.9	28.4	23.2	2.9	35.4	9.8	38.5	14.8	10.9

tances from the point of their release. One tagged abalone released in the Inner Surge Channel was recovered alive approximately 9 yr later by a sportdiver near Caspar State Beach, a distance 2.4 km north of the study site in least-linear transect from the point of release. In addition, a shell from a tagged abalone released in the Inner Surge Channel was found 3 yr after that release near Caspar State Beach. Other evidences for extensive movements by abalone were corroborated by recorded observations that showed specimens released in one tag zone were subsequently identified as having moved into another zone, then later located, after another move, in the zone on the other side of their original release zone.
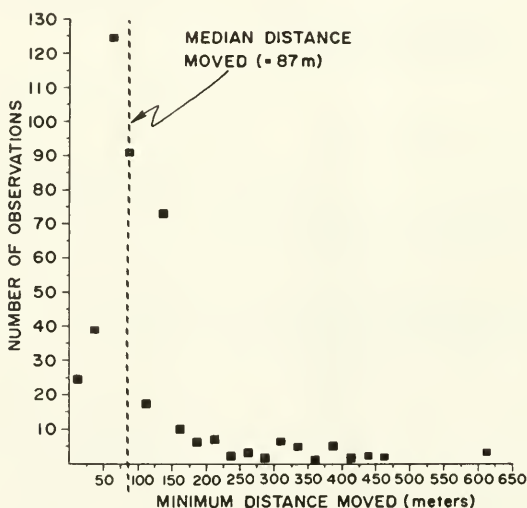
FIGURE 7.   Least-linear distance traversed by numbers of abalone observed to have moved for all zones combined.

TABLE 5.   Distribution of Tagged Abalone by Four Size Intervals, Number of Recoveries, and Their Rates of Movement.

Size Class (mm)	Number Tagged	Number Moved Out of Designated Tag Zone	% Moving	Range of Elapsed Time Post-Tag (Months)	Range of Movement Per Month (Meters/Month)
≤ 100	988	75	7.59%	3—61	1.05– 59.6
100—130	1,079	73	6.77%	3—86	0.89–153.8
131—160	685	73	10.66%	4—86	0.80– 66.5
> 160	1,125	203	18.04%	3—86	1.02–153.8
	3,877	424	10.94%	3—86	0.89–153.8
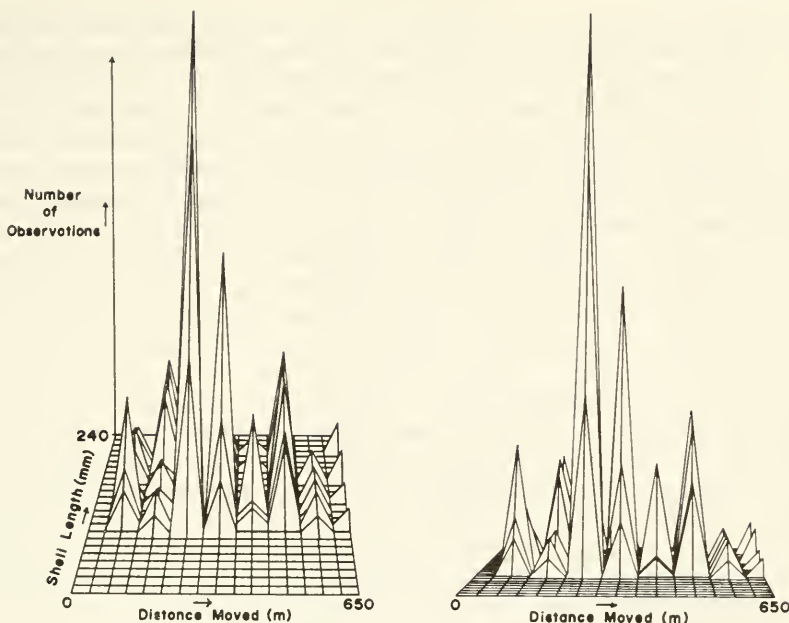
FIGURE 8.   Three dimensional surface plot of numbers of observations as a function of abalone shell length and the distance moved.

Tagged population abundance in the study area followed approximately an exponential decline. Our findings indicate that dispersal rates vary among size classes ($X^2_{11} = 74.03$, $p < .001$). For those animals resighted at least one time, two discrete ($X^2_2 = 64.45$, $p < .001$), but contiguous, groups of abalone that were known to have moved were apparent: (i) specimens > 150 mm ($X^2_5 = .24$, n.s.), and (ii) specimens ≤ 150 mm ($X^2_9 = 10.91$, n.s.). Abalone > 150 mm shell length had the highest rates of movement; 27.4% of those resighted at least once had moved out of their release zone. This compared with 13.6% of those abalone ≤ 150 mm. Generally, less than 20% of those abalone released within a particular zone would still be located in the same zone two years after tagging. Apparently the red abalone population at Point Cabrillo was in a constant state of flux due to movement and dispersal, with the new members entering the area as well as those leaving the area. However, some abalone remained in the same general vicinity for relatively long periods. We probably have underestimated the extent of movements as it is likely that some abalone left the zone in which they were released, only to return to the same general vicinity in which they were released before our next observation.

DISCUSSION

The incidence of movement among red abalone at Point Cabrillo was high. Large distances were traversed by individual abalone in relatively short periods of time. These results contrast somewhat from those of Bonnot (1948), Cox (1962), and Hines and Pearse (1982) on *H. rufescens.* This is perhaps because of: (i) limited sample sizes; (ii) general problems of sampling marine systems (Dayton and Tegner 1984); (iii) time constraints used in sampling programs; and (iv) possible effects of higher predation rates by sea otters not present in our study site. We observed movements by abalones up and down the coastline, perhaps in response to physiological and environmental stress. Further, these findings augment field and laboratory observations of others that have suggested regular translocation and very active movement recorded for other haliotids (Stephenson 1924, Ino 1952, Newman 1966, Momma and Sato 1969, Poore 1972, Shepherd 1973).

At Point Cabrillo predation is limited. Population pressure on red abalone tends to be intraspecific; positioning for available current and food, minimization of disturbance, and the facilitation of reproduction and recruitment are the primary concerns for vitality (Ault 1985b). Movement may involve avoiding the hazards of climate and food shortage during unfavorable environmental events, at the costs of the hazards of migration and ultimate survival in a new area.

The incidence of movement in the red abalone population varied from year to year, and directly and indirectly depended upon sea conditions. Since red abalone feed primarily on drift kelp, currents coupled with food supply, light, and season in the nearshore area probably dictate the amount and quality of the algae to which a particular abalone might have access. In the winter suitable food supply is found at relatively shallow depths. However, there is a tradeoff because turbulence and wave action can disrupt the boulder habitat to which abalone adhere. Storm conditions increase the probability of abrasion, crushing and detachment of abalone, and severe sea conditions apparently force movement to deeper water or safer domain. Several authors have stated that haliotid movements are prompted by physical disturbance (Graham 1941, Sinclair 1963, Poore 1972, Shepherd 1973). Poore (1972) stated that movement of juvenile *H. iris* in New Zealand was seasonal, being greatest in the fall and winter when rough water disturbed the habitat more frequently. Red abalone will leave sites on the sandline when threatened by smothering sand, drift and debris. In the present study the recovery of tagged abalone was higher below 8 m. Presumably rough weather had less effect on abalone positioned in deeper waters.

In northern California a clear distinction between the microhabitats of juvenile and adult red abalone was observed, and is similar to that reported for southern California (Leighton, 1968) and central California (McLean, 1962). Due to size-stratified differences in dietary requirements, and the cryptic nature of juvenile abalone versus the more exposed positioning of adults, some migration between juvenile to adult habitat must occur as abalone grow. Migration between habitat types for juvenile and adult abalone has been reported by Newman (1966) for *H. midae,* and by Shepherd (1973) for *H. iris.* In general, older red abalone occupy deep depressions on the surface of rocks indicating the dearth of movement from that particular spot. These spots generally occupied by larger abalone appear to be prime feeding locations. The most important single factor ensuring

an adequate food supply is the abalone's preference for resting places on open rock where drifting algae are carried or deposited. At Point Cabrillo, due to the lack of predation by sea otters, being exposed on open rock face was allowable.

It is generally accepted that most abalone participate in nocturnal feeding excursions, moving out after dark to graze on surrounding algae (Graham 1941, Bonnot 1948, Sinclair 1963, Leighton 1968, Momma and Sato 1969 & 1970, Poore 1972, Shepherd 1973). However, there is considerable debate as to whether these foraging abalone return to their "home scar". Some abalone apparently spend their entire life on small isolated stones, boulders or rocks from which they do not move (Cox 1962). The persistence of the abalone's foot on a specific area for prolonged periods of time contributes to scar formation. Scars can become very deep, especially in soft mudstone or sandstone, as periodic twisting of the shell by an abalone may cause abrasion of the substrate. Scar formation led to the assumption of homing according to Sinclair (1963) and Tunbridge (1967). Homing to a fixed particular scar is well known in limpets (prosobranch relatives of haliotids), and is influenced by the size of an animal, the texture and stability of the homesite rock, and the availability of food (Branch, 1981). Bonnot (1948) stated that *H. rufescens* forage during the night and will sometimes travel considerable distances, returning to their "home spot" by day break. By contrast, Leighton (1968) stated that his tagging observations indicated that homing is not universal in adult *H. rufescens* and is virtually unestablished in young juveniles, as no scar is present under these abalone. Other California haliotids, *H. corrugata* and *H. sorenseni,* are believed to move as much as several meters at night, sometimes returning to previously occupied scars by dawn (Tutschulte 1968, 1976). Both Forster (1962), with *H. tuberculata,* and Shepherd (1973), with *H. ruber,* stated that abalone normally live in a retreat from which nocturnal feeding excursions are made, though these abalones may not invariably return to the same retreat before morning. If homing by red abalone occurs it is probably a means of regulating population density relative to food abundance. A shortage of food may be the key factor increasing the observed incidence of non-homing abalone. Thus, dispersion away from a neighbor, if movement is linked to food shortage, can spread the population and reduce competition for food and space. Our work demonstrates that red abalone do move, but they do not necessarily home to the same scar which they had previously occupied. Furthermore, an animal might spend years in the same general area, only to depart suddenly and be found elsewhere at a later date. Homing is not an important factor in red abalone; however, the acquisition of an unoccupied scar could be of primary importance in that it provides a site for good attachment and food procurement.

Our observations also suggest that hunger may stimulate movement. The extent to which an abalone moves probably depends upon available food supply. In the presence of sufficient food, abalone movements were meager. These observations are congruent with those of Hines and Pearse (1982) who stated that abalone in their central California study site, in the presence of sea otters, habitually remained within their respective cracks, and that movement appeared to be in positive response to the presence of drifting pieces of the giant kelp, *Macrocystis pyrifera.* The fraction of the population that disperses outside the boundaries of the original home territory is expected to be high when environmental conditions locally eliminate a particular food supply and create new supplies in other places (Cohen 1967, Vadas 1977).

In areas of regular food supply little movement occurs. At Fort Bragg in the winter, movement might be induced by the seasonal paucity of the kelps. If nec-essary, adult red abalone will scrape benthic diatoms with their radula to survive during periods of scarce food supply. MacGinitie and MacGinitie (1966) re-ported, from laboratory observations, that starvation did not stimulate *H. corrugata* to move. Indeed, this scenario may be the impetus for red abalone movement. Translocation to areas which possibly afford less protection, and the unknown probability of successful food procurement, could be detrimental to a particular mobile abalone and therefore mal-adaptive.

SUMMARY

Movement and dispersal in a northern California red abalone population oc-curred. However, some individual abalone exhibited no apparent movement during our study. The general stimulus for movement may be due to limited food supply, although physical disturbance may also prompt movement. A general tendency exists for adult abalone to reposition on scars after movement, regard-less of whether or not the scar was theirs previously. The apparent trend for movement was from shallow to deep water in the spring-summer, and from deep to shallow water in fall-winter in response to the highly seasonal and depth lim-ited abundance of algae. Intraspecific competition may limit population density by density dependent mortality, or by influencing the rate of emigration in re-lation to food availability. The incidence of movements and resulting population size flux is great. Densities of abalone remained fairly constant through time for our particular location because much emigration and immigration occurred. Small dense groups of subadult abalone may be capable of replenishing exploited stocks of larger abalone in their vicinity by movement to these favorable but ex-ploited reefs. Although strong inferences may be made here, further studies must be conducted to determine the relationship between dispersion and natural mor-tality before any absolute assessment of the fraction of population loss or gain due purely to movements can be ascertained.

ACKNOWLEDGMENTS

LITERATURE CITED

Abbott, I.A. and G.J. Hollenberg. 1976. Marine Alga of California. Stanford University Press. Stanford, California. 827p.

Ault, J.S. 1985a. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—black, green and red abalones. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.32) U.S. Army Corps of Engineers, TR EL-82-4. 19p.

Ault, J.S. 1985b. Some quantitative aspects of reproduction and growth of the red abalone, *Haliotis rufescens* Swainson. J. World Maricult. Soc. 16: 398–425.

Bonnot, P. 1948. The abalones of California. Calif. Fish Game 34(4):140–169.

Branch, G.M. 1981. The biology of limpets: physical factors, energy flow, and ecological interactions. Oceanogr. Mar. Biol. Ann. Rev., 19:235–380.

Clavier, J. and R. Olivier. 1984. Experimental study of the movements of the ormer (*Haliotis tuberculata*) in nature. Rev. Trav. Inst. Peches marit. 46(4):315–325.

Cohen, D. 1967. Optimization of seasonal migratory behavior. Amer. Natur. 101:5–17.

Cox, K.W. 1960. Review of the abalone in California. Calif. Fish and Game 46(4):381–406.

Cox, K.W. 1962. California abalones, family Haliotidae. Calif. Fish and Game Bull. No. 118, 133p.

Dayton, P.K. and M.J. Tegner. 1984. The importance of scale in community ecology: a kep forest example with terrestrial analogs. In "A New Ecology: Novel Approaches to Interactive Systems", Chap. 17, P.W. Price, C.N. Slobodchikoff and W.S. Gaud (eds.) Wiley, New York.

Draper, N.R. and H. Smith. 1981. Applied Regression Analysis. John Wiley and Sons, New York. 709p.

Forster, G.R. 1962. Observations on the ormer population of Guernsey. J. mar. biol. Assoc. U.K. 42:493–498.

Graham, D.H. 1941. Breeding habits of twenty-two species of marine Mollusca. Trans. Royal. Soc. of New Zealand 71:152–159.

Hancock, D.A. 1979. Population dynamics and management of shellfish stocks. Rapp. P.-v. Reun. Cons. int. Expor. Mer 175:8–19.

Hines, A.H. and J.S. Pearse. 1982. Abalones, shells, and sea otters: dynamics of prey populations in central California. Ecology 63(5):1547–1560.

Ino, T. 1952. Biological studies on the propagation of Japanese abalone, genus *Haliotis*. Tokai-Ku Suisan Kenkyoju Hokoku 5:1–102.

Leighton, D.L. 1968. A comparative study of food selection and nutrition in the abalone, *Haliotis rufescens* (Swainson) and the sea urchin, *Stronglyocentrotus purpuratus* (Stimpson). Dissertation. Univ. of Calif., San Diego. 197p.

Leighton, D.L., Byhower, M.J., Kelly, J.C., Hooker, G.N. and D.E. Morse. 1981. Acceleration of development and growth in young green abalone, *Haliotis fulgens*, using warmed effluent seawater. J. World. Maricul. Soc. 12(1):170–180.

Marquardt, D.W. 1963. An algorithm for least squares estimation of nonlinear parameters. J. Soc. Ind. Appl. Math. 11:431–441.

MacGinitie, N. and G.E. MacGinitie. 1966. Starved abalones. Veliger 8:313.

McLean, J. 1962. Sublittoral ecology of the kelp beds of the open coasts near Carmel, California. Biol. Bull. 122:95–114.

Momma, H. and R. Sato. 1969. The locomotion behavior of the disc abalone, *Haliotis discus hannai* Ino, and the Siebold's abalone, *Haliotis seiboldii* Reeve, in the fishing grounds. Tohoku J. Agric. Res. 20(3):150–157.

Momma, H. and R. Sato. 1970. The locomotion behavior of the disc abalone, *Haliotis discus hannai* Ino, in a tank. Tohoku J. Agric. Res. 21(1):20–25.

Newman, G.G. 1966. Movements of the South African abalone, *Haliotis midae*. Investl. Rep. Div. Sea Fish. S. Africa 56: 1–20.

Poore, G.C.B. 1972. Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda) 2. Seasonal and diurnal movement. New Zealand J. Mar. Fresw. Res. 6(3):246–258.

Shepherd, S.A. 1973. Studies on southern Australian abalone (genus Haliotis): I. Ecology of five sympatric species. Aust. J. Mar. Freshw. Res. 24(3):217–257.

Sinclair, M. 1963. Studies on the paua, *Haliotis iris* Martyn, in the Wellington district, 1945–1946. Zool. Publ. from Victoria Univ. of Wellington 35, 16p.

Snedecor, G.W., and W.G. Cochran. 1980. Statistical Methods. The Iowa State University press. Ames, Iowa. 507p.

Stephenson, T.A. 1924. Notes on *Haliotis tuberculata*. J. mar. biol. Assoc. U.K. 13(2):480–495.

Tunbridge, B.R. 1967. Feeding habits of paua. New Zealand Mar. Dept. Fish Tech. Rept. 20:1–18.

Tutschulte, T.C. 1968. Monitoring the nocturnal movements of abalones. Underwater Naturalist 5(3):12–15.

Tutschulte, T.C. 1976. The comparative ecology of three sympatric abalones. Dissertation. Univ. of Calif., San Diego. 335 p.

Vadas, R.L. 1977. Preferential feeding: an optimization strategy in sea urchins. Ecological Monographs 47:337–371.

THE USE OF BAITED STATIONS BY DIVERS TO OBTAIN FISH RELATIVE ABUNDANCE DATA [1]

DANIEL W. GOTSHALL
California Department of Fish and Game
Marine Resources Division
2201 Garden Road
Monterey, California 93940

Divers were used to count fishes at 317 baited stations at Cojo Anchorage near Point Conception, California between September 1980 and June 1981. This method was tested in order to develop a quantitative technique to assess impacts, on fish populations, of a proposed liquefied natural gas terminal. The counts were conducted in depths 30 to 70 feet (9.2–21.4m) on bedrock substrate. Forty-three identifiable species were attracted to these baited stations. To test the effectiveness of the method to detect temporal and spacial changes in abundances, five species plus total combined fishes were selected to compare differences in counts among seasons within each study area and among four study areas for each season. The baited station counts yielded significant differences in seasonal counts for rainbow surfperch, *Hypsurus caryi;* kelp bass, *Paralabrax clathratus;* black surfperch, *Embiotoca jacksoni;* and onespot fringehead, *Neoclinus uninottus,* at one or more of the four study areas. There were also significant differences for these same species when counts between study areas were compared.

INTRODUCTION

Biologists have been utilizing scuba for a number of years to obtain quantitative data on shallow-water fishes and invertebrates. Various non-destructive methods have been used in attempts to obtain this data. For example, Miller and Geibel (1973) used permanent 30-m transects in Monterey Bay to obtain counts of kelp-bed fishes in order to determine daily and seasonal fluctuations in abundance. Ebeling, Larson, Alevision, and Bray (1980) used an underwater movie camera to produce their "cinetransects" in kelp forests off Santa Barbara to obtain species composition and annual variability in numbers of fishes between canopy and bottom habitats. Another approach has been used by Jones and Thompson (1978) who counted fish species rather than individuals of a particular species, during specific time periods, while "swimming around" coral reefs off Florida. Their method was designed to compare species abundance quantitatively through time or between areas. All of these methods provide indices of abundance that work better for some species than others.

All of the non-destructive observational methods utilizing divers are subject to uncontrolled factors that would influence variation, including difficulty in the diver's ability to objectively judge distances and sizes of fish along the transect, and to accurately identify fishes, particularly those at the outer edge of visibility, and the varying behavior of species either to be attracted to or repelled by divers. In addition cryptic and crevice dwelling species are usually missed by divers. The use of all of the techniques in central and northern California has been further questioned due to the role that surge and turbidity play in hampering the diver's ability to concentrate on identifying and counting fishes. Also, heavy surge can

---

[1] Accepted for publication January 1987.

cause many fishes that live near or on the bottom to seek shelter in caves and crevices where the divers may not see them. Finally, there is the problem of accuracy of diver counts of large schools that may contain 50 or more fish. Because of all of these factors none of the diver survey methods can yield accurate species composition data.

An alternative method, which involves counts of fishes attracted to baited stations, required testing to determine whether at least some of the variability inherent in the three methods discussed above could be reduced. The objective of this study was therefore to develop such a method to attempt to produce relative abundance (catch-per-unit-of-effort, CPUE) data which would be useful in assessing impacts on fish populations. In this case, the sport and commercial species in the vicinity of a proposed liquefied natural gas (LNG) terminal. Two null hypotheses were tested: (i) there were no significant seasonal changes in abundance of the dominant fishes that live on or near the bottom; and (ii) there were no significant differences in abundance of the dominant fishes between the proposed LNG terminal area and two control areas.

DESCRIPTION OF STUDY AREA

The present study was conducted at Cojo Anchorage, just south of Pt. Conception, California (Figure 1). The study area at Cojo Anchorage consists of large areas of relatively flat bedrock interspersed with sand patches and channels. Six study areas were established: a shallow (CW30) and deep (CW60) control area west of the proposed LNG terminal site, a shallow (T30) and deep (T60) area at the terminal site, and a shallow (CE30) and deep (CE60) control area east of the proposed LNG terminal site (Figure 1). The west end of the study area contains large sandy areas, particularly in depths greater than 14 m. Most of the substrate in the proposed LNG terminal area is low-relief (1 m) of flat bedrock with one major sand channel. The eastern portion of the study area consists of a mixture of sand and bedrock in waters shallower than 14 m and low-relief bedrock in deeper water (14–18 m). Much of the bedrock substrate supports beds of giant kelp, *Macrocystis pyrifera,* and the brown alga, *Pterygophora californica.*

METHODS

Sampling was conducted during four quarters beginning in September 1980 and concluding in June 1981. Counts were originally made at the six locations mentioned above. The deep west control area (CW60) and shallow east control area (CE30) were deleted from the sampling plan during the spring and summer 1981 surveys, because of lack of bedrock substrate. Seven random locations within each study area were selected to be sampled each quarter. During the spring and summer 1981 surveys, random stations were increased from 7 to 11. Counts at the baited stations were conducted between one hour after sunrise and one hour before sunset; however most counts were done between 0800 and 1500 h.

At each random station two divers descended to the bottom with a canvas bag containing two lengths of 2-m chains connected in the middle. A bait container filled with roe and guts from four to six sea urchins *(Strongylocentrotus)* was attached to the center of the chains after the chains were laid out in the form of a cross. The arms of the cross formed the radii of a circle two meters in diameter. In effect the baited station acted as a trap with virtually unlimited access for
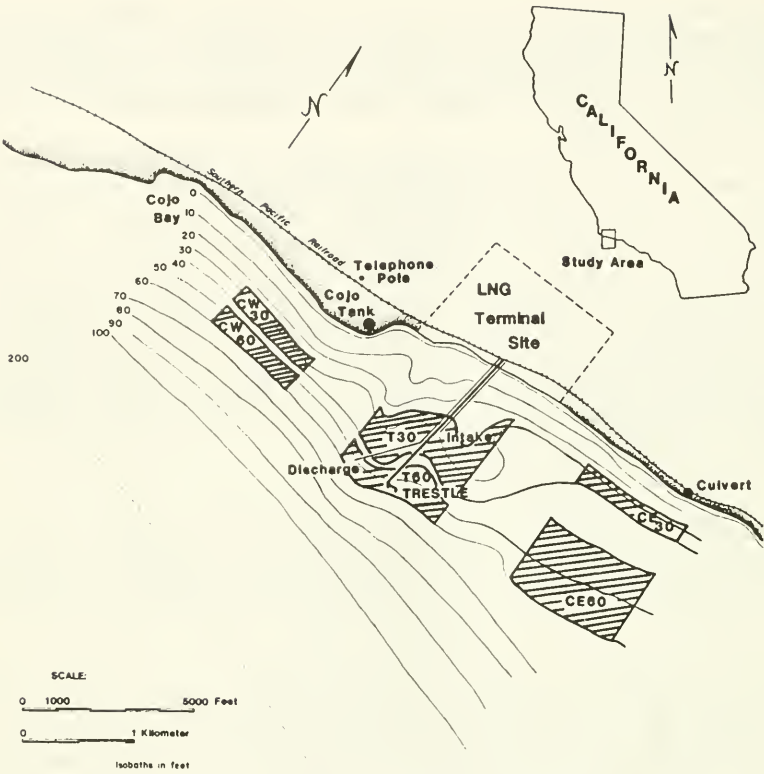
FIGURE 1.   Locations of study areas for visual fish observations at baited stations: CW60 = deep
            west control, CW30 = shallow west control, T60 = deep trestle site, T30 = shallow
            trestle site, CE60 = deep east control, CE30 = shallow east control.

fishes. At the signal of the diver team leader, each diver began recording the
numbers of each species of fish that entered the circle and within one meter of
the bottom. The counts were recorded on a minute-by-minute basis for ten min-
utes. The ten minute observation period was selected by using pre-survey data
to plot numbers of fishes (all species) observed each minute for ten minutes at
all stations. The resulting curve peaked at five minutes (Figure 2). Based on this
curve we selected the ten minute observation period as a compromise between
increasing the number of fishes that might occur with a longer observational pe-
riod and the number of stations the divers could complete on a single tank of air.
The divers also kept track of and recorded the total number of each species that
entered the circle during the ten minute count. At the completion of the first
count, the divers laid out a 30-m transect line due north of the first station. At the
terminus of the 30-m transect, a second ten minute count was conducted. At the
shallow study areas a third ten minute count was conducted 30-m west of the
second station. At each station the divers also recorded depth, substrate type,
presence of *Macrocystis* and *Pterygophora*, and horizontal visibilities as mea-
sured on the transect tape. Immediately upon completion of the dives, the divers

compared counts to resolve any differences. These composite counts were recorded on a separate data sheet. Water temperatures were taken at the surface with Martek VI water quality analyzer.
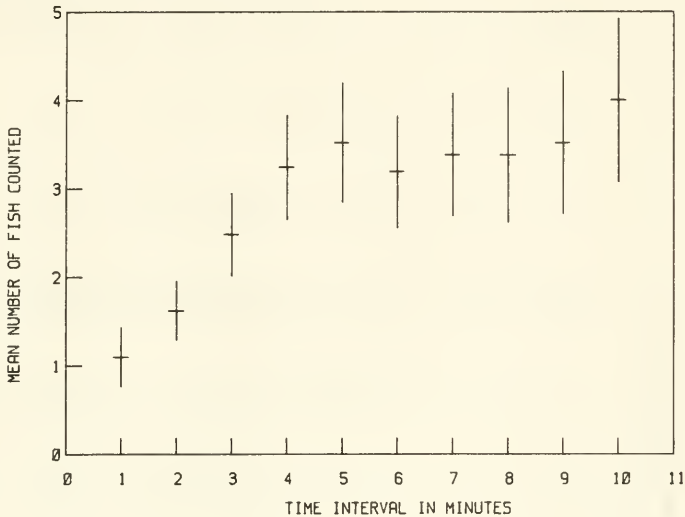
FIGURE 2. Mean number (± one standard error) of fishes, all species combined, observed each minute at 21 pre-survey baited stations, Cojo Anchorage, June-July 1980.

Target Species

To test the effectiveness of the baited stations to reflect any changes in abundance, five species were selected from among the ten most frequently observed species (Table 1): rainbow surfperch, *Hypsurus caryi;* kelp bass, *Paralabrax clathratus;* black surfperch, *Embiotoca jacksoni;* onespot fringehead, *Neoclinus uninotatus;* and smooth ronquil, *Rathbunella hypoplecta.* I also selected for testing the total fishes (all species combined) observed at the stations. The results of the fish counts at Station CW60 and at Station CE30 are not included in this report because the final sampling plan was based on observations only on bedrock substrate.

Quarterly distributions of the count-per-station for each of five species, and total fishes, for each study area were tested for normality using the Komogorov-Smirnov goodness of fit test (Sokal and Rholf 1969). The Kruskal-Wallis test (K-W) (Sokal and Rohlf 1969) was used, at a significance level of $p \leq 0.05$, to determine if differences in average counts were significant among study areas and quarters. Dunn's Multiple Comparisons (Dunn 1964) were used to locate the significant differences. An experimental error rate of $p \leq 0.10$ was selected for these tests.

Pearson's correlation (Sokal and Rohlf 1969) was used to test the null hypothesis that there was no correlation between species counts and bottom temperatures recorded at each observation site.

Kendall's correlation coefficient (Sokal and Rohlf 1969) was used to test the null hypothesis that there was no correlation between the counts of two species at an observation site.

TABLE 1. Fishes Observed at Baited Stations by Divers, Cojo Anchorage, October 1980 through June 1981.

Species*	Study Areas											
	**Sum	T60 Mean	%fo	Sum	T30 Mean	%fo	Sum	CE60 Mean	%fo	Sum	CW30 Mean	%fo
Scyliorhinidae												
Cephaloscylium ventriosum	1	0.01	1.4	0			0			1	0.01	1.3
Squatinidae												
Squatina californica	3	0.04	2.8	0			0			1	0.01	1.3
Myliobatididae												
Myliobatis californica	0			0			1	0.01	1.4	0		
Ophidiidae												
Ophidion scrippsae	0			0			0			1	0.01	1.3
Gasterosteidae												
Aulorhynchus flavidus	0			0			26	0.37	2.8	3	0.04	2.5
Syngnathidae												
Syngnathus spp.	1	0.01	1.4	0			0			0		
Serranidae												
Paralabrax clathratus	56	0.80	22.8	130	1.34	43.3	144	2.03	50.7	44	0.56	30.4
Embiotocidae												
Cymatogaster aggregata	1	0.01	1.4	0			0			0		
Embiotoca jacksoni	25	0.36	11.4	96	0.99	30.0	139	1.96	50.7	65	0.82	38.0
Embiotoca lateralis	1	0.01	1.4	3	0.03	3.1	3	0.04	1.4	0		
Hypsurus caryi	78	1.11	18.6	216	2.23	32.0	356	5.01	56.3	91	1.15	32.9
Phanerodon furcatus	14	0.20	11.4	24	0.25	13.4	65	0.92	36.6	0		
Rhacochilus toxotes	2	0.03	2.8	8	0.08	4.1	7	0.10	8.4	1	0.01	1.3
Rhacochilus vacca	20	0.28	11.4	29	0.30	4.1	55	0.77	32.4	8	0.10	7.6
Labridae												
Oxyjulis californica	31	0.44	7.1	5	0.05	4.1	53	0.75	16.9	96	1.22	19.0
Semicossyphus pulcher	1	0.01	1.4	10	0.10	9.3	1	0.01	1.4	0		
Bathymasteridae												
Rathbunnela hypoplecta	49	0.70	47.1	42	0.43	30.9	31	0.44	28.2	9	0.11	10.1
Clinidae												
Gibbonsia spp.	0			0			0			1	0.01	1.3
Neoclinus blanchardi	7	0.10	4.3	0			0			0		
Neoclinus stephensae	1	0.01	1.4	19	0.20	13.4	4	0.06	5.6	37	0.47	27.8
Neoclinus uninotatus	23	0.33	22.8	43	0.44	30.0	22	0.31	22.5	67	0.85	39.2
Stichaeidae												
Anoplarchus purpurescens	0			0			0			1	0.01	1.3
Pholididae												
Ulvicola sanctaerosae	0			0			1	0.01	1.4	0		
Gobiidae												
Coryphopterus nicholsi	61	0.87	34.3	14	0.14	11.3	8	0.11	8.4	42	0.53	30.4

TABLE 1. (cont)

| | | | | | | | Study Areas | | | | | |
Species*	**Sum	T60 Mean	%fo	Sum	T30 Mean	%fo	Sum	CE60 Mean	%fo	Sum	CW30 Mean	%fo
Scorpaenidae												
Sebastes atrovirens	0			0			1	·	1.4	2	0.02	1.3
Sebastes auriculatus	0			7	0.07	6.2	2	0.03	2.8	0		
Sebastes carnatus	2	0.03	1.4	0			0			1	0.01	1.3
Sebastes caurinus	1	0.01	1.4	1	0.01	1.0	4	0.06	4.2	0		
Sebastes chrysomelas	0			2	0.02	2.1	1	0.01	1.4	0		
Sebastes mystinus	0			0			1	0.01	1.4	0		
Sebastes serranoides	0			0			1	0.01	1.4	3	0.04	2.5
Sebastes spp., juveniles	1	0.01	1.4	0			3	0.04	4.2	2	0.02	2.5
Hexagrammidae												
Hexagrammos decagrammus	1	0.01	1.4	1	0.01	1.0	2	0.03	2.8	0		
Ophiodon elongatus	0			1	0.01	1.0	2	0.03	2.8	0		
Oxylebius pictus	7	0.10	8.6	10	0.10	9.3	3	0.04	4.2	11	0.14	12.6
Agonidae												
Odontopyxis trispinosa	0			0			0			1	0.01	1.3
Cottidae												
Artedius corallinus	1	0.01	1.4	1	0.01	1.0	0			1	0.01	1.3
Artedius notospilotus	2	0.03	2.8	0			3	0.04	4.2	2	0.02	2.5
Enophrys taurina	0			0			0			0		
Icelinus filamentosus	1	0.01	1.4	0			0			0		
Leptocottus armatus	0			1	0.01	1.0	0			0		
Leiocottus hirundo	0			0			1	0.01	1.4	1	0.01	1.3
Orthonopias triacis	15	0.21	14.3	23	0.24	13.4	37	0.52	29.6	29	0.37	27.8
Bothidae												
Citharichthys spp.	134	1.91	41.4	21	0.22	14.4	19	0.27	16.9	64	0.81	44.3
Citharichthys sordidus	22	0.31	7.1	0			0			0		
Xystreurys liolepis	1	0.01	1.4	0			0			0		
Pleuronectidae												
Pleuronichthys coenosus	0			1	0.01	1.0	0			0		
Pleuronichthys decurrens	0			0			1	0.01	1.4	0		
Unidentified Fishes ***	1	0.01	1.4	0			1	0.01	1.4	1	0.01	1.3
Totals	564	8.06		708	7.30		998	14.06		587	7.43	
Total Stations	70			97			71			79		

* Sequence follows Robins et al., 1980
** Sum = Total of each species observed
*** Fishes that could not be identified at least to genus.
Mean = Mean count per station.
%fo = Percent frequency of occurrence.

Means and standard errors are used in the graphs (Figure 3-8) to show changes in abundance.

The Mann-Whitney test (Sokal and Rohlf 1969) was used to test the null hypothesis that there was no difference between the shallow stations (T30 and CW30) with the deep stations (T60 and CE60) for each species to see if depth was a factor in the differences in abundance between stations.

RESULTS

A total of 317 visual fish counts was completed at the four bedrock study areas (T60, T30, CE60, and CE30). Forty-seven species were identified, of which four could only be taken to genus (Table 1).

Fishes that occurred on or near the bedrock included swell shark, *Cephaloscyllium ventriosum*; smooth ronquil, *Rathbunella hypoplecta*; flatfishes, Bothidae and Pleuronectidae; fringeheads, *Neoclinus* spp.; sculpins, Cottidae; surfperches, Embiotocidae; greenlings, Hexagrammidae; wrasses, Labridae; and kelp bass, *Paralabrax clathratus*. The sandy areas were frequented by California lizardfish, *Synodus lucioceps*; midshipmen, *Porichthys* spp.; Pacific angel shark, *Squatina californica*; and flatfishes. The highest number of species was observed at study area CE60 (Table 1). The most frequently observed species at each of the four study areas were: the smooth ronquil at T60, kelp bass at T30, sanddabs at CW30, and rainbow surfperch at CE60. Only a few rockfishes were observed at any of the study areas.

The results of the Kolmogorov-Smirnov tests of the counts were significantly different from normal and non-parametric tests were then used to analyze the data.

Comparison of Counts Among Seasons

The Kruskal-Wallis test for the four sampling periods (seasons) showed significant differences of counts for the following species: rainbow surfperch (at study areas T30, CE60, and CW30), kelp bass (T30, CE60, and CW30), black surfperch (T30, CE60, and CW30) (Table 2). Generally these three species were most abundant during summer or fall sampling periods (Figures 3, 4, and 5). Onespot fringehead showed a different trend, these cryptic fish were more abundant during the winter sampling period (Figure 6); differences in counts were significant only at T30 (Table 2). Counts of smooth ronquil did not produce any significant differences between sampling periods (Table 2, Figure 7). When the comparisons of total fish counts at each study area were made the seasonal differences between these total fish counts were significant at all of the study areas (Table 2, Figure 8).

Dunn's Multiple Comparisons indicated where significant seasonal differences occurred between sampling periods. These differences occurred at all four study areas between combinations of summer/winter or spring and fall/winter or spring (Table 3).
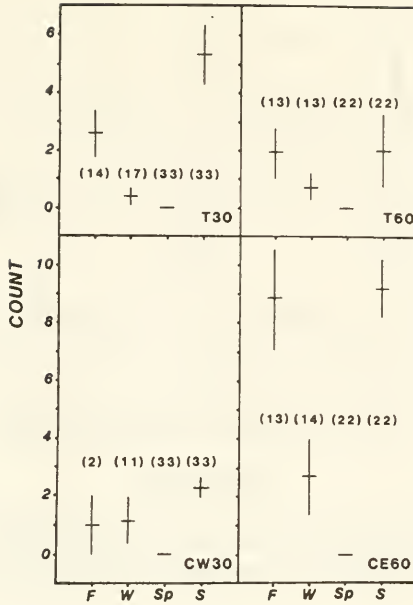
FIGURE 3. Mean counts per station (one standard error) for rainbow surfperch observed by divers at baited stations, Cojo Anchorage, October 1980 to June 1981, (N) = number of stations.
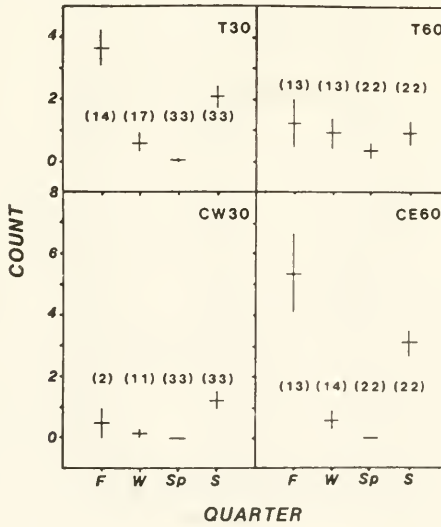
FIGURE 4. Mean counts per station (± one standard error) of kelp bass observed by divers at baited stations, Cojo Anchorage, October 1980 to June 1981, (N) = number of stations.
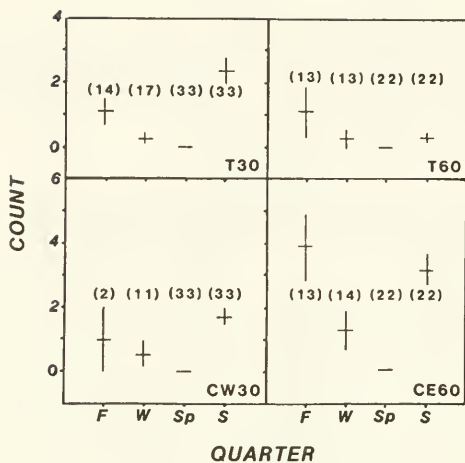
FIGURE 5.   Mean counts per station (± one standard error) of black surfperch observed by divers at baited stations, Cojo Anchorage, October 1980 to June 1981, (N) = number of stations.
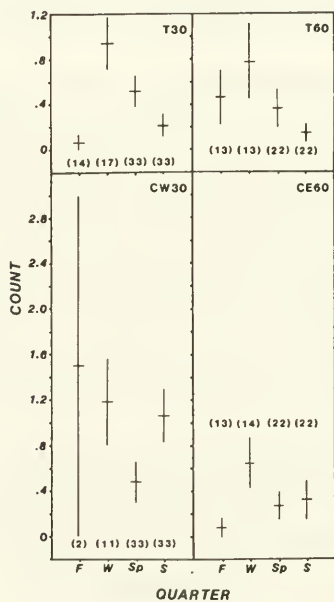
FIGURE 6.   Mean counts per stations (± one standard error) of onespot fringehead observed by divers at baited stations, Cojo Anchorage, October 1980 to June 1981, (N) = number of stations.
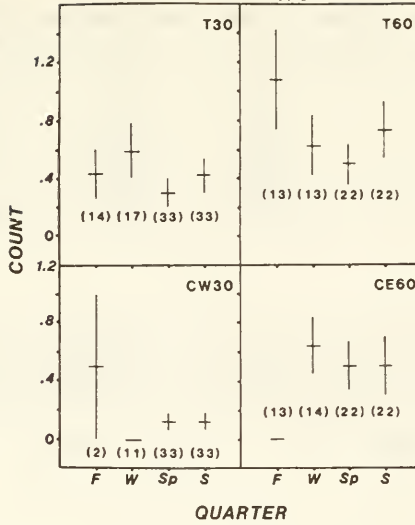
FIGURE 7. Mean counts per station (± one standard error) of smooth ronquil observed by divers at baited stations, Cojo Anchorage, October 1980 to June 1981, (N) = number of stations.
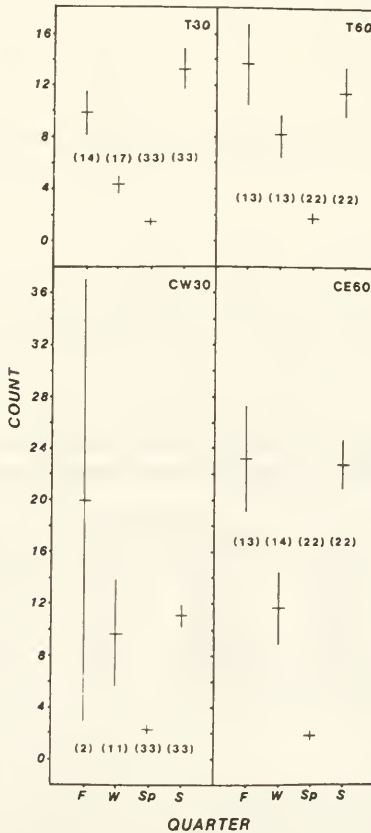
FIGURE 8. Mean counts per station (± one standard error) of total fishes observed by divers at baited stations, Cojo Anchorage, October 1980 to June 1981, (N) = number stations.

TABLE 2. Significance Levels of Kruskal-Wallis Tests of Comparisons of Quarterly Counts Per Station of Fishes at Each Study Area, Cojo Anchorage, October 1980 to June 1981.

Species	T60	T30	CE60	CW30
Rainbow surfperch	0.053	< 0.001 *	< 0.001 *	< 0.001 *
Kelp bass	0.340	< 0.001 *	< 0.001 *	< 0.001 *
Black surfperch	0.135	< 0.001 *	< 0.001 *	< 0.001 *
Onespot fringehead	0.294	0.001 *	0.074	0.152
Smooth ronquil	0.574	0.589	0.051	0.226
Total fishes	< 0.001 *	< 0.001 *	< 0.0001 *	< 0.001 *

* Significant at $p \leq 0.05$

TABLE 3. Dunn's Multiple Comparison Values for Tests of Diver Fish Counts Between Sampling Periods, (for six combinations), Cojo Anchorage, October 1980 to June 1981.

Sampling Period Combinations	Rainbow Surfperch	Kelp Bass	Black Surfperch	Onespot Fringehead	Smooth Ronquil	Total Fishes
T30						
Summer/Fall	–	–	–	–	–	–
Summer/Winter	+ *	–	+ *	+ *	–	+ *
Summer/Spring	+ *	+ *	+ *	–	–	+ *
Fall/Winter	–	+ *	–	+ *	–	–
Fall/Spring	+ *	+ *	+ *	–	–	+ *
Winter/Spring	–	–	–	–	–	+ *
T60						
Summer/Fall	–	–	–	–	–	–
Summer/Winter	–	–	–	–	–	–
Summer/Spring	–	–	–	–	–	–
Fall/Winter	–	–	–	–	–	–
Fall/Spring	–	–	–	–	–	+ *
Winter/Spring	–	–	–	–	–	+ *
CW30						
Summer/Fall	–	–	–	–	–	–
Summer/Winter	–	+ *	+ *	–	–	–
Summer/Spring	+ *	+ *	+ *	–	–	–
Fall/Winter	–	–	–	–	–	–
Fall/Spring	–	–	–	–	–	–
Winter/Spring	–	–	–	–	–	–
CE60						
Summer/Fall	–	–	–	–	–	–
Summer/Winter	+ *	+ *	+ *	–	–	–
Summer/Spring	+ *	+ *	+ *	–	–	+ *
Fall/Winter	+ *	+ *	+ *	–	–	–
Fall/Spring	+ *	+ *	+ *	–	–	+ *
Winter/Spring	–	–	–	–	–	+ *

* Positive signs indicate significant differences $(p \leq 0.10)$

TABLE 4. Significance Levels of Kruskal-Wallis Tests of Comparisons Between Study Areas, of Counts Per Station of Fishes, Cojo Anchorage, October 1980 to June 1981.

Species	QUARTER				All Quarters Combined
	Fall	Winter	Spring	Summer	
Rainbow surfperch	0.004 *	0.209	no fish	0.001 *	0.001 *
Kelp bass	0.001 *	0.779	0.176	0.001 *	0.001 *
Black surfperch	0.001 *	0.430	0.535	0.001 *	0.001 *
Onespot fringehead	0.130	0.607	0.635	0.002 *	0.026 *
Smooth ronquil	0.010 *	0.058	0.062	0.033 *	0.001 *
Total fishes	0.026 *	0.157	0.307	0.001 *	0.002 *

* Significant at $p \leq 0.05$

Comparison of Counts Between Study Areas

Significant differences in counts occurred between study areas for rainbow surfperch, kelp bass, black surfperch, smooth ronquil, and total fishes during the fall (Table 4). There were no significant differences between study areas for any of the tested species during the winter and spring. Conversely, all of the tested species showed significant differences in counts for the summer sampling period and for all sampling periods combined. Most of these differences for the all seasons combined data were between T30 and CE 60, T60 and CE 60, and CW30 and CE 60 (Table 5).

TABLE 5.   Dunn's Multiple Comparison Values for Tests of Diver Fish Counts Between Study Areas (for six combinations). All Sampling Periods Combined, Cojo Anchorage, October 1980 to June 1981.

Study Areas	Rainbow Surfperch	Kelp Bass	Black Surfperch	Onespot ** Fringehead	Smooth Ronquil	Total Fish
T30/T60	−	−	−	−	−	−
T30/CW30	−	−	−	−	+ *	−
T30/CE60	+ *	−	+ *	−	−	+ *
T60/CW30	−	−	+ *	−	+ *	−
T60/CE60	+ *	+ *	+ *	−	−	+ *
CW30/CE60	+ *	+ *	−	−	−	+ *

* Positive values indicate significant differences ($p \leq 0.10$).
** Pairwise differences were not significant because of the experimental error rate although overall comparisons was significant (TABLE 4).

DISCUSSION

A baited station can be visualized as a trap with a diameter of 2 m and a height of 1 m. This trap allows unlimited access by fishes to the bait and allows the diver to record those species that might not have been able to find the entrance to a conventional trap or those that were able to escape.

The successful use of CPUE (relative abundance) data for calculating population size assumes that the catchability does not change due to seasonal changes in abundance or the fishes' behavior, and there is no difference in individual vulnerability (Ricker 1975). Recruitment, natural mortality, immigration and emigration can also introduce error into population estimates that use CPUE data. The purpose of this study was to determine if CPUE data from baited stations would show seasonal changes in abundances and differences in abundance due to depth and habitat type.

CPUE from trap data have been used to determine changes in abundances of a number of marine species (e.g., Dungeness crab, *Cancer magister*, Gotshall 1978). Baited traps have also been used extensively on land to sample insects for population estimates (Southwood 1966).

It was assumed that individuals of each species of fish that would be attracted to the baited stations would be attracted at some constant rate that reflected their abundance in the study area. It is implied in the use of baited stations that not all species of fishes in the study area would be attracted to the bait.

Differences Among Seasons

All but one of the species (smooth ronquil) tested showed significant differences in mean counts among the four seasons. In all cases, except for the onespot fringehead, the lowest counts occurred during the spring quarter. It is assumed that there was no difference in the attractiveness of the bait during the four seasons and that the numbers of fishes that visited the observation site represented their true abundance in the study area. Based on our counts at the baited stations and observations during dives in the study area it was concluded that some of the fish tested left the study area during late winter and spring. Unfortunately, I have only one year of observations, so I cannot say whether this apparent decline in abundance is an annual event. However, similar reductions in abundance of kelp bass, rainbow surfperch, and other kelp bed fishes during winter and spring months were observed by Miller and Geibel (1973). Laur and Ebeling (1983), consider rainbow surfperch as "transients" at their study area at Naples Reef off Santa Barbara; these surfperch arrive in late spring and depart in the fall. The movement out of the study area may be due to several factors. Kelp bass tagging studies showed that at least some of these fish moved away from the tagging site; 3% of 410 recovered tagged kelp bass moved five or more miles and 5% moved up to four miles from the original tagging site (Collyer and Young 1953). Kelp bass spawn from late spring into late summer (Frey 1971) and their movement may be associated with spawning activity. The shallow waters of the Cojo Anchorage area became very turbid during periods of winter and spring storms; this turbidity may have affected either the food supply or the ability of some fishes to obtain food and forced them to move offshore.

Both black surfperch and rainbow surfperch are viviparous; the young are born during late summer and early fall (Behrens 1977). Dave Behrens (PG&E, Avila Beach, pers. comm.) speculates that mating probably occurs during late fall. Behrens (1977) also noted that rainbow surfperch moved out of his study area (Half Moon Bay, central California) in October and November. Thus, the movement of these two species could be related to mating and/or pregnancy and birth. Onespot fringehead showed a different pattern, their greatest abundance occurred during the winter quarter (except at CE30). John Stephens (Occidental College, pers. comm.) has observed similar movements of this species in the Redondo Beach area. Studies in Monterey Bay (Lindquist 1981) indicated a spawning season for onespot fringehead from January to September. Thus, onespot fringehead at Cojo Anchorage may move into deeper water during the spawning season (Figure 6).

Changes in temperature may act as a signal to fishes indicating arrival of spawning season or poor feeding conditions in inshore waters. The Pearson's correlation test yielded significant p values (≤ 0.05) for rainbow surfperch, kelp bass, black surfperch, and total fishes. Temperature accounted for 23% of the variation in counts for rainbow surfperch, 30% for kelp bass, 24% for black surfperch and 36% for total fishes. From these results, I conclude that temperature probably is not a major factor influencing movements of those fishes that were tested.

It was also thought that predatory fishes might inhibit smaller species from entering the baited stations. Significant Kendall's correlation coefficients ($p \leq 0.05$) were obtained between rainbow surfperch and kelp bass, black surfperch and kelp bass, and rainbow surfperch and onespot fringehead, however the r values were all less than 0.30. Thus, there is little evidence that the presence of kelp bass inhibits that of adults of small species. It is more likely that microhabitat selection of kelp bass and black and rainbow surfperches is similar. A positive correlation may also reflect the greater mobility of these relatively large species. Negative correlation between rainbow surfperch and onespot fringehead probably reflects the latter species microphabitat preference of flat bedrock containing pholad clam holes.

The smooth ronquil showed some differences in relative abundance at all the stations but none were significant. Based on these data, I believe that this specifies is a permanent resident of the area.

Differences Among Stations

The significant differences in abundance of species between the four stations may reflect the difference in microhabitat of each of the stations. For example, kelp bass were most abundant at T30 and CE60, (both of these areas contained medium profile reefs, 0.5–1.0 m), while T60 and CW30 were almost devoid of any type of reef structure. Both rainbow surfperch and black surfperch were most abundant at CE60 and T30 and the presence of medium profile reefs may also have been responsible for their abundance at these two study areas. Onespot fringehead were most abundant at CE30 (apparently the bedrock substrate here provided more pholad holes for them to live in). The fact that smooth ronquils were most abundant at T60 probably is due to their preferring deeper water. The presence of medium profile reefs at CE60 may account for the larger number of fishes being counted at this study area.

The comparison between shallow stations and deep stations for each species was significant for onespot fringehead, smooth ronquil, and total fishes. This significant difference in mean counts between depths for onespot fringehead and smooth ronquil may be a reflection of microhabitat as well as depth differences. The significant difference obtained for total fishes probably is due to microhabitat selectivity as well as a depth range preference by some species.

There is little doubt that some species are attracted to divers or bait. In previous studies at Cojo Anchorage (R. Dixon, Calif. Dept. Fish and Game, unpublished data), we tried using a method where two divers descended to a certain spot and counted all fishes that they could observe around them for a period of five minutes. This method was dropped because not enough fishes were attracted to the divers.

CONCLUSIONS

The use of baited stations to obtain CPUE data on those fishes attracted to bait has been shown to have both advantages and disadvantages. Based on our initial tests of baited stations, before this present study was begun, we knew that there would be difficulty in counting large numbers of fishes (e.g., señorita, *Oxyjulis californica*) during each one-minute time period. Thus making it very difficult in

keeping track of individual fish as they entered and left the observation site during the entire ten-minute count. We also knew that the method could not be used to calculate population numbers for a particular species unless the fishes attracted to the station were killed or removed from the population. In order to make such an estimate the exact area influenced by the bait for each species would also have to be determined.

Factors that might cause variations in baited station counts include:
(i)   the time of day the stations are occupied;
(ii) the length of time between when the bait is set and the divers begin counting;
(iii) strength and direction of currents;
(iv) differences in the gear divers use, i.e., colors, regulator type; etc., and
(v)   increased response to baited station, particularly if the fish were able to obtain some of the bait from the baited canister.

The initial tests suggested several advantages, including: (i) the method allows divers to complete more stations in a small area during a working day than swimming transects (a pair of divers can complete two to three stations in the same area covered by a transect per dive, thus increasing the number of samples to be used for statistical analysis), (ii) the baited station functions as a fish trap and has the advantage over an actual trap in that all fishes attracted within the boundaries of the station are "captured" by observation of the diver (standard fish traps only capture those fishes that enter the trap and do not escape), (iii) this method reduces the bias of how much time divers swimming a transect spend looking for midwater, demersal, or cryptic fishes, (iv) divers are able to concentrate on counting fish rather than being distracted by the efforts of swimming along a transect, particularly during periods of surge or low visibility, and (v) the baited stations attract some cryptic species that might be missed by divers swimming a transect line.

I believe that the results of this study show that baited stations offer a standardized, controlled, and repeatable method of obtaining CPUE data for fishes attracted to baited stations. The method provides good quantification for the species tested and is operationally simple. Individuals of each species probably respond to the bait at different rates. If this response rate does not fluctuate significantly during the year, then the CPUE data reflect the relative abundance for that species. In order to obtain relative abundance data on fishes not attracted to baited stations, one would have to use some other method.

The data from this study showed that there were significant differences in seasonal abundances for kelp bass, rainbow surfperch, and onespot fringehead. Other studies in central and southern California have shown similar changes in seasonal abundance. The comparison of counts among study areas indicated significant differences that reflect the well accepted concept that high profile reefs support a more diverse and abundant fish fauna. Future baited station studies could consider using a mean of the ten one-minute counts of each species or the maximum one minute count for statistical calculations. Gary Davis (National Park Service, pers. comm). recently has used maximum one minute counts for statistical analysis of baited station data collected from the Channel Islands National Park. Separate studies could be conducted to determine which bait or combination of baits will work best in a particular area and for particular species.

It would also be useful to test the area influenced by a particular bait for each species and the best time of day to conduct sampling.

The data indicate that the shallow waters of Cojo Anchorage support a wide diversity of fishes, but in most cases the species observed in the study area were not very abundant. The abundances of several species changed seasonally. Habitats in the four study areas were probably responsible for the significant differences in CPUE between the study areas for four of the species tested.

ACKNOWLEDGMENTS

LITERATURE CITED

Behrens, D. W. 1977. Fecundity and reproduction of the viviparous perches *Hypsurus caryi* (Agassiz) and *Embiotoca jacksoni* (Agassiz). Calif. Fish and Game 63(4): 234–252.

Collyer, R. D. and P. H. Young. 1953. Progress report on a study of the kelp bass, *Paralabrax clathratus*. Calif. Fish and Game 39(2): 191–208.

Dunn, O. J. 1964. Multiple comparisons using rank sums. Technometrics (6): 241–254.

Ebeling, A. W., R. J. Larson, W. S. Alevision, and R. N. Bray. 1980. Annual variability of reef-fish assemblages in kelp forests off Santa Barbara, California. Fishery Bull. 78(2): 361–377.

Frey, H. W. 1971. California's living marine resources and their utilization. Calif. Dept. Fish and Game, Sacramento, 148 p.

Gotshall, D. W. 1978. Catch-per-unit-of-effort studies of northern California Dungeness crabs, *Cancer magister*. Calif. Fish and Game. 64(3): 189–199.

Jones, R. S. and M. J. Thompson. 1978. Comparison of Florida reef fish assemblages using a rapid visual technique. Bull. Mar. Sci. 28(1): 159–172.

Laur, D. R. and A. W. Ebeling. 1983. Predator-prey relationships in surfperches. Env. Biol. Fish. 8(3/4): 217–229.

Lindquist, D. G. 1981. Reproduction of the onespot fringehead, *Neoclinus uninotatus* in Monterey Harbor, California. Bull. Calif. Acad. Sci. 80(1): 12–22.

Miller, D. J. and J. J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; a reef ecology study: and giant kelp *Macrocystis pyrifera*, experiments in Monterey Bay, California. Calif. Dept. of Fish and Game, Fish. Bull. 158: 137 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Dept. of the Environment Fisheries and Marine Service. Bull. 191: 382 p.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. The principles and practices of statistics in biological research. W. H. Freeman and Co. San Francisco, CA., 776 p.

Southwood, T.R.E. 1966. Ecological Methods with Particular Reference to the Study of Insect Populations. Methuen and Co. Ltd. London. 391 p.

SURVIVAL AND RECOVERY RATE ESTIMATES OF NORTHERN PINTAIL BANDED IN CALIFORNIA, 1948–79[1]

WARREN C. RIENECKER
California Department of Fish and Game
1416 Ninth Street
Sacramento, CA 95814

Estimates of survival and recovery of northern pintail, *Anas acuta*, banded preseason (N=168,763) and postseason (N=59,165) at seven stations in California were analyzed. Postseason banded pintails followed the same pattern of survival rate estimates as those from preseason bandings. Adults had higher survival and lower recovery rate estimates than did immatures. Adult males had higher survival and recovery rate estimates than did adult females. Pintails banded in Imperial Valley have lower survival rates than those banded in northern California.

INTRODUCTION

Most survival studies in the past two decades have been done on the mallard, *Anas platyrhynchos*, whereas only one (Anderson and Sterling 1974) has been compiled on the northern pintail. Based on wintering population and total harvest, northern pintail are the most important species of waterfowl in California (Pacific Flyway midwinter waterfowl surveys, USFWS waterfowl parts collection surveys). An average of 2 million migrate there annually from northern breeding grounds, accounting for approximately half of the total ducks wintering in California (Bellrose 1976). About 56% of the U.S. harvest of pintails occurs in the Pacific Flyway of which over half takes place in California (USFWS waterfowl parts collection surveys). Females are harvested closer to the breeding grounds and show a greater homing instinct to the area of banding than do males (Reinecker 1987). Males tend to range wider and are more likely to be recovered in Mexico, Central America or on one of the other flyways than are females.

The purpose of this report is to examine and compare survival and recovery rate estimates for pintail banded at seven stations in California (Figure 1).

METHODS

A total of 245,174 northern pintail was banded in California from 1948 to 1979. Of these, 227,928 were used to determine survival and band recovery rate estimates for the major banding stations (Table 1). In the 1950's and 1960's pintail were banded on many waterfowl concentration areas in California. Some of these bandings were exploratory and lasted only a year or two. On the more important areas, banding was nearly continuous through the 1950's. Thereafter, only Klamath Basin NWRs and Gray Lodge Wildlife Area were used as banding stations. All pintails to be banded were caught in baited, wire, swim-in traps or on baited cannon net sites. Traps were checked daily, caught pintail were banded with standard FWS aluminum leg bands and released. Only preseason (1 July–30 September, N=168,763) and postseason (16 January–15 March, N=59,165) banded pintails recovered as direct or indirect recoveries through 1979 were used. Direct recoveries are banded birds recovered during the first hunting

---

FIGURE 1.   California pintail banding stations used in determining survival and recovery rate esti-
          mates.

season after banding (Anderson 1975). Indirect recoveries are band recoveries
in subsequent years following the year of banding. All recoveries were wild birds
shot or found dead during the hunting season.

Survival rate is defined as the probability that a bird alive at the approximate
midpoint of the banding period in one year survives until the midpoint of banding
the following year. Recovery rate is defined as the probability that a banded bird
alive at the midpoint of the banding period in one year will be shot or found dead
the following hunting season and the Bird Banding Laboratory notified. It is as-
sumed that band reporting rates do not change during the study period.

Models of recovery data from all banding stations were examined, and the
model that best fit the data was presented by age and sex groups for each banding
station. A Z test (Brownie et al. 1978) was used to test for differences between
survival and recovery rates for different time periods. The level of significance
was $P < 0.05$.

TABLE 1.   Summary of 227,928 Pintails Banded in California from which Survival and Band Recovery Rates Were Estimated.

		PRESEASON				
		Number banded				
Station	Year	AM	IM	AF	IF	Total
Klamath Basin	1948–79	29,922	13,384	3,910	4,915	52,131
Honey Lake	1950–59	5,796	5,466	2,228	4,073	17,563
Gray Lodge	1949–79	15,446	11,824	7,535	9,500	44,305
Suisun	1951–58	3,889	2,798	828	1,200	8,715
So. S.F. Bay	1954–58	1,810	1,377	198	704	4,089
Los Banos	1948–64	9,961	7,891	2,090	4,913	24,855
Imperial Valley	1951–59	4,161	7,078	2,151	3,715	17,105
TOTAL		70,985	49,818	18,940	29,020	168,763
		POSTSEASON				
Gray Lodge	1954–79	15,672		8,607		24,279
Los Banos	1948–58	2,277		1,491		3,768
Imperial Valley	1951–73	17,523		13,595		31,118
TOTAL		35,472		23,693		59,165

RESULTS AND DISCUSSION

Adult and immature female recovery data from the South San Francisco Bay station were insufficient to estimate survival and recovery rates. Also, no reasonable model fit could be obtained for data sets of adult and immature females from the Klamath Basin 1964–1979 and for adult and immature males from the Suisun station. Estimates of parameters on an annual basis are subject to large sampling variances and therefore average survival and recovery rates are presented (Table 2).

Adult males generally had higher survival rates than females. Survival rate estimates for preseason banded adult males ranged between 75.8 ± 8.2% on the South San Francisco Bay station to 64.3 ± 4.0% at Imperial Valley. Survival rate estimates for preseason banded adult females ranged between 65.6 ± 6.3% at Honey Lake to 48.7 ± 7.3% at Imperial Valley. Survival rates for immature pintails also indicate that males generally had higher survival rates than females. Survival rate estimates for immature males ranged between 62.9 ± 7.4% for birds banded at Gray Lodge to 49.5 ± 5.1% from Imperial Valley. Average survival rate estimates for immature females ranged between 69.0 ± 5.0% at Gray Lodge to 36.0 ± 12.3% at Suisun. Fewer immature females were banded than other age and sex classes, resulting in greater variance in survival rate estimates for immature females than other classes. Adult males were banded and recovered in large numbers; thus estimates for them are more precise.

Postseason banded pintail followed the same pattern of survival rates as those from preseason bandings (Table 2). Survival rate estimates for postseason males ranged between 77.0 ± 7.3% at Gray Lodge to 66.0 ± 2.2% at Imperial Valley. Female survival ranged between 65.0 ± 2.6% at Gray Lodge and 50.8 ± 4.6% at Los Banos.

Comparing banding stations, the average survival rate estimates for adult males, adult females and immature males were lowest at Imperial Valley (Table 2). Most pintail banded in the Imperial Valley were from a population separate from those banded in northern California and were more closely linked to the Central and Mississippi flyways (Rienecker 1987). This suggests that pintail outside of the Pacific Flyway may have a lower survival rate. Conversely, Anderson

and Sterling (1974) found no difference in survival of adult male pintail banded in south-central Saskatchewan (1955–1958) and recovered in Texas (69.11%) and California (70.77%). However, their analysis assumed that birds wintering in one area (e.g., Texas) did not shift to other areas (e.g., California) in subsequent years. California bandings showed that some birds used both areas (Rienecker 1987).

Average estimated recovery rates for California banded adult male pintails were 5% compared to 4% for adult females, 9% for immature males and 7% for immature females (Table 2). Recovery rates are an index to harvest rates (Henny and Burnham 1976).

Studies of mallard, American wigeon, *Anas americana,* and ring-necked duck, *Athya collaris,* have also shown that survival and recovery rates of females are lower than those of males (Anderson 1975, Rienecker 1976, Conroy and Eberhardt 1983). The assumption is that females have higher non hunting mortality, particularly during the nesting season, than that of males, thus resulting in the lower survival and recovery rates. Males, in turn, are more intensively harvested and thus have greater band recovery rates. Differential migration (males moving into higher harvest areas earlier than females), hunter selectivity for males and fewer females available to hunters because of predation on the breeding grounds are possible causes for higher band recovery rates of males.

Several factors could contribute to the variation in band recovery rates among the banding stations but differences in hunting pressure, sample size and reporting rate are probably the main causes. Lower band recovery rates from postseason vs. preseason banded birds occur because of the time period between banding and hunting seasons. Postseasons banded birds go through spring migration and breeding before the hunting season starts and thus are subjected to a greater preseason mortality resulting in fewer band recoveries from hunters.

Survival rates are based on the assumption that the same population is banded each year. Many preseason banded birds are only passing through when banded, and several subpopulations are probably banded at the same station during the same period (Rienecker 1987). Thus, preseason banded samples may not provide accurate estimates for specific wintering populations. These data suggest that postseason bandings were more representative of pintails wintering in the vicinity of the banding station and less likely to contain several subpopulations.

The only significant difference between survival rates was for Klamath Basin adult males that had higher survival rates during the 1950's (81%) than during the 1960's (72%, Table 3). Recovery rates for Klamath Basin male pintails were significantly lower during the 1960's (AM 2.7%–IM 6.2%) than during either the 1950's (AM 3.9%–IM 10.0%) or the 1970's (AM 3.7%–IM 7.8%). For all age and sex classes banded both preseason and postseason at Gray Lodge, the only significant difference was a higher immature male recovery rate in the 1950's (8.9%) than in the 1960's (7.0%).

Mixing of subpopulations of pintails on the wintering grounds make management by subpopulations difficult. The problem with managing several subpopulations as a unit is that they could have varying harvest rates and/or nonhunting mortality rates. While one subpopulation might be able to sustain an increase in harvest, others might not. Thus, special management measures on wintering populations would have to be formulated cautiously.

TABLE 2. Average Survival and Recovery Rate Estimates for California Pintail Banding and Recovery Data.

Banding station	Banding period	Years	Age-sex Model	class	Survival Rate		Recovery Rate [*]	
					S	$SE(S)$	f	$SE(f)$
Klamath Basin	Preseason	1948–63	H2	AM	0.750	0.020	0.035	0.002
Klamath Basin	Preseason	1964–79	H02	AM	0.749	0.009	0.034	0.001
Honey Lake	Preseason	1950–58	H1	AM	0.699	0.030	0.046	0.002
Gray Lodge	Preseason	1949–63	H1	AM	0.721	0.033	0.038	0.002
Gray Lodge	Preseason	1964–79	H1	AM	0.724	0.015	0.039	0.002
South S.F. Bay	Preseason	1955–58	H2	AM	0.758	0.082	0.089	0.008
Los Banos	Preseason	1950–61	H2	AM	0.716	0.019	0.056	0.003
Imperial Valley	Preseason	1951–59	H2	AM	0.643	0.040	0.050	0.004
Klamath Basin	Preseason	1948–63	H02	AF	0.597	0.025	0.025	0.003
Honey Lake	Preseason	1950–58	H1	AF	0.656	0.063	0.038	0.004
Gray Lodge	Preseason	1949–63	H02	AF	0.590	0.014	0.028	0.002
Gray Lodge	Preseason	1964–79	H02	AF	0.639	0.028	0.024	0.003
Suisun	Preseason	1951–55	H1	AF	0.619	0.225	0.069	0.008
Los Banos	Preseason	1950–61	H02	AF	0.612	0.022	0.044	0.004
Imperial Valley	Preseason	1951–59	H2	AF	0.487	0.073	0.051	0.006
Klamath Basin	Preseason	1948–63	H2	IM	0.597	0.040	0.086	0.004
Klamath Basin	Preseason	1964–79	H02	IM	0.561	0.038	0.073	0.005
Honey Lake	Preseason	1950–58	H1	IM	0.509	0.039	0.090	0.004
Gray Lodge	Preseason	1949–63	H1	IM	0.595	0.061	0.080	0.005
Gray Lodge	Preseason	1964–79	H1	IM	0.629	0.074	0.080	0.006
South S.F. Bay	Preseason	1955–58	H2	IM	0.615	0.105	0.148	0.010
Los Banos	Preseason	1950–61	H2	IM	0.509	0.042	0.076	0.005
Imperial Valley	Preseason	1951–59	H2	IM	0.495	0.051	0.065	0.004

Klamath Basin	Preseason	1948–63	H02	IF	0.468	0.061	0.054	0.006
Honey Lake	Preseason	1950–58	H1	IF	0.472	0.058	0.074	0.005
Gray Lodge	Preseason	1949–63	H02	IF	0.690	0.050	0.052	0.006
Gray Lodge	Preseason	1964–79	H02	IF	0.609	0.100	0.060	0.008
Suisun	Preseason	1951–55	H1	IF	0.360	0.123	0.096	0.010
Los Banos	Preseason	1950–61	H02	IF	0.422	0.042	0.075	0.006
Imperial Valley	Preseason	1951–59	H2	IF	0.529	0.101	0.062	0.005
Gray Lodge	Postseason	1954–68	M2	AM	0.726	0.014	0.031	0.002
Gray Lodge	Postseason	1971–79	M0	AM	0.770	0.073	0.039	0.003
Los Banos	Postseason	1952–56	M3	AM	0.666	0.049	0.050	0.005
Imperial Valley	Postseason	1954–70	M1	AM	0.660	0.022	0.034	0.001
Gray Lodge	Postseason	1954–68	M2	AF	0.650	0.026	0.020	0.002
Gray Lodge	Postseason	1971–79	M2	AF	0.637	0.038	0.020	0.002
Los Banos	Postseason	1952–56	M3	AF	0.508	0.046	0.037	0.005
Imperial Valley	Postseason	1952–61	M1	AF	0.541	0.029	0.024	0.002

* In models (M0, H2) with different parameters for recovery rates of birds during the first vs. subsequent hunting seasons after banding, first-season recovery rate estimates are presented.

TABLE 3. Comparisons of Survival and Recovery Rate Estimates for California Pintails for Different Time Periods.*

Location	Banding period	Age-sex	Periods compared		Survival rate tests				Recovery rate tests			
			A	B	A	B	z	P	A	B	z	P
Klamath Basin	Preseason	AM	1950–59	1960–69	0.81	0.72	2.39	0.02	0.039	0.027	4.38	0.00
		YM	1950–59	1960–69	0.66	0.56	1.31	0.19	0.100	0.062	5.31	0.00
Klamath Basin	Preseason	AM	1960–69	1970–79	0.72	0.76	−1.16	0.24	0.027	0.037	−4.01	0.00
		YM	1960–69	1970–79	0.56	0.63	−0.72	0.47	0.062	0.078	−1.98	0.05
Klamath Basin	Preseason	AM	1950–59	1970–79	0.81	0.76	1.52	0.13	0.039	0.037	0.93	0.35
		YM	1950–59	1970–79	0.66	0.63	0.31	0.76	0.100	0.078	2.84	0.00
Gray Lodge	Preseason	AM	1950–59	1960–69	0.71	0.75	−0.64	0.52	0.039	0.038	0.55	0.58
		YM	1950–59	1960–69	0.63	0.52	1.14	0.25	0.089	0.070	2.03	0.04
Gray Lodge	Preseason	AM	1960–69	1970–79	0.75	0.72	0.69	0.49	0.038	0.039	−0.57	0.57
		YM	1960–69	1970–79	0.52	0.68	−1.14	0.25	0.070	0.081	−1.11	0.27
Gray Lodge	Preseason	AM	1950–59	1970–79	0.71	0.72	−0.06	0.95	0.039	0.039	0.06	0.95
		YM	1950–59	1970–79	0.63	0.68	−0.34	0.73	0.089	0.081	0.80	0.42
Gray Lodge	Preseason	AF	1950–59	1960–69	0.58	0.57	0.09	0.93	0.026	0.024	0.44	0.66
		YF	1950–59	1960–69	0.77	0.64	0.47	0.64	0.056	0.057	−0.10	0.92
Gray Lodge	Preseason	AF	1960–69	1970–79	0.57	0.64	−0.36	0.72	0.024	0.026	−0.034	0.74
		YF	1960–69	1970–79	0.64	0.66	−0.03	0.97	0.057	0.057	0.01	0.99
Gray Lodge	Preseason	AF	1950–59	1970–79	0.58	0.64	−0.33	0.74	0.026	0.026	0.02	0.98
		YF	1950–59	1970–79	0.77	0.66	0.32	0.75	0.056	0.057	−0.10	0.92
Gray Lodge	Postseason	AM	1954–68	1971–79	0.73	0.77	−0.59	0.56	+	+	+	+
Gray Lodge	Postseason	AF	1954–68	1971–79	0.65	0.64	0.28	0.78	+	+	+	+

* Tests based on estimates summarized in Table 2.
+ Recovery rates for postseason-banded birds represent products of survival and harvest rates. They are difficult to interpret and no tests are presented here.

Resumption of pintail banding in California is recommended to monitor survival and recovery rates in addition to monitoring migration and distribution patterns. Banding was terminated in 1979 at a time when the population was trending downward. Biotelemetry of pintail in the Central and Imperial Valleys would improve knowledge of daily and seasonal movements within these Valleys and provide data on the area used by each wintering subpopulation.

ACKNOWLEDGMENTS

LITERATURE CITED

Anderson, D.R. 1975. Population ecology of the mallard: V. Temporal and geographic estimates of survival, recovery and harvest rates. U.S. Dept. Inter., Fish and Wildl. Serv. Resour. Publ. 125. 110 p.

————, and R.T. Sterling. 1974. Population dynamics of molting pintail drakes banded in south-central Saskatchewan. J. Wildl. Manage., 38(2): 266–274.

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, PA. 544 p.

Brownie, C., D.R. Anderson, K.P. Burnham and D.S. Robson. 1978. Statistical inference from band recovery data—a handbook. U.S. Fish and Wildl. Serv., Resour. Publ. 131. 212 p.

Conroy, M.J. and R.T. Eberhardt. 1983. Variation in survival and recovery rates of ring-necked ducks. J. Wildl. Manage., 47: 127–137.

Henny, C.J. and K.P. Burnham. 1976. A mallard reward band study to estimate band reporting rates. J. Wildl. Manage., 40(1): 1–14.

Rienecker, W. C. 1976. Distribution, harvest and survival of American wigeon banded in California. Cal. Fish and Game, 62(2): 141–153.

————. 1987. Migration and distribution of pintails banded in California. Cal. Fish and Game. 73(3): 139–155.

MANAGEMENT OF MIDGES AND OTHER INVERTEBRATES FOR WATERFOWL WINTERING IN CALIFORNIA[1]

NED H. EULISS, JR.[2]
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon 97331

and

GAIL GRODHAUS
California Department of Health Services
Berkeley, California 94704

A review of recent waterfowl food habit studies showed that invertebrates are of major dietary importance to ducks wintering in California. However, current wetland practices are directed at production of plant foods and seldom consider the propagation of invertebrates. We suggest that invertebrate repopulation of seasonally flooded marshes will occur more rapidly if an inoculum of invertebrates is provided via small ponds flooded several weeks before general marsh flooding in fall. Managers will require considerably more information before management of aquatic invertebrates can be fully developed.

INTRODUCTION

Invertebrates, principally midge larvae (Chironomidae) are important waterfowl foods during the breeding season (Bartonek 1972, Krapu 1974, Landers et al. 1977, Reinecke and Owen 1980, Sugden 1973, Swanson and Bartonek 1970, Swanson et al. 1977). It is less well known that northern pintails, *Anas acuta acuta*, mallards, *A. platyrhynchos*, and green-winged teal, *A. crecca carolinensis*, consume significant amounts of midge larvae and other invertebrates during the non-breeding period in California (Beam and Gruenhagen 1980, Connelly and Chesemore 1980, Pederson and Pederson 1983, Euliss and Harris 1987, Miller 1987). Consequently, it may be desirable to increase invertebrate production in California marshes as a means of raising the carrying capacity of wetlands for waterfowl. This is especially important because of continued wetland losses (Tiner 1984) and the need to manage remaining wetlands more efficiently (Bellrose and Low 1978). Although midges and other invertebrates have been the subject of many studies, the management of midge populations for waterfowl has received little attention.

The objectives of this paper are to assess the potential of managing invertebrates for waterfowl, to summarize the pertinent literature, and to offer preliminary suggestions for wetland management designed to increase production of invertebrates in seasonally flooded and permanently flooded marshes in California's Central Valley. Additionally, general midge ecology, vegetative substrates that are suitable for invertebrate colonization, and human health considerations are discussed. Lastly, "brood-stock ponds" (BSP's) are introduced as a conceptual method that managers may use to increase repopulation rates of aquatic invertebrates in seasonally flooded marshes.

GENERAL ECOLOGY OF MIDGES

Midges and other aquatic invertebrates use a wide range of microhabitats in marshes. Plant substrates, however, offer the best management potential because invertebrates could be produced along with waterfowl food plants. Previous workers have suggested that the abundance and diversity of aquatic invertebrates increase with plant biomass (Krecker 1939, Berg 1949, McGaha 1952, Rosine 1955, Darby 1962, Krull 1970, Magy et al. 1970, Lamberti and Resh 1984). Further, the density and diversity of invertebrate populations fluctuate seasonally and according to plant species and physiological state. With certain exceptions (e.g. obligate benthic forms), most marsh-inhabiting midge larvae are epiphytic and forage mainly on epiphytic algae and metaphyton. Foraging midges can significantly reduce epiphytic algae biomass (Cattaneo 1983) while interfering little with the growth of macrophytes. Structurally complex plants are preferable to simple ones, because the former provide more surface area for colonization of epiphytes and generally harbor greater numbers of midges.

Although midge abundance on specific plants has been studied, relatively few workers have examined the abundance of these insects on common waterfowl food plants. High densities of midge larvae have been observed in stands of sago pondweed, *Potamogeton pectinatus*, horned pondweed, *Zannichellia palustris*, southern naiad, *Najas guadalupensis*, common burhead, *Echinodorus cordifolius*, and common widgeongrass, *Ruppia maritima*, (Gerry 1954, Darby 1962, Magy et al. 1970, Lamberti and Resh 1984, Grodhaus, unpubl. data). Darby (1962) reported that living stands of tule bulrush, *Scirpus acutus*, common cattail, *Typha latifolia*, and common barnyardgrass, *Echinochloa crusgalli*, were relatively unproductive of midges. However, Euliss (1984) observed that midges, *Cricotopus* sp., were abundant in stands of senescent common barnyardgrass. High densities of midge larvae have been reported in decomposing substrates provided by other plant species (Danell and Sjoberg 1979, Pederson and Pederson 1983).

MANAGEMENT CONSIDERATIONS
General

Wetland managers should develop management plans directed at particular species of midges because some species are much more productive than others. For example, there were at least 7 midge species present on Kern National Wildlife Refuge (NWR), California (Euliss 1984) yet only 4, *Chironomus stigmaterus*, *C. decorus, Cricotopus* sp., and *Apedilum subcinctum*, dominated the midge biomass in waterfowl diets. Similar findings were reported by Pederson and Pederson (1983) on Lower Klamath NWR, California. Therefore, we encourage managers of waterfowl areas to identify local midge populations as a basis from which to develop management efforts.

Surveys to determine general invertebrate community structure in marshes would be profitable. Survey techniques and invertebrate identification keys are included in Usinger (1956), Ward and Whipple (1959), Pennak (1978), and Merritt and Cummins (1984). The keys to genera of Chironomidae in Wiederholm (1983) and Coffman and Ferrington (1984) cover wide geographic areas. Several useful keys to midge species are available which cover specific habitats or geographic areas (Roback 1957, Darby 1962, Grodhaus 1967, Mason 1968, Oliver et al. 1978, Simpson and Bode 1980).

Seasonally Flooded Marshes

In seasonal marshes, the time required for midges to establish populations is extremely variable and unpredictable. The life cycle of most midges includes standing water and freshly laid eggs (Oliver 1971). This suggests that the rate of repopulation in wetlands would depend on the availability of suitable species in nearby wetlands at the time of flooding. In seasonal marshes, repopulation is a passive process in which viable midge eggs and larvae are introduced into freshly flooded marshes via the water used for ponding and/or from adults flying in from surrounding areas. In either case, there may be considerable variation in the species and numbers available to colonize marshes from year to year. Midge eggs or larvae may be present in some water sources but not others. In years of severe drought, wells may be the only water source and the establishment of adequate midge populations may be delayed because this water is free of midges. The availability of midges and other invertebrates in purchased water sources is uncertain. During normal and drought years, wetland basins surrounding seasonal marshes may be dry, and few midges would be available to lay eggs in freshly flooded marshes. In years of above normal precipitation and runoff, midge species available in nearby wetlands may not be well suited to the particular habitats flooded on a waterfowl area or they may be present in insufficient densities to enable rapid repopulation.

As an alternative to the passive repopulation of invertebrates just described, we suggest the use of brood-stock ponds (BSP's) as an active restocking approach. We define BSP's as subunits of main ponds that are flooded 1–2 months before remaining habitats. These ponds should have the same basic vegetative composition as main ponds and they would serve as culturing sites for invertebrates that invade from outside sources. Ideally, BSP's would be established within a main pond that is used to convey water to other ponds of similar vegetative composition. Thus, when remaining habitats are flooded, the invertebrates present in BSP's would be introduced into freshly flooded wetlands. In waterfowl areas that flood a variety of habitat types, we recommend that BSP's be established in each of the habitat types provided. This should allow a more rapid colonization of freshly flooded wetlands than occurs presently because it would provide an inoculum of invertebrates that are specifically adapted to particular vegetative types in managed wetlands.

In California, seasonal marshes are generally flooded during late summer or early fall when water temperatures are high. With the onset of winter, midge development and production of egg-laying adults slows because of lower water temperatures (Oliver 1971). Thus, BSP's may increase the biomass of midge larvae produced in seasonal marshes during the winter because more eggs would be deposited in marshes before the onset of cold weather. The objective of this plan would be to maximize midge biomass in initial generations when water temperatures are favorable. Warm water temperatures (24 C) may allow adult midges to develop from eggs in as little as 2 weeks (Euliss 1984).

Seasonal marshes in California are normally flooded 6–8 months each year. The winter diets of pintails and green-winged teal consist of a substantial proportion of midge larvae about 2 months after the ponds are flooded in the fall (Connelly and Chesemore 1980, Euliss and Harris 1987). This delay is likely caused because midge populations are low initially and available adults are insufficient to saturate the marshes with eggs. Assuming a 6 month period of sea-

sonal inundation, BSP's have the potential to increase the availability of midge larvae over an additional 33% of the wintering period.

Research is needed to evaluate BSP's and to identify specific features of practical importance to wetland managers. Because of the great reproductive potential of midges (Oliver 1971), relatively few adults are required to generate large populations of larvae. Thus, a relatively small area may be required for BSP's, but the exact size relative to seasonal marsh types is uncertain.

Permanently Flooded Marshes

The management of invertebrates in permanent marshes can also provide additional foods for waterfowl. Both nonvegetated (i.e. phytoplankton dominated) and vegetated (i.e. submersed aquatic macrophyte dominated) habitats can be extremely productive of midges and other invertebrates. Most species of submersed waterfowl food plants provide large surface areas for invertebrate colonization. However, the invertebrates present in deep-water marshes may not be highly available to waterfowl. Lowering of water levels to provide numerous shallow areas would concentrate invertebrates and enhance their availability to dabbling ducks. The objective of water level manipulation would be to increase the availability of invertebrates during periods of high waterfowl use and when the nutritional demands of waterfowl for animal foods are high. However, complete drawdowns have detrimental effects on aquatic invertebrates (Kadlec 1962) and a reestablishment period would be required after reflooding.

Permanently flooded marshes often contain abundant fish populations that may include predators on midge larvae. Mosquitofish, *Gambusia affinis*, do not consume significant numbers of midges (Bay and Anderson 1966), but it is likely that most other eurythermal fish prey on chironomid larvae. Threespine stickleback, *Gasterosteus aculeatus*, carp, *Cyprinus carpio*, and goldfish, *Carassius auratus*, are particularly efficient midge predators (Bay and Anderson 1965, Fleming and Schooley 1984) and should be discouraged from permanent marsh impoundments.

HUMAN HEALTH AND NUISANCE CONSIDERATIONS

The goal of wetland managers should be to enhance the productivity and availability of midge larvae and pupae rather than to produce adult insects. As mentioned previously, relatively few adults are required to produce large populations of larvae. There are certain adverse consequences of excessive numbers of adult midges near human activities. The allergenic potential of inhaled fragments (Bauer et al. 1983) and the possibility of highway accidents due to obscured visibility (Mortenson et al. 1967) are important problems, but property defacement is the most frequent unwanted outcome of excessive midge production (Ali 1980).

The most serious insect problem associated with waterfowl management is mosquito production. Plans to enhance populations of midges and other invertebrates on wintering areas in California are not expected to create serious conflicts with mosquito-control interests. Although there is some overlap with the mosquito season during the fall and spring, the management of midges would be conducted mostly during the winter months when mosquito populations are typically low. Moreover, plans to enhance midge production (e.g. BSP's) would not require flooding main ponds any earlier than currently practiced. However,

wetland managers should incorporate sound mosquito-control practices into management programs. Because of the diversity of mosquito species and habitat requirements, we recommend that wetland managers coordinate their efforts with local mosquito abatement districts to minimize mosquito production.

CONCLUSION

The management of midges and other aquatic invertebrates is in its infancy and many aspects of specific strategies have not been developed. However, the potential benefit for wintering waterfowl and other wildlife is great. Considerable innovation by both managers and researchers will be required to develop practical and effective invertebrate management programs. We encourage the various agencies to obtain accurate records of midge and other invertebrate usage of specific plant types and in areas where specific management strategies are practiced. Plans to enhance invertebrate populations appear feasible and results from recent research efforts should enable managers to develop initial plans at a fairly rapid pace.

ACKNOWLEDGMENTS

LITERATURE CITED

Ali, A. 1980. Nuisance chironomids and their control: a review. Bull. Entomol. Soc. Amer. 26:6–16.

Bartonek, J. C. 1972. Summer foods of American widgeon, mallards, and a green-winged teal near Great Slave Lake, N.W.T. Can. Field-Nat. 86:373–376.

Bauer, X., M. Dewair, K. Haegele, H. Prelica, A. Scholl, and H. Tichy. 1983. Common antigenic determinants of hemoglobin: a basis of immunological cross reactivity between chironomid species (Diptera: Chironomidae). Clin. Exp. Immunol. 54:599–607.

Bay, E. C., and L. D. Anderson. 1965. Chironomid control by carp and goldfish. Mosq. News 25:310–316.

———. 1966. Studies with the mosquitofish *Gambusia affinis* as a chironomid control. Ann. Ent. Soc. Am. 59:150–153.

Beam, J., and N. Gruenhagen. 1980. Feeding ecology of pintails (*Anas acuta*) wintering on the Los Banos Wildlife Area, Merced County, California. Calif. Dep. Fish and Game, Fed. Aid Wildl. Restor. Prog. Rep., Proj. W-40-D-1. 23pp.

Bellrose, F. C., and J. B. Low. 1978. Advances in waterfowl management research. Wildl. Soc. Bull. 6:63–72.

Berg, C. O. 1949. Limnological relations of insects to plants of the genus *Potamogeton*. Trans. Am. Microscop. Soc. 68:279–291.

Cattaneo, A. 1983. Grazing on epiphytes. Limnol. Oceanogr. 28:124–132.

Coffman, W. P., and L. C. Ferrington. 1984. Chironomidae. Pages 551–652 *in* R. W. Merritt and K. W. Cummins (eds.), An introduction to aquatic insects of North America. 2nd ed. Kendall Hunt Publ., Dubuque, Iowa.

Connelly, D. P., and D. L. Chesemore. 1980. Food habits of pintails, *Anas acuta*, wintering on seasonally flooded wetlands in the northern San Joaquin Valley, California. Calif. Fish and Game 66:233–237.

Danell, K., and K. Sjoberg. 1979. Decomposition of *Carex* and *Equisetum* in a northern Swedish lake: dry weight loss and colonization by macro-invertebrates. J. Ecol. 67:191–200.

Darby, R. E. 1962. Midges associated with California rice fields, with special reference to their ecology. Hilgardia 32:1–206.

Euliss, N. H., Jr. 1984. The feeding ecology of pintail and green-winged teal wintering on Kern National Wildlife Refuge. M. S. Thesis, Humboldt State Univ., Arcata. 188pp.

———, and S. W. Harris. 1987. Feeding ecology of northern pintails and green-winged teal wintering in California. J. Wildl. Manage. 51: 724–732.

Fleming, K. J., and J. K. Schooley. 1984. Foraging patterns and prey selection by marsh fish. Proc. Calif. Mosq. Vector Control Assoc. 52:139.

Gerry, B. I. 1954. Ecological conditions which influence control of mosquito-like pests. Mosq. News 14:145–149.

Grodhaus, G. 1967. Identification of chironomid midges commonly associated with waste stabilization lagoons in California. Calif. Vect. Views 14:1–12.

Kadlec, J. A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43:267–281.

Krapu, G. L. 1974. Foods of breeding pintails in North Dakota. J. Wildl. Manage. 38:408–417.

Krecker, F. H. 1939. A comparative study of the animal population of certain submerged aquatic plants. Ecology 20:553–562.

Krull, J. N. 1970. Aquatic plant-macroinvertebrate associations and waterfowl. J. Wildl. Manage. 34:707–718.

Landers, J. L., T. T. Fendley, and A. S. Johnson. 1977. Feeding ecology of wood ducks in South Carolina. J. Wildl. Manage. 41:118–127.

Lamberti, G. A., and V. H. Resh. 1984. Seasonal patterns of invertebrate predators and prey in Coyote Hills Marsh. Proc. Calif. Mosq. Vector Control Assoc. 52:126–128.

Magy, H. I., G. Grodhaus, J. D. Gates, and J. Montez. 1970. Pondweed—a substrate for chironomids, especially *Paralauterborniella subcincta*. Proc. 37th Ann. Conf. Calif. Mosq. Assoc., Jan. 27–29, 1969. 37:115–119.

Mason, W. T. 1968. An introduction to the identification of chironomid larvae. Fed. Water Pollut. Control Adm. Dist. by NTIS, U. S. Dept. of Commerce, Springfield, VA 87pp.

McGaha, Y. J. 1952. The limnological relations of insects to certain aquatic flowering plants. Trans. Am. Microscop. Soc. 71:355–381.

Merritt, R. W., and K. W. Cummins (eds.). 1984. Aquatic insects of North America. 2nd ed. Kendall Hunt Publ., Dubuque, Iowa. 441pp.

Miller, M. R. 1987. Fall and winter foods of northern pintails on three northern California refuges. J. Wildl. Manage. 51:403–412.

Mortenson, E. W., G. Grodhaus, C. M. Myers, and D. C. White. 1967. A report on the San Luis midge problem, Merced County, California. Department of Public Health, Bureau of Vector Control, 10pp. (mimeographed).

Oliver, D. R. 1971. Life history of the Chironomidae. Ann. Rev. Entomol. 16:211–230.

_____, D. McClymont, and M. E. Roussel. 1978. A key to some larvae of Chironomidae (Diptera) from the Mackenzie and Porcupine River watersheds. Ottawa, Ontario. Canada. Fish. and Mar. Serv. Tech. Rep. No. 791. 73pp.

Pederson, G. B., and R. L. Pederson. 1983. Feeding ecology of pintails and mallards on Lower Klamath marshes. Final rept. on U. S. Fish and Wildl. Serv. contract 14-16-001-79106. Humboldt State Univ. Foundation, Arcata. 89pp.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States. 2nd ed. John Wiley and Sons, New York. 803pp.

Reinecke, K. J., and R. B. Owen, Jr. 1980. Food use and nutrition of black ducks nesting in Maine. J. Wildl. Manage. 44:549–558.

Roback, S. S. 1957. The immature tendipedids of the Philadelphia area. Monogr. Acad. Nat. Sci., Philadelphia 9:1–152.

Rosine, W. N. 1955. The distribution of invertebrates on submerged aquatic plant surfaces in Muskee Lake, Colorado. Ecology 36:308–314.

Simpson, K., and R. Bode. 1980. Common larvae of Chironomidae (Diptera) from New York streams and rivers, with particular reference to the fauna of artificial substrates. Bull. New York State News. 439:1–105.

Sugden, L. G. 1973. Feeding ecology of pintail, gadwall, American widgeon and lesser scaup ducklings in southern Alberta. Can. Wildl. Serv. Rept. Series No. 24. 43pp.

Swanson, G. A., and J. C. Bartonek. 1970. Bias associated with food analysis in gizzards of blue-winged teal. J. Wildl. Manage. 34:739–746.

_____, G. L. Krapu, and J. R. Serie. 1977. Foods of laying female dabbling ducks on the breeding grounds. Pages 47–57 *in* T. A. Bookhout, (ed.), Waterfowl and wetlands: An integrated review. Proc. 1977 Symp., Madison, Wis., N. Cent. Sect., The Wildl. Soc.

Tiner, R. W., Jr. 1984. Wetlands of the United States: current status and recent trends. Government Printing Off., Washington, D.C. 59pp.

Usinger, R. L. 1956. Aquatic insects of California. Univ. Calif. Pr., Berkeley. 508pp.

Ward, H. B., and G. C. Whipple. 1959. Fresh-water biology. 2nd ed. John Wiley and Sons, New York. 1248pp.

Widerholm. T. (ed.). 1983. Chironomidae (Diptera) of the Holarctic Region—keys and diagnoses. Part 1. Larvae. Entomol. Scandanavica Suppl. 19:1–457.

NOTES

YELLOWTAIL CHAFING ON A SHARK: PARASITE REMOVAL?

Ectoparasites are commonly found on a variety of pelagic fishes. That they cause irritation has not been determined through experimentation, but has provided the basis of explanations that: (i) attribute leaping by mantas (Mobulidae) and billfishes (Istiophoridae) to attempts at dislodging parasites (Böhlke and Chaplin 1968, Walford 1974) and (ii) attribute chafing on substrates in at least 30 families of fishes to removal of sources of irritation (Wyman and Walters-Wyman 1985). In many pelagic fishes vigorous leaping is not observed. Furthermore, they do not have ready access to substrates or cleaning fishes or invertebrates (usually restricted to inshore areas). Although there does not appear to be any published documentation of chafing in pelagic fishes there are various objects in the pelagic environment which might serve as "chafing posts" against which parasites could be dislodged.

On 30 August 1986 at approximately 1500 h I observed a group of 8–15 yellowtail, *Seriola lalandi*, (Carangidae), at the surface of Bahia San Hippolito on the west coast of Baja California, Mexico. They were swimming alongside a small (1.5–1.6 m) blue shark, *Prionace glauca*, and apparently using the shark as an object for chafing. The yellowtail were continuously bunched along both sides of the posterior half of the shark. They repeatedly rushed up to the shark, made side-to-side contact and swam with an obvious rubbing motion toward the anterior end of the shark. The chafing was always disengaged prior to passing the shark's pectoral fin.

That dislodging of ectoparasites was the purpose of the behavior could not be determined with certainty; however, I ruled out aggression because the shark continued swimming slowly throughout the entire 3–4 min that the behavior was observed. No obvious change in swimming speed or direction on the part of the shark resulted from physical contact by the yellowtail, but minor lateral displacement caused by the chafing itself was evident. Examination of several (ca. 30) yellowtail caught that afternoon in the same location revealed that ectoparasitic copepods were present in low numbers (1 or 2) on approximately 60–70% of the yellowtail.

LITERATURE CITED

Böhlke, J.E. and C.C.G. Chaplin. 1968. Fishes of the Bahamas and adjacent tropical waters. Livingston Publishing Co.: Wynnewood, Pennsylvania. 771 p.

Walford, L.A. 1974. Marine game fishes of the Pacific coast from Alaska to the Equator. T.F.H. Publications: Neptune, New Jersey. 205 p

Wyman, R.L., and M.F. Walters-Wyman. 1985. Chafing in fishes: occurrence, ontogeny, function and evolution. Env. Biol. Fish. 12:281–289.versity, Nash 104, Corvallis, OR 97331-3803. Accepted for publication May 1987.

—*Bruce E. Coblentz, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331-3803. Accepted for publication May 1987.*

ATYPICAL PLUMAGE OF A FEMALE CALIFORNIA QUAIL

Reversal of secondary sex characteristics, most noteably plumage color and pattern, has been reported in several species of gallinaceous birds, including ring-necked pheasants, *Phasianus colchicus* (Bent 1932), Japanese quail, *Coturnix coturnix japonica* (Kannankeril and Domm 1968), and northern bobwhites, *Colinus virginianus* (Brodkorb and Stevenson 1934, Buchanan and Parkes 1948). There is, however, a paucity of information relating to the reversal of plumage in other Phasianidae. Herein we report on an adult, female California quail, *Callipepla californica*, with mixed male and female plumage characters that was collected on 7 November 1986 at the E.E. Wilson Wildlife Management Area, 15 km north of Corvallis, Benton County, Oregon.

The plumage of this bird, which had completed her annual molt, contained some feathers that were typically female, some that were male-like, and others that were intermediate between the sexes (Figure 1). The throat patch was a mixture of black (male-like) and grayish-brown (female-like) feathers surrounded by a white stripe that contained some brown feathers and lacked the distinct edge of the male. The crown was light chestnut with some streaking and the forehead was brown with a dirty white background. A white stripe extended from the forehead to the black auricular feathers. The nape was female-like in appearance except that the brown edges of the feathers were darker than normal. Three of the topknot feathers were elongated and intermediate in length between male and female; the remaining feathers of the crest were female-like. The breast was a mixture of brown (female-like) and gray (male-like) feathers. The upper abdominal feathers were light tan (intermediate between male and female) and the borders of the "scaled" abdominal feathers were black (male-like). The lower abdomen lacked the chestnut patch characteristic of males.

Plumage of female gallinaceous birds is controlled, or at least influenced, by female sex hormones, which are produced largely by the ovary (Voitkevich 1966). Male-like plumage in females has been associated with pathogenic regression (Witschi 1961), atrophication with age (Bent 1932), and abnormal enlargement (Buchanan and Parkes 1948) of the ovary, as well as sinistral ovarectomization (Kannankeril and Domm 1968). Gross and histological examination of the reproductive tract of this female California quail revealed the presence of an oviduct (left only) of normal size and cellular structure for a non-laying hen. No gonads or other accessory structures were found. The ovary apparently either regressed to a size that we were unable to locate or was absent.

The scant amount of information about the reversal of plumage characters in female quail indicates this phenomenon is unusual. This bird represents the only example we have observed of a California quail with atypical plumage among approximately 450 birds from this study area that have been examined from 1975 through 1986.

The skin of this California quail was deposited in the wildlife collection of the Department of Fisheries and Wildlife, Oregon State University (Specimen No. FW 5153). Appreciation is expressed to R.L. Jarvis for his review of the manuscript. This paper is Technical Publication No. 8120 of the Oregon Agricultural Experiment Station.
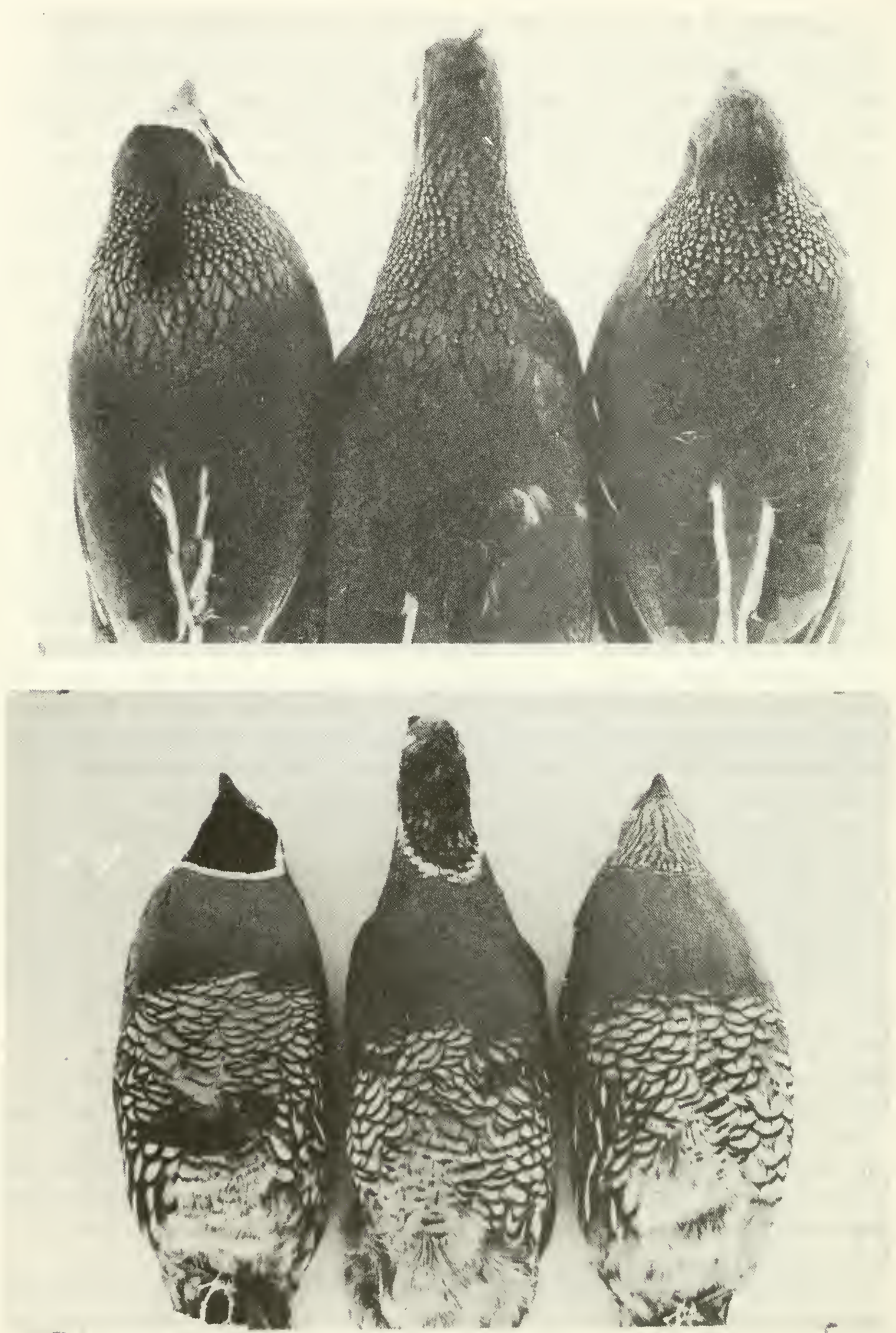
FIGURE 1.   Dorsal and ventral views of typical male (left), typical female (right), and female California quail with mixed male and female plumage characters (center) taken in Benton County, Oregon, 7 November 1986.

LITERATURE CITED

Bent, A.C. 1932. Life histories of North American gallinaceous birds. U.S. Nat. Mus. Bull, 162. 490 p.

Brodkorb, P. and J. Stevenson. 1934. Additional northeastern Illinois notes. Auk, 51:100–101.

Buchanan, F.W. and K.C. Parkes. 1948. A female bob-white in male plumage. Wilson Bull., 60:119–120.

Kannankeril, J.V. and L.V. Domm. 1968. The influence of gonadectomy on sexual characteristics in Japanese quail. J. Morphol., 126:395–412.

Voitkevich, A.A. 1966. The feathers and plumage of birds. Sidgwick and Jackson, London. 331 p.

Witschi, E. 1961. Sex and secondary sexual characters. Pages 115–168 in A.J. Marshall, ed. Biology and Comparative Physiology of Birds. Academic Press, London.

—*J. A. Crawford, P. J. Cole, and K. M. Kilbride, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon 97337 and A. Fairbrother, U.S. Environmental Protection Agency, Corvallis, Oregon 97330. Present address for P. J. Cole: Idaho Department of Fish and Game, Jerome, Idaho 83338.*

BOOK REVIEWS

MARINE MAMMALS (OF THE EASTERN NORTH PACIFIC AND ARCTIC WATERS)
Edited by Delphine Haley. Second Edition, Revised. Pacific Search Press, Seattle, Washington, 1986, 296 p.; $22.95 paper.

This brief treatment of each of the marine mammals of the eastern North Pacific is very good. It could function nicely as a text for an introductory course in marine mammals of the eastern North Pacific, and would be a good reference book for students of these mammals at all levels.

The book is abundantly illustrated with photographs and range maps. The photographs, while generally splendid, have apparently sometimes lost a bit of their crispness in the reproduction process. Occasionally some of the detail that is described as clearly visible, clearly is not.

The list of contributors would provide a good start on a "who's who" in marine mammal research. One can feel the excitement that many of the authors have for their work. Although a "protectionist" philosophy occasionally permeates a section to the extent that real resource conflicts are relegated to ranting by overzealous fishermen, on the whole the book objectively presents information, pointing out adequacies and inadequacies.

I recommend the book to anyone interested in marine mammals.

—*Jack A. Ames*

DISEASES AND PARASITES OF MARINE FISHES
by H. Möller and K. Anders, Verlag Moller, Kiel, 1986, 365 p. Illustrated, cloth 50 DEM (ca. $25 US).

This book represents an ambitious effort to provide basic information to the layman and still be of interest to the professional. I believe that Möller and Kiel have succeeded. The authors had the foresight to have specialists review the various sections, thus avoiding obvious mistakes. There are many good line drawings and more than 200 photographs, some in color, which should help the layman identify micro- and macroparasites and the causes of skeletal abnormalities and tumors. The book includes sections on the techniques used in fish parasitology and lists of current fish health textbooks and journals. Workers in fish disease and parasitology will appreciate the bibliography which follows each section and the many tables and figures.

The chapters include such topics as parasites as biological tags, human pathogens transferred by fish and spoilage of fish due to parasites. I found the sections on epidemiology and pollution, the authors' specialties, especially informative. The case study of fish disease in the Elbe Estuary demonstrates the complex relationship between pollution, disease and natural parameters.

As a suggestion for future editions, the authors might include a section on the fast-growing field of fish immunology. I recommend this book; it is well worth the price.

—*Mike Moser*

EIDER DUCKS IN CANADA
Edited by Austin Reed. 1986. Canadian Wildlife Service Report Series Number 47, Ottawa. 1977. $23.50.

This is another in the excellent series of reports by the Canadian Wildlife Service dealing with various aspects of wildlife biology and management in Canada. This publication consists of 18 separate papers which cover eider status and ecology, most concentrating on the Common Eider, *Somateria mollissima*, with some information presented on King Eider, *S. spectabilis*. Twelve of the papers are presented in English and five in French, with abstracts in the second official language. The final paper is written in both languages.

The report is organized into six parts. The eight papers of Part I cover distribution and abundance, with each paper discussing a separate population in geographical order from east to west. Part II consists of two papers on identification and distribution of eastern races of Common Eiders. The single paper in Part III discusses winter numbers and distribution of Gulf of St. Lawrence eiders. Part IV contains four papers on ecology, primarily on the breeding grounds, with one devoted to Inuit knowledge of Common Eider ecology. There are two papers on use of eiders by people in Part V, and Part VI, titled Conclusions, contains a single paper summarizing population size and status of Common Eiders in eastern North America. It incorporates the findings of the other papers in the publication to create a population model for six subpopulations of Common Eiders, with recommendations for further research and management.

This is a technical report with copious maps, figures and tables. It is well written and up to the usual scholarly standards of the Canadian Wildlife Service. However, except for someone with an all-consuming interest in eiders, because of the high cost of the report most readers might want to peruse a copy from their local government repository library, rather than buy it.

—*Bruce E. Deuel*

OCEAN FORUM
By Ron I. Jackson and William F. Royce; Fishing News Books Ltd, Farnham-Surrey-England 1986; 240 p. $31.50

An exceptional amount of information on North Pacific resources and fisheries from the fur trade period to the present is contained in this 240 page book. The authors provide "an interpretive history of the International North Pacific Fisheries Commission." From the chaos of war amid national differences in fishing methods, policies, and objectives emerged the International Convention for the High Seas Fisheries of the North Pacific Ocean among Japan, Canada, and the United States in 1952. The Convention established the International North Pacific Fisheries Commission (INPFC) to promote and coordinate scientific studies to ascertain conservation measures to secure the maximum sustained productivity and each nation would carry out such recommendations. A feature of the Convention was the unprecedented principle of abstention, contrary to the prevailing concepts of freedom of the seas. Japan and Canada agreed to abstain from fishing in named Convention areas; the major abstention was by Japan for salmon east of 175° West Longitude.

Confrontations in negotiations and renegotiation sessions and in annual meetings are described as are the collaborations and cooperation in the massive fishery research programs carried out by member nations. Interwoven in the history of INPFC are early dissatisfactions of national fishing groups, the reemergence of Japan as the world fishing leader, new principles of law of the seas, extended jurisdictions, the naturation of fishery science, the explosive growth of north Pacific fisheries, changing business practices and markets, and the development of respect and trust among participants.

The focus in early years of INPFC was on salmons, halibut, and herring. In latter years the tremendous groundfish resources of the north Pacific greatly influenced the actions of INPFC.

Details are provided on individuals, their perspectives and their roles in forging the direction of INPFC. Summaries of fisheries, fishery biology anhd oceanography in the north Pacific are succinct and bring the reader abreast of the past and current major fisheries from California to the Bering Sea, with emphasis on the North Pacific.

The appendices contain the 1953 the 1979 Conventions, past and present INPFC commissioners and secretariats, biographies of major participants, and a list of INPFC publications. The preface and epilogue are concise summaries of the formation, activities, accomplishments, and future of the INPFC. The details and comprehensive features of this book add to the reader's understanding of INPFC and its role.

Both authors had substantive roles in INPFC. Jackson was the first permanent Executive Director and Royce served as an U.S. advisor to commissioners and as an expert on the Commission's Biology and Research Committee. They contend that INPFC, the Ocean Forum, will be needed now more than ever with current dynamic changes in fisheries, national jurisdictions, and fish businesses.

Many current fisheries from central California to the Bering Sea now have multi-national processing and marketing features. Anyone involved with fisheries of the northeastern and North Pacific will benefit from reading this book.

—*Tom Jow*

INDEX TO VOLUME 73
AUTHORS

SUBJECT

SCIENTIFIC NAMES

INSTRUCTIONS TO AUTHORS

EDITORIAL POLICY

California Fish and Game is a technical, professional, and educational journal devoted to the conservation and understanding of fish and wildlife. Original manuscripts submitted for consideration should deal with the California flora and fauna or provide information of direct interest and benefit to California researchers. Authors may submit an original plus two copies, each, of manuscript, tables, and figures at any time.

MANUSCRIPTS: Authors should refer to the *CBE Style Manual* (Fifth Edition) and a recent issue of *California Fish and Game* for general guidance in preparing their manuscripts. Some major points are given below.

1. *Typing*—All material submitted, including headings, footnotes, and literature cited must be typewritten doublespaced, on white paper. Papers shorter than 10 typewritten pages, including tables, should follow the format for notes.

2. *Citations*—All citations should follow the name-and-year system. The "library style" will be followed in listing literature cited.

3. *Abstracts*—Every article must be introduced by a concise abstract. Indent the abstract at each margin to identify it.

4. *Abbreviations and numerals*—Use approved abbreviations as listed in the *CBE Style Manual*. In all other cases spell out the entire word.

TABLES: Each table should be typewritten with the heading margin left justified. Tables should be numbered consecutively beginning with "1" and placed together in the manuscript following the Literature Cited section. Do not double space tables. See a recent issue of *California Fish and Game* for format.

FIGURES: Consider proportions of figures in relation to the page size of *California Fish and Game*. The usable printed page is 117 by 191 mm. This must be considered in planning a full page figure, for the figure with its caption cannot exceed these limits. Photographs should be submitted on glossy paper with strong contrasts. All figures should be identified with the author's name in the upper left corner and the figure numbers in the upper right corner. Markings on figures should be made with a blue china marking pencil. Figure captions must be typed on a separate sheet headed by the title of the paper and the author's name.

PROOFS: Galley proofs will be sent to authors approximately 60 days before publication. The author has the ultimate responsibility for the content of the paper and is expected to check the galley proof carefully.

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