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EFFECTS OF KELP CANOPY REMOVAL ON YOUNG-OF-THE-YEAR ROCKFISH ABUNDANCE, USING TWO CENSUS METHODS

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MARINE RESOURCES DIVISION

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ABSTRACT

In 1976 an experimental research project was initiated to examine the possible effects of the removal of a giant kelp, *Macrocystis pyrifera*, canopy in a central California kelp bed on Young-of-the-Year (YOY) fish populations. A total of 7823 fishes was captured and marked using freeze branding. Pre-canopy removal population estimates were made using the Schnabel method and post-canopy removal population estimates were made using the Petersen method (Lincoln Index). A significant ($p < .0004$) reduction of fish occurred immediately after the canopy was removed and the population remained at a reduced level for at least 60 days. This information warranted the creation of a second expanded project.

In 1977 we established three study areas consisting of a kelp bed to be harvested (C), a kelp bed not to be harvested (NC) and a control kelp bed. We captured and marked over 82,000 YOY fish in Areas C and NC. Using the same statistical methods from the 1976 study, a significant reduction was found to occur in fish populations within harvested Area C and unharvested area NC; however, the reductions were not significantly different between the two areas. The large reduction in the fish population in the harvested area occurred when fish moved into the unharvested area. The large, unexpected reduction in fish numbers in the unharvested area (NC) occurred when larger predatory YOY bocaccio moved into the control area (X) as the experimental area (C) was being harvested. The bocaccio removed in excess of 20% of the biomass of YOY blue rockfish, which was composed of resident fish and recently migrated fish from the harvested kelp bed. Predation on YOY blue rockfish was also evident in the harvested area.

Population estimates using visible fish transects by divers correlated well with population estimates from the capture/recapture studies in 1976, but correlation was poorer the following year when many more fish were present.

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INTRODUCTION

In 1975 the Central California Marine Sportfish Project of the Department of Fish and Game began experiments to observe the effects of legal harvest of giant kelkp, *Macrocystis pyrifera* on populations of recently settled young-of-the-year (YOY) rockfishes. Initial studies in 1976 (unpublished project data) showed that YOY fish were affected by canopy removal. McCleneghan and Houk (1985) discovered that kelp plants were also affected adversely after canopy removal. Diving observations demonstrated that the use of the kelp canopy shadowing by YOY rockfish is species specific.

A preliminary experiment in 1976 revealed that populations of YOY fish declined in a kelp bed area which had experienced canopy removal (unpublished project data). An adjacent kelp bed which was not harvested did not show a decline in population abundance during the same time period. A mark/recapture study was planned to estimate YOY populations and to compare them with estimates from permanent fish transects. The study plan included freeze branding of fish, harvesting of 20-30 tons of kelp and developing proper fish capture and fish counting techniques. These techniques were used to examine YOY population structure, species composition, movements, effects of kelp canopy harvest on population structure, and the effects of predation on YOY rockfishes.

This paper examines effects of canopy removal only on the

two most abundant species of YOY rockfish during the study year; blue rockfish, *Sebastes mystinus* and its predator, bocaccio *Sebastes paucispinnis*. Data on other species of YOY, juvenile, and adult fishes observed during the study are also presented.

MATERIALS AND METHODS

A study site (Figure 1), was selected by viewing aerial infrared photographs of the central California Coast area of Monterey Bay taken by this project in 1975. The site consisted of 3 separate but closely related rocky reefs with good kelp growth. Reefs were mapped to show rocky areas, sandy areas, and kelp plants. Four permanent fish transect lines were established, each 33 m long, on the north to south axis of the reef to be harvested (Area C)(Figure 2). Three permanent transect lines were established on the west to east axis of the unharvested reef (Area NC). Area C was further divided into six zones and Area NC into three zones to determine movement between and within areas. The third reef area (Area X) was established as a control with no kelp harvest or fish capture occurring. Two permanent transect lines were established in this area.

A net was developed to capture fish, (McCleneghan and Houk, 1978), and freeze branding was chosen as the tagging method, based on work by Mighell (1969) and Everest and Edmundson (1967). A freeze branding chamber was modified from the original chamber developed by Mighell (1969). Liquid nitrogen was readily

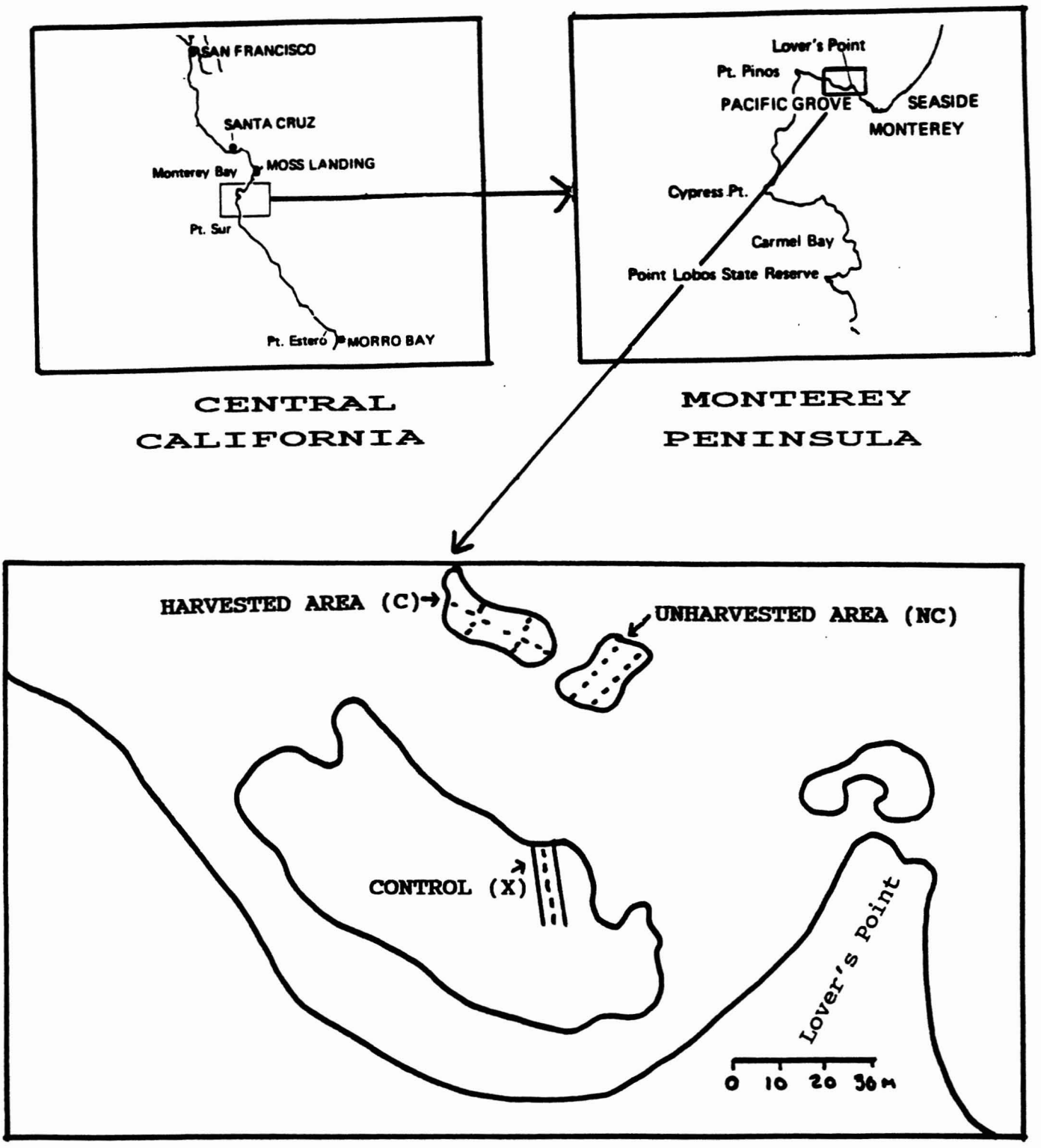


Figure 1. Study Site Used to Examine Effects of Kelp Canopy Removal to Young-of-the-Year Rockfishes.

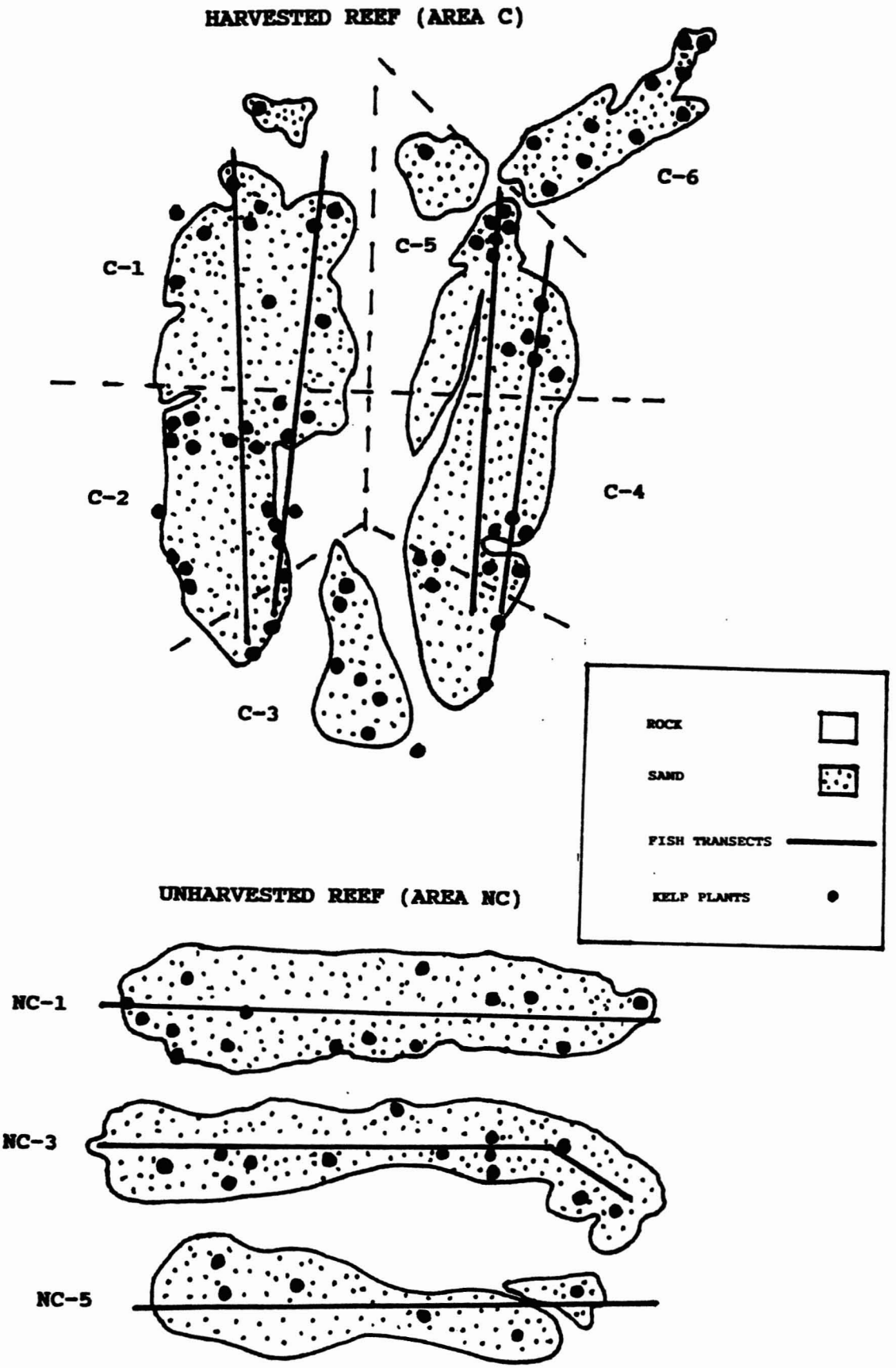


Figure 2. Topography of the harvested (c) and unharvested (nc) reef systems including division by zone, permanent fish-transect lines, and giant kelp plants.

available, inexpensive, and 2 l lasted for the entire day stored in a vented stainless steel thermos. Captured fish were stored in 58 l plastic garbage cans open at the top. Each container had holes to provide water exchange and temperature control. Float collars were attached to these plastic cans for stabilization and buoyancy. Containers were covered when fish were returned to the exact area of capture.

Two methods were used to determine species composition and population abundance of YOY rockfish. The first method used fixed-line fish transects. Fish counts along transect lines were based on methodology used by Hobson and Chess (National Marine Fisheries Service, Tiburon, pers. commun.) which consisted of a team of two SCUBA divers. Each diver counted all fish along the transect in a 1 m wide area within 2 meters of the surface. This was then repeated along the same transect on the bottom. All work was performed using the 21 ft inboard-outboard R/V Ophiodon. Counts were summed for the two divers and averaged, (number of fish/transect), converted to density (number of fish/meter squared), and then multiplied by the reef area.

The second method envolved capturing and marking YOY rockfish and analyzing subsequent recaptures (Jones 1976). The pre-harvest population was estimated using the Schnabel method (Figure 3). After harvest of the kelp canopy, a 4 day intensive capture and marking of fish was followed by one massive recapture day. Recaptured fishes were examined for mark (brand) retention, obvious problems, stress, and their previous mark was recorded.

The Petersen method (Lincoln Index), was used to estimate the post harvest population size (Figure 3).

Fishes were marked by a special brand symbol for harvested and unharvested areas and for each day of capture. Marks were applied at one of six locations on the fish depending on the zone in which the fish had been captured (Figure 4).

Two divers captured fishes and two deck personnel separated, handled, and marked them. As tagging progressed during the day the two divers returned each container of marked fish to the initial area of capture.

Kelp was harvested by divers at a depth of 4 ft below the water surface in accordance with Fish and Game Code, Title 14, Section 165, part c, no. 2, which states "no *Macrocystis* (giant kelp) shall be harvested at a depth of more than 4 feet below the surface of the water at the time of cutting". All harvested kelp fronds were placed into plastic garbage cans, weighed, and counted.

SCHNABEL METHOD

$$\hat{N}=\frac{\sum (C_t M_t)}{R}$$

Where:

$\hat{N}$= The number in the population
$M=\sum M_t$, the total number marked
M_t= the total marked fish at large at the start of the t^{th} day, i.e., the number previously marked less any accidently killed at previous recaptures.
C= the sum of C_t the total number captured
C_t= the total sample taken on day t
$R=\sum R_t$ the total recaptures during the experiment
R_t= the number of recaptures in the sample C

PETERSEN METHOD (LINCOLN INDEX)

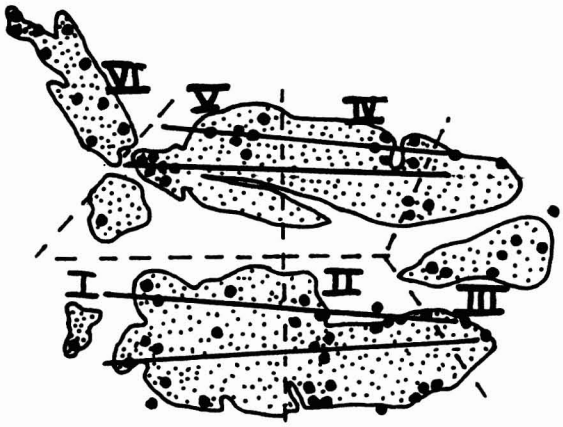
$$x=\frac{an}{r}$$

Where:

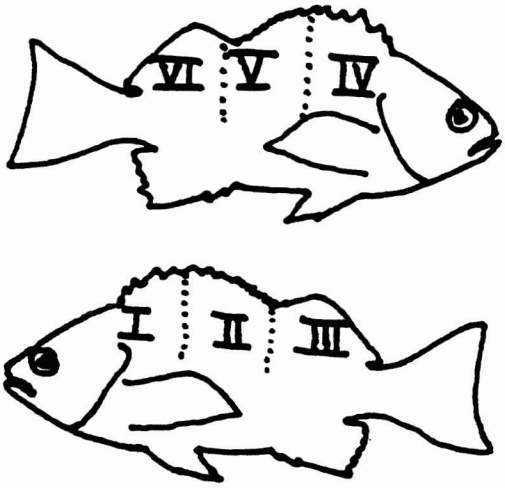
x=the number in the population
a=individuals caught the first time
n=the total number of individuals caught the second time.
r=the number of individuals that repeated or were taken in both the first and second capture periods

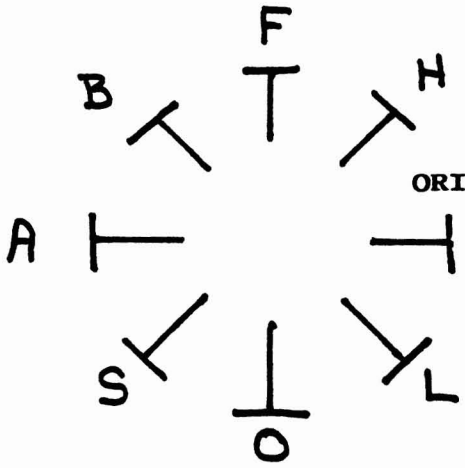
Figure 3. Mark and recapture analyses used to estimate fish populations before and after canopy removal.

HARVESTED AREA C, ZONES I-VI



MARKING LOCATIONS DESIGNATING HARVESTED AREA C, ZONES I-VI





ORIENTATION OF BRAND TO DESIGNATE DATE OF CAPTURE

EXAMPLE;

BRAND B	**=JULY 11, 1977**
BRAND O	**=JULY 20, 1977**
BRAND L	**=JULY 19, 1977**
BRAND C	**=UNHARVESTED AREA**

RECAPTURE EXAMPLE 1

Captured July 11, Zone C-1
Recaptured July 20, Zone C-3

RECAPTURE EXAMPLE 2

Captured in Zone NC-3 (Date not important)
Recaptured July 11, Zone C-4
Recaptured July 19, Zone C-4

Figure 4. Designated areas on fish illustrating area of capture with two illustrations explaining reading techniques to determine date and location of capture or recapture.

RESULTS

A total of 30 days was spent in the field either capturing and marking fish, swimming fish transects, or harvesting the kelp canopy (Table 1). Many fishes other than blue rockfish were captured in the lift net or sighted on transects. A complete list of all 88 species or groupings observed is presented in Table 2.

Population Estimates From Mark/Recapture

Population Estimate Before Harvest

A total of 89,060 YOY fishes was captured using the lift net during 21 days of marking. Of that total, 80,637 were YOY blue rockfish. Of these, 63,346 were never recaptured, 16,476 were recaptured once, 795 were recaptured twice and 20 were recaptured three times (Table 3).

A population estimate of 130,921 YOY blue rockfish was made using the Schnabel census before the kelp canopy was harvested. YOY blue rockfish abundance estimates for the six zones within Area C ranged from 12,771 to 29,800 (Table 4).

A population estimate of 44,708 YOY blue rockfish was made for the uncut Area NC using the same Schnabel analysis before the kelp canopy was harvested in Area C. Estimates of the three zones within Area NC ranged from 9,408 to 19,315 (Table 4).

Table 1. Work Schedule for mark/recapture experiments, June-September, 1977.

Date 1977	Function	Area	Zone	# fish caught	# transects
28 June	Transects	C,NC	Bot & Sur		C=16,NC=12
30 June	Transects	NC	Bot & Sur		NC=12
1 July	Transects	C,X	Bot & Sur		C=16, X=4
5 July	Mark	C	6	1570	
6 July	Mark	C	1 thru 5	3263	
7 July	Mark	C	1 thru 5	3781	
8 July	Mark/Transts	C/NC	1-5; 1-5	3564	NC=12
9 July	Mark	NC	1, 3, 5	2391	
11 July	Mark/Recap	C	1 thru 5	3605	
12 July	Mark/Recap	C	1 thru 5	2506	
13 July	Mark/Recap	NC	1, 3, 5	3415	
15 July	Mark/Recap/T	C/C,NC	1-5; 1-5	3987	C=16,NC=12
16 July	Mark/Recap/T	C/X	1,2,3,5;X	3429	X=8
18 July	Mark/Recap	NC	1,3,5	3115	
19 July	Mark/Recap	C	1 thru 5	2912	
20 July	Transects	C	Bot-Surf		C=16
21 July	Mark/Recap	NC	1,3,5	2422	
22 July	Transects	C,NC,X	Bot-Surf		C,NC,X=36
25 July	Recapture	NC	1,3,5	5003	
26 July	Recapture	C	1 thru 6	7937	
27 July	Kelp Canopy in Area (C) Harvested				
28 July	Transects	C,NC,X	Bot-Surf		C,NC,X=36
1 Aug	Mark	C	1-6	4609	
2 Aug	Mark	C	1-6	4226	
3 Aug	Mark	C	1-6	5421	
4 Aug	Mark	NC	1,3,5	4130	
5 Aug	Transects	C,NC,X	Bot-Surf		C,NC,X=36
8 Aug	Recapture	C	1-6	6380	
10 Aug	Recapture	NC	1,3,5	2971	
13 Sept	Transects	C,NC,X	Bot-Surf		C,NC,X=36

Table 2. Fish species (omitting YOY blue rockfish and bocaccio) captured by lift net.

Fish Species	Area C	Area NC	Total
Widow "green" rockfish	1,038	277	1,315
Copper rockfish	34	9	43
"Unknown" rockfish sp.	141	43	184
Kelp rockfish YOY	21	46	67
Kelp rockfish Adults	15	11	26
Black rockfish YOY	5	37	42
Black rockfish Adults	6	33	39
Unidentified fish	2	0	2
Rainbow surfperch	2	1	3
Shortbelly rockfish	5	1	6
Adult blue rockfish	1	0	1
Unident perch	1	0	1
Striped surfperch	2	4	6
Black/yellow rockfish	1	0	1
Kelp perch	1	0	1
Blacksmith	35	2	37
Black surfperch	0	3	3
Pile surfperch	0	3	3
Lingcod YOY	0	1	1
Senorita	0	1	1
Olive rockfish	0	1	1
Mola	1	0	1

Note: Fish observed on transects but not captured were yellowtail, copper, gopher, and olive rockfish, sharpnose and kelp sufperch, kelp greenling and cabezon.

Table 3. Total fish captured and marked in each area with primary, secondary, and tertiary recaptures.

HARVESTED AREA (C)	UNHARVESTED AREA (NC)	BOTH AREAS (C)+(NC) COMBINED
Total fish caught and marked=63,593	Total fish caught and marked=23,447	Total fish caught and marked=87,040
Total fish caught and marked two times=12,770	Total fish caught and marked two times=3,706	Total fish caught and marked two times=16,476
Total fish caught and marked three times=572	Total fish caught and marked three times=223	Total fish caught and marked three times=795
Total fish caught and marked four times=15	Total fish caught and marked four times=5	Total fish caught and marked four times=20

Table 4. Population estimates and changes after canopy harvest for young-of-the-year blue rockfish using only mark/recapture data.

AREA	POPULATION BEFORE HARVEST	POPULATION AFTER HARVEST	% INCREASE/ DECREASE
(C-1)	25,413	11,525	-54.5% (-13,888)
(C-2)	19,045	9,469	-50.3% (-9,576)
(C-3)	12,771	20,626	+61.5% (+7,855)
(C-4)	15,538	15,987	+02.9% (+449)
(C-5)	29,800	34,555	+16.0% (+4,755)
(C-6)	28,354	22,522	-20.6% (-5,832)
Total (C-1 to C-6)	130,921	114,684	-12.4% (-16,237)
(NC-1)	19,315	13,397	-30.6% (-5,918)
(NC-3)	9,408	8,130	-13.6% (-1,278)
(NC-5)	15,985	12,411	-22.4% (-3,574)
Total (NC-1 to NC-5)	44,708	33,938	-24.1% (-10,770)

Population Estimates After Harvest

After the kelp canopy was removed in Area C, populations were estimated for the two areas using the Petersen method (Lincoln Index). The population estimates for Areas C and NC were 114,684 and 33,939 YOY blue rockfish, respectively (Table 4).

Population Estimates Using Fish Counts

Population Estimates Before Harvest

Population estimates of YOY blue rockfish from transects were divided into two areas to represent fish counted within 2 m of the surface of the water and fish counted within 2 m of the bottom. These estimates are not directly comparable with the previous method because the transects only estimated fish populations at the bottom and top 2 m of the water column. In Area C, we estimated the population of YOY blue rockfish to be 55,755 (mean = 840 fish/transect) on the bottom and 2548 (mean= 38 fish/transect) on the surface. In Area NC, we estimated the population of YOY blue rockfish to be 32,451 (mean= 488 fish/transect) on the bottom and 2587 (mean= 39 fish/transect) at the surface. The Area X control had a mean of 442 fish/transect on the bottom and a mean of 39 fish/transect at the surface.

Population Estimates After Harvest

Population estimates after the harvest in Area C were 56,810 (mean= 855 fish/transect) on the bottom and 660 (mean= 10

fish/transect) at the surface. The population estimate after the harvest in Area NC was 39,768 (mean= 598 fish/transect) and at the surface was 1056 (mean= 15.9 fish/transect). The counts in area X after the harvest in Area C had a mean of 268 fish/transect on the bottom and a mean of 14 fish/transect at the surface (Table 5).

Movement Using Capture/Recapture Data

Movement of YOY rockfish before kelp harvest between zones 1, 2, 3, 4, 5, and 6 in Area C was similar throughout the duration of the study. For each replicate capture between 12% and 25% of the fish from the previous capture had moved out of the zone being sampled into another zone . Conversely, between 15% and 30% of the fish captured had moved from another zone into the zone being sampled. Thus of the fish recaptured fish, which ranged from 12% to 23% of all fish caught (Table 6) a minimum of 30% and a maximum of 52% were transients that had moved from one zone another in Area C.

Movement within Area NC was much less frequent. Recaptured fish accounted for 15% to 21% of the total fish captured (Table 7); of these a minimum of 6% and a maximum of 13% had moved between the three zones in Area NC. Thus, a minimum of 84% and a maximum of 90% of the recaptures showed no movement.

Movement from Area C to Area NC was lower (mean= 0.85%, SD=0.72) than from Area NC to Area C (Table 8) (mean= 3.14%,

Table 5. Population estimates and changes after canopy harvest for young-of-the-year blue rockfish using fish transect data.

AREA		Population Before Harvest		Population After Harvest		% Increase or Decrease
		$\bar{x}$ no. trans.	Expand pop.	$\bar{x}$ no. trans.	Expand pop.	Same for trans and expand pop
C	Bottom	840	55,755	855	56,810	+2%
	Surface	38	2,548	10	660	-74%
NC	Bottom	488	32,451	598	39,768	+18%
	Surface	39	2,587	16	1,056	-59%
X	Bottom	442	36,244	268	21,976	-40%
	Surface	39	3,198	14	1,148	-64%

Table 6. Movement of marked YOY blue rockfish between zones in the harvested area (C-1 through 6) and between harvested and unharvested areas.

	C-1	C-2	C-3	C-4	C-5	C-6	Total C	Total C+NC
Percent recaptured/ total number marked (B/A)	18%	23%	19%	22%	18%	12%	19%	19%
Percent of no movement to total recaptures (C/B)	64%	57%	48%	63%	65%	70%	61%	68%
Percent movement out of the area to other C area (D/B)	20%	25%	20%	12%	19%	10%	18%	15%
Percent movement into sampled area from other C area (E/B)	16%	17%	30%	24%	15%	19%	20%	15%
Percent movement of marked fish between C and NC (F/B)	<1%	<1%	2%	2%	<1%	<1%	<1%	1.5%

A=80,637, Total fish captured
B=14,956, Number of fish recaptured once
C=10,222, Fish did not move from capture area in C
D=2,205, Movement out of the area of capture in area C
E=2,299, Movement into the area of capture from other C area
F=230, movement between area C and area NC

Table 7. Movement of marked YOY blue rockfish between zones in the unharvested area (NC-1,3,5) and between the unharvested and harvested areas.

	NC-1	NC-3	NC-5	Total NC
Percent recaptured/ total number marked (B/A)	15.3%	20.9%	17.5%	17.5%
Percent of no movement to total recaptures (C/B)	87.9%	84.5%	90.0%	87.7%
Percent movement out of the area to other NC area (D/B)	3.1%	7.1%	4.5%	4.8%
Percent movement into sampled area from other NC area (E/B)	2.5%	6.2%	3.8%	4.2%
Percent movement of marked fish between NC and C (F/B)	6.3%	2.2%	1.7%	3.3%

A=23,447, Total YOY blue rockfish captured
B=14,956, Number of fish captured once
C=10,222, Fish did not move from capture area in NC
D=2,205, Movement out of the area of capture in area NC
E=2,299, Movement into the area of capture from other NC area
F=230, Movement between area NC and area C

SD=2.56).

Of the 122 fish that moved from Area C to Area NC, 80 were recaptured in NC-1, the area closest to Area C. Of the 91 fish that moved from NC to C, 60 were recaptured in C-3 or C-4, the areas closest to Area NC.

Of four fish originally marked in NC-3 one was recaptured in C-4, one in C-5 and 2 fish were recaptured in C-1. All four of these fish were caught a third time back in NC-3. Two fish originally captured in NC-1 were first recaptured in C-5 and then recaptured again in NC-1. Two fish marked in C-5 were caught three more times in NC-5.

No movement of fishes to Area X was observed from the harvested and unharvested areas.

Kelp Harvest

A total of 7,708 kg (8.52 tons) of kelp was harvested from Area C at Lover's Point in 1977. This consisted of 2,394 fronds, of which 57 fronds were randomly sampled and weighed. They ranged from 1.1 kg to 5.8 kg each with a mean of 3.22 kg (Table 9). During the previous year these same kelp plants had produced younger and fewer stipes before harvesting (Table 9).

YOY Bocaccio Predation on YOY Blue Rockfish

As the last kelp canopy was removed from Area C, a large

Table 8. Results from harvested zones C-1 through C-6 and unharvested zones NC-1, 3 and 5 showing total fish marked and movement of fish between the harvested Area C and the unharvested Area NC.

Area C, Zone 6. Of 8,493 fish marked 3 went to the control area 1 went to C-1	Area C, Zone 5. Of 13,109 fish marked 35 went to the control area 24 went to C-1 5 went to C-3 6 went to C-5	Area C, Zone 4. Of 9,311 fish marked 31 went to the control area 21 went to C-1 4 went to C-3 6 went to C-5
Area C, Zone 1. Of 9,725 fish marked 5 went to the control area 4 went to C-1 0 went to C-3 1 went to C-5	Area C, Zone 2. Of 9,047 fish marked 29 went to the control area 18 went to C-1 3 went to C-3 8 went to C-5	Area C, Zone 3. Of 7,505 fish marked 19 went to the control area 10 went to C-1 8 went to C-3 1 went to C-5

Area NC, Zone 1 Of 8,652 fish marked, 65 fish moved to Experimental Area. 7 went to E-1 6 " " E-2 12 " " E-3 25 " " E-4 12 " " E-5 3 " " E-6	Area NC, Zone 3. Of 5,859 fish marked, 9 fish moved to Experimental Area. 1 went to E-1 0 " " E-2 8 " " E-3 0 " " E-4 0 " " E-5 0 " " E-6	Area NC, Zone 5. Of 8,936 fish marked, 17 fish moved to Experimental Area. 0 went to E-1 0 went to E-2 6 went to E-3 9 went to E-4 2 went to E-5 0 went to E-6

Table 9. Results of kelp harvested from Area C during two successive years.

1976	1977
Date: October 20	Date: July 27
Stipes harvested: 1,840	Stipes harvested: 2,394
Stipes weighed: 45	Stipes weighed: 57
Stipe weight: range = 0.5 to 2.4 Kg $\bar{x}$ = 1.32 Kg s. d. = 0.43 Kg	Stipe weight: range = 1.1 to 5.8 Kg $\bar{x}$ = 3.22 Kg s. d.= 1.17 Kg
Calculated Kg of kelp harvested: 1,840 x 1.32 = 2,424.71 Kgs = 5,358.61 lbs = 2.68 tons	Calculated Kg of kelp harvested: 2,394 x 3.22 = 7,708 Kgs = 17,036.18 lbs = 8.52 tons

ball of rockfish formed, including YOY blue and kelp rockfish, and YOY bocaccio. This whirling, revolving ball of fish fragmented in all directions. In the next few days the population of bocaccio increased dramatically, due to immigration of larger pelagic YOY bocaccio, especially in the area not cut (Area NC) (Figure 5). These bocaccio fed voraciously on smaller YOY rockfish. YOY bocaccio occurring in kelp areas in June and July typically range in size from 70 to 120 mm, but the bocaccio entering the kelp areas from pelagic waters ranged in size from 140 to 150 mm (Unpublished project data) . By removing and measuring YOY blue rockfish from bocaccio stomachs it was observed that bocaccio of 120 mm TL are able to prey on YOY blue rockfish up to 60 mm TL while YOY bocaccio of 154 mm TL can prey on YOY blue rockfish up to 120 mm TL.

DISCUSSION

Any substantial change in fish populations that might have occurred between Area C (harvested), Area NC (not harvested) and Area X (no capture of fish) was masked by the immigration of significant numbers of larger predatory YOY bocaccio which reduced the numbers of YOY blue rockfish in all three areas. If the area had not been affected by kelp harvesting, we feel that the opportunistic predation by bocaccio would have been greatly reduced.

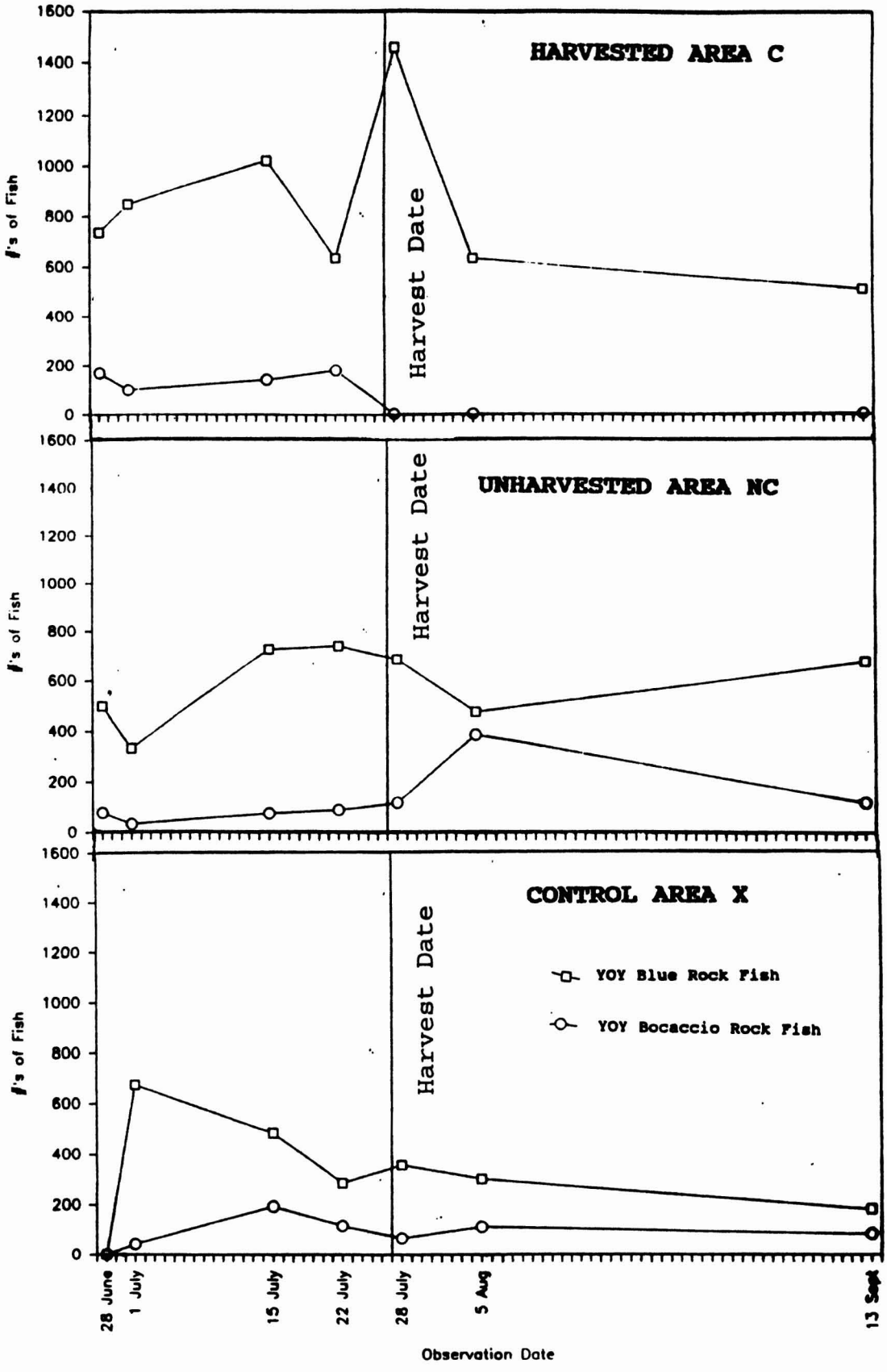


Figure 5. Permanent line fish transect counts showing decreases in YOY blue rockfish and bocaccio populations after canopy removal in the harvested Area C along with a decrease in YOY blue rockfish and a large increase o YOY bocaccio in the unharvested Area NC.

Fixed-line transects have been used in other studies of fish abundance (Miller and Geibel, 1972). By adding the mark recapture method, we were better able to estimate population size and occurrence throughout the water column. This also allowed us to document an increase in large YOY bocaccio. Species population levels are difficult to estimate using only fixed-line fish transects because this type of fish transects is useful to estimate relative recruitment levels but should not be used to estimate the size of a population of YOY fish alone.

Fixed-line fish transects and mark-recapture methods both contain positive and negative attributes for estimating population levels and changes. Both methods rely on physical parameters such as water clarity which affects visibility, the amount of surge moving the fish, kelp and the capture net, the time of day, and the water temperature. When these parameters change, the population estimates can also change. We feel the mark-recapture census was more accurate than fixed-line transects when both kelp canopies were present but the opposite was true after the canopy in one area was removed (Table 10). It was much more difficult to net-capture fish after canopy removal; likewise, fish were much more dispersed throughout a much larger area after canopy removal which lowered fixed-line transect estimates.

The capturing of fish by net also works very well when recruitment levels of YOY rockfishes are moderate to high. It works poorly when populations of YOY rockfishes are extremely

Table 10. A comparison of population estimates using fixed-line fish-transects and a mark-recapture method on the same population of YOY blue rockfish in 2 successive years, 1976 and 1977.

1976 Harvested Area (C) only			
	Transect method	Mark/Recapture	% Agreement
Population before kelp harvested	Area C 2,704	Area C 2,796	Area C 95%
Population after kelp harvested	Area C 1,055	Area C 284	Area C 27%

1977 Harvested (C) and Unharvested (NC) Areas						
	Transect Method		Mark- Recapture		% Agreement	
Population before kelp harvested	C 58,303	NC 35,038	C 130,917	NC 41,708	C 44%	NC 84%
Population after kelp harvested	C 57,470	NC 40,824	C 114,684	NC 33,939	C 50%	NC 83%

low. This study was undertaken during an extremely abundant recruiting year for most kelp bed rockfishes. Abundant quantities of YOY blue rockfish enabled us to capture and freeze brand as many as 12,000 fish in a day.

When densities of YOY fish are low, much more effort is expended capturing fish. When populations of YOY rockfishes are extremely high, it may be physically impossible to visually count all fish present on fixed-line transects and populations may be underestimated. Our observations of YOY bocaccio have shown that they recruit into kelp bed areas at a total length of approximately 50 mm. Bocaccio recruitment is protracted, lasting at least 6-months, as recently settled YOY of approximately 50-55 mm TL can be collected anytime between April and October in most years. These YOY bocaccio rapidly increase in size and upon reaching approximately 120 mm TL in July begin to school, leave the kelp areas, and swim around in a pelagic manner. A few months later at a size of 170-180 mm TL, they leave the nearshore areas for deeper water. The bocaccio that entered our areas at the time of harvest were pelagic schooling fish averaging 154 mm TL. This is much larger than the normal 120 mm TL size of bocaccio occurring in kelp beds.

The amount of movement of YOY rockfish between the six zones in Area C was not surprising. It appears that a certain percentage of fish are moving continuously but are confined to areas with a continuous kelp canopy cover. Fishes rarely crossed an open sand area lacking kelp canopy to arrive at a new area.

The amount of kelp harvested was typical of a mature kelp bed. Approximately five times more canopy was harvested in 1977 than in 1976 from exactly the same area because the kelp plants in 1976 were not yet mature and produced many less fronds. Fish oriented to the kelp canopy and became more concentrated as the canopy was removed. The behavior of YOY blue rockfish was not predictable as predation by YOY bocaccio occurred in each observed area. Numbers of YOY bocaccio were much higher in Area C, the uncut area. Bocaccio entered the area on the day of harvest just as the last kelp was being removed from Zone C. The predation on YOY blue rockfish by YOY bocaccio was probably opportunistic and was highest in Area NC, next highest in Area C and lowest in Area X.

This study utilized literature available up to 1977. More recent investigations include using carbon dioxide for freeze branding (Bryant et al. 1990), and other new techniques for tagging (Wydoski and Emery 1983, McFarlane et al. 1990). Another successful technique for capturing fish is saltwater electrofishing (Stewart and Cameron 1974, Phillips and Scolaro 1980). Attempts to collect fishes using baited stations as an attractant and electroshocking as a collection technique are unsuccessful (Unpublished project data) due to interspecific behavioral differences between southern California reef fishes and central California rockfishes. Matthews and Reevis (1990) and Matthews et al (1990) explain other methods of tracking and following different reef rockfishes.

CONCLUSIONS

1. The methods developed to capture and mark fish were highly successful. The square, diver-operated lift net was capable of capturing as many as 12,000 YOY rockfish per day. The cold brand system using liquid nitrogen was very effective in identifying fish for a minimum of 45 d.
2. Estimating fish abundance levels using visual counts on fish transect lines can be compared to mark-recapture methods but they must be carefully adjusted for numbers of fish, species of fish and observer differences.
3. Residentiality of YOY rockfish was obvious. Apparent movement occurred between areas on the same continuous reef but was minimal between adjacent reefs separated by as little as 10 m.
4. Removal of kelp canopy greatly affected behavior and population size of YOY blue rockfish and YOY bocaccio.

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