

Behavior of Nine Species of Pacific Rockfish after Hook-and-Line Capture, Recompression, and Release

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Abstract.—We evaluated the effect of barotrauma on the behavior of nine species of Pacific rockfish *Sebastes* spp. after hook-and-line capture and release using a video-equipped underwater release cage. Sampling was conducted across a range of bottom depths (12–194 m), mostly where barotrauma resulting from an expanded swim bladder and gaseous release of dissolved blood gases would be expected. Behavioral impairment from barotrauma was depth related but highly species specific. Increased depth of capture was associated with lower behavioral scores for black rockfish *S. melanops*, blue rockfish *S. mystinus*, and yelloweye rockfish *S. ruberrimus*, but not for canary rockfish *S. pinniger*. Behaviorally impaired fish showed a decreased ability to maintain vertical orientation and were slower in exiting the release cage. Species differed in the degree of behavioral impairment resulting from barotrauma and in how rapidly behavioral impairment increased with depth of capture. When captured at depths between 40 and 99 m, blue rockfish showed the most serious behavioral impairment, 8 of 18 (44%) failing to swim away at the time of release and simply drifting off in a sideways or upside-down posture. In the same depth range all of the other species sampled showed only moderate behavioral impairment, which is indicative of some potential for survival after discard by the fishery. Surface observations of the external signs of barotrauma were variable among species and were poor indicators of which species would show behavioral impairment upon release at depth. Within individual species, however, the external signs of barotrauma were associated with an increased probability of behavioral impairment at time of release.

One of the primary management measures used on the U.S. West Coast to rebuild overfished stocks of canary rockfish *Sebastes pinniger* and yelloweye rockfish *S. ruberrimus* is a ban on the retention of fish in commercial and recreational hook-and-line fisheries (PFMC 2004). The effectiveness of non-retention as a management measure for rockfish *Sebastes* spp. is difficult to evaluate because discard survival rates are unknown and are likely to be dependent on depth of capture. Survival rates are often assumed to be quite low for rockfish captured at depths greater than about 20–30 m because of injuries that can result from the rapid expansion of gases trapped in their closed swim bladders (Starr et al. 2002). Expanding gases can cause swim bladder rupture, emboli, and protrusion of internal organs into the mouth (Parker et al. 2006; Burns and Restrepo 2002). In most rockfish species, the expanded gas is retained behind the everted esophagus, creating excess buoyancy and making it difficult for the fish to return to depth after release. Even when a rockfish can overcome the buoyancy problem the likelihood of its survival may be reduced by severe organ and tissue damage caused by expanded swim bladder gases, as demonstrated in other species

such as red snapper *Lutjanus campechanus* (Rummer and Bennett 2005).

Tools to help buoyant fish return to deep water more readily have been developed and include inverted barbless hooks, disposable gaffs, and remotely-triggered release cages (Theberge and Parker 2005). The venting of swim bladder gases with a hypodermic needle is also used to reduce excess buoyancy (Gotshall 1964; Keniry et al. 1996). However, overcoming surface buoyancy does not ensure the survival of a discarded fish. Returning to depth does recompress expanded gases, thereby reducing buoyancy and increasing the solubility of gases in body fluids. However, tissue and organ injuries from gas expansion and emboli may remain. The magnitude and proximate causes of mortality from capture and associated barotrauma are poorly understood for most rockfish species. To determine if nonretention is a sensible management measure for Pacific rockfishes more information is needed on the effects of barotrauma on survival.

Many of the standard techniques used to assess discard survival of fish are difficult to apply to Pacific rockfishes. Laboratory studies will not be representative of survival in the wild unless fish can be held at high pressure for extended periods and rapidly recompressed after simulated capture, as was done with black rockfish *S. melanops* by Parker et al. (2006) and with red snapper by Rummer and Bennett (2005). For deep-

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living rockfishes the required pressures can be difficult to obtain in flow-through tanks that also maintain acceptable water quality. Long-term holding also requires that fish be fed, a difficult task in high pressure holding tanks. Relating laboratory survival studies to what happens in the wild, where predation can be important, is also problematic. Field tagging or caging studies often introduce factors that confound estimates of survival, such as tag- or cage-related mortality, tag nonreporting, and tag shedding (Ricker 1975). For overfished rockfish species, restrictive management measures used to reduce fishery impacts also limit opportunities for tag recovery. Confronted with similar problems researchers studying discard survival in red snapper applied an observational approach to surface discard to estimate maximum potential survival based on the demonstrated ability of a fish to resubmerge (Wilson and Burns 1996; Baker et al. 2004). In this study we used a similar observational approach to evaluate the potential for survival of line-caught and released rockfish but applied it to postrecompression release behavior to eliminate effects strictly related to excess buoyancy from behavioral impairment caused by barotrauma. Specifically, we used a video-equipped underwater release cage to observe the behavior of rockfish released at depth to determine whether differences in depth of capture or severity of barotrauma signs at the surface could be linked to obvious behavioral impairment at time of release.

Methods

To observe rockfish behavior during recompression and release at depth we constructed a video camera-cage system that could be monitored and triggered from a vessel at the surface. The cage frame was constructed of 19 mm (inside diameter) aluminum tubing welded into a pyramid shape 51 cm high \times 81 cm wide at the base (Figure 1). The pyramid shape was used to match the field of view of an underwater video camera. The cage was covered in 10-mm square-mesh black plastic screen to provide a good background for observing fish. The base of the pyramid was hinged so that it could swing open and was held closed with a spring gate latch. We modified the latch with a piston and cylinder mechanism designed so that a blast of compressed air could drive the piston and release the latch. The cage system incorporated a four-point bridle made of 11-mm poly-dacron line configured to suspend the cage on its side while being lowered in the water column so that the door would open and swing downward by gravity to release the fish. The release cage was lowered and retrieved using an 11-mm poly-dacron support line. A separate line (91 m

long) between the camera-cage and the surface consisted of an insulated electrical cable to carry the video feed attached together at 1-m intervals to a polyethylene air hose for triggering the cage latch. Air for triggering the latch was provided by a scuba cylinder on deck. We used a Deep Sea Power and Light SSC-5000, low-light camera mounted at the apex (looking inward towards the cage door) of the cage-camera system to observe fish inside the cage using ambient light only.

Rockfish were captured by drifting over known rocky reef areas using hook-and-line gear typical of the recreational fishery, usually a combination of flies, plastic worms, and chunks of bait on hooks. Since we were interested in the effect of barotrauma on released rockfish, deeper reefs (>30 m) were initially targeted for sampling; however, some shallower reefs were also sampled (Figure 2). Each rockfish captured was quickly identified, measured (fork length [FL]; cm), and scored for external signs of barotrauma using the criteria shown in Table 1. Bottom depth at the capture site was noted for each fish and used for analysis of depth effects on barotrauma and behavior. For demersal rockfishes bottom depth was assumed to be representative of both capture depth and depth of neutral buoyancy that should be most closely related to the severity of barotrauma at capture. Some species, including blue rockfish *S. mystinus*, widow rockfish *S. entomelas*, and yellowtail rockfish *S. flavidus*, were often hooked above the bottom. For these species bottom depth may not be representative of capture depth or the depth of neutral buoyancy.

Depending on how many fish had been caught in each drift, up to three fish were immediately placed inside the cage (<2 min at the surface) and quickly lowered (descent rate of about 10–25 m/min) to a depth where obvious signs of barotrauma were no longer visible. Fish were not vented before being placed in the cage and released. The use of multiple fish in the cage allowed more observations of release behavior because ship time was limited; however, this caused another problem. Sometimes fish of the same species and approximate size were placed in the cage together. In such cases, individual fish observed on video could not be uniquely matched to the external barotrauma signs recorded at the surface. External sign data are not reported for these fish.

The depth of release varied with the bottom depth at capture and was measured by means of a depth gauge fastened within the cage to be readable off the video display. Deeper release depths were used for fish that appeared to have high surface buoyancy as evidenced by the swollen abdomen and the eversion of the esophagus into or beyond the mouth. The depth of

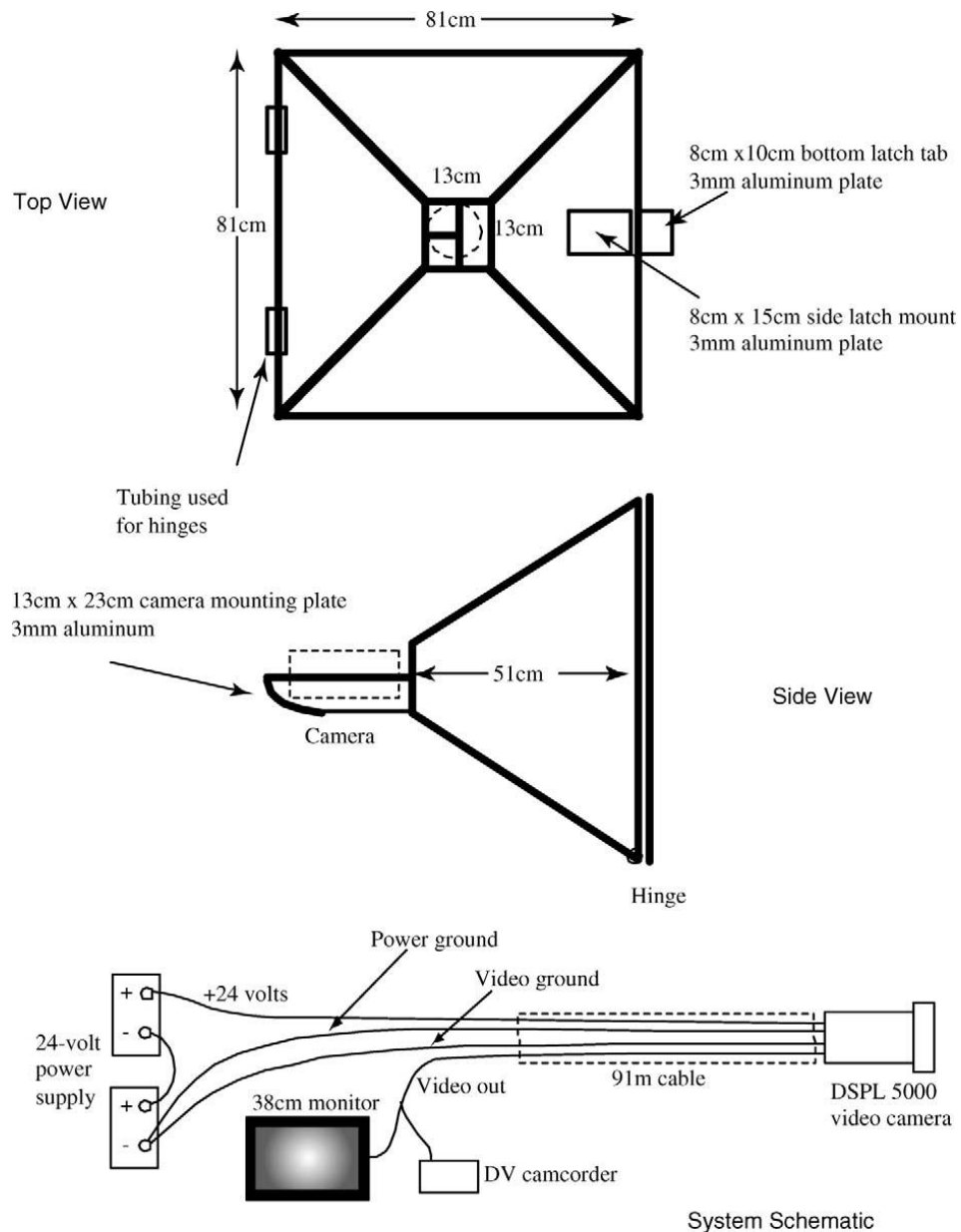


FIGURE 1.—Schematic of the video-equipped underwater release cage used to study the effects of barotrauma in Pacific rockfish.

release was a variable that could not be tightly controlled for individual fish because of variable vessel drift conditions, which limited the maximum depth at which the cage-camera system could be placed. Also, with multiple fish in the cage, often with differing degrees of barotrauma, depth of release could not be optimized for an individual fish. We triggered the cage door within about 5 s after reaching the maximum depth for each release. We observed the behavior of each fish on a video screen at the surface during

descent and escape from the cage. The video feed was simultaneously recorded to allow for later analysis of behavior.

To quantify differences between fish in the relative degree of behavioral impairment due to capture and barotrauma we scored each fish on four measures using a simple presence-absence system for each behavior. Since barotrauma and other possible effects from handling and capture (e.g., hook wounds) occurred simultaneously, it was not possible to differentiate

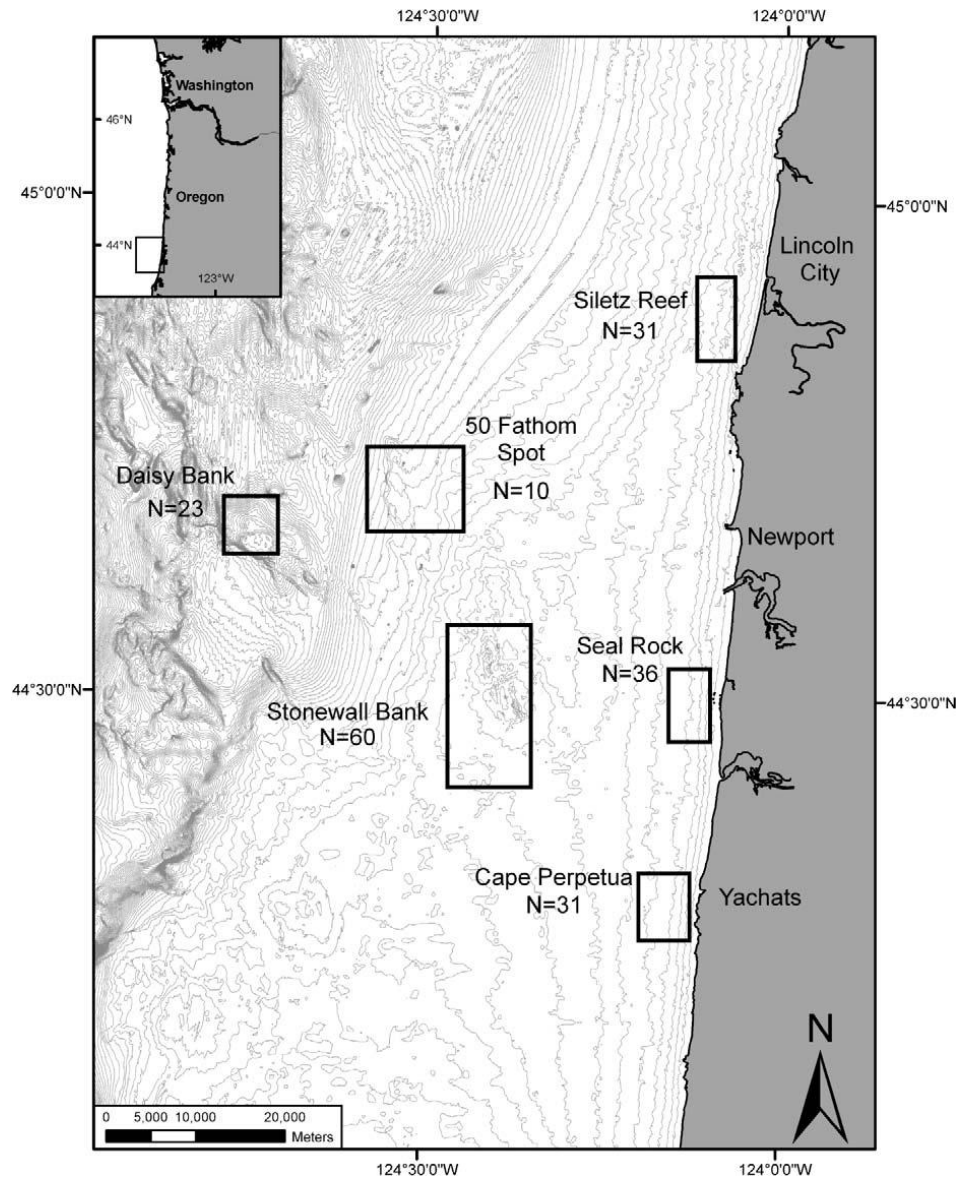


FIGURE 2.—Pacific rockfish sampling locations off the central Oregon coast. The letter *N* refers to the number of rockfish sampled at each location; the contour interval is 10 m.

these effects on release behavior. Because we handled the fish carefully, sampled across a wide depth range, and focused on depths at which the effects of barotrauma would be visually evident, we considered it reasonable to assume that the overriding cause of changes in release behavior would be the effect of injuries and stress from barotrauma. The behavioral measures we evaluated at release were as follows:

1. Did the fish demonstrate an ability to orient vertically within the cage at any time during descent?

2. Did the fish exit the cage vertically, sideways, or upside down?

3. Did the fish eventually swim away from the cage or simply drift out of view?

4. Did the fish swim away from the cage within 3 s of the opening of the cage door or take longer to exit?

The opening of the cage door was deemed to have occurred as soon as the door was open wide enough for a fish to escape, and not when the latch was triggered (there was often a short delay). Vertical orientation behavior was measured in relation to the upward

TABLE 1.—Indicators used to define external signs of barotrauma in Pacific rockfishes.

Sign	Indicator
Tight abdomen	Abdomen swollen, tight to the touch
Bulging membrane	Bulge in the branchiostegal membrane
Air in membrane	Air spaces or bubbles visible within the branchiostegal membrane
Bulging eye (popeye)	Eyes distended outwards from head
Gas in eye	Air present within the eye or the membrane covering the eye
Gut in mouth	Eversion of esophageal tissue (at least 1 cm in diameter) into the buccal cavity

direction determined from a small float suspended on a string inside the cage that could be viewed on the video feed. A fish was considered to be vertically oriented if it displayed swimming behavior in a downward direction or swam with its dorsal side towards the surface. A fish was deemed to be swimming away when sustained oscillation of the caudal fin was observed moving it in a direction away from the cage.

Behavioral scores on each measure were summed to provide a composite score for each fish and were also averaged across fish within each species and then summed to allow calculation of a mean composite score for each species sampled. To provide a dichotomous variable reflecting the presence or absence of behavioral impairment, we considered each fish that failed to display any evidence of an ability to orient (a zero on both 1 and 2 above) or signs of sluggishness (a zero on 3 or 4 above) to be behaviorally impaired.

For species with a sufficient number of observations (>20 individuals), we examined the effect of depth of

capture on behavioral impairment in two ways. We binned data from individual fish by depth of capture using nadirs in the depth frequency distribution as bin limits (12–39, 40–99, and 100–194 m). Mean composite behavioral scores by species were compared among these three depth zones using the nonparametric Kruskal–Wallis test (Sokal and Rohlf 1981). We also used logistic regression to measure the influence of depth on the probability of a fish being behaviorally impaired at time of release. Fitted logistic curves were compared graphically to evaluate between-species differences in the effect of depth on behavioral impairment. To further investigate differences among species we compared mean composite behavioral scores among species, within depth zones, using the Kruskal–Wallis test. We also examined the association between the external signs of barotrauma and the presence of behavioral impairment using Fisher’s exact test (Sokal and Rolf 1981).

Results

We observed the release behavior and external signs of barotrauma for 191 rockfish comprising nine different species captured at six sites in 2004 ($N = 119$), 2005 ($N = 50$), and 2006 ($N = 22$) (Figure 2). Bottom depth at the capture locations ranged from 12 to 194 m, with most of the observations ($N = 111$) from fish captured at bottom depths between 40 and 99 m. The most observations were collected from canary rockfish ($N = 48$; 20–53 cm FL), yelloweye rockfish ($N = 34$; 37–62 cm FL), black rockfish ($N = 34$; 30–49 cm FL), and blue rockfish ($N = 35$; 22–44 cm FL). Other species captured and observed included silvergray rockfish *S. brevispinis* ($N = 12$; 52–61 cm FL), widow rockfish ($N = 10$; 30–38 cm FL), yellowtail rockfish ($N = 7$; 30–49 cm FL), quillback rockfish *S. maliger* ($N = 6$; 31–40 cm FL), and tiger rockfish *S. nigrocinctus* ($N = 5$; 35–46 cm FL).

Increased depth of capture was associated with lower behavioral scores for black rockfish, blue rockfish, and yelloweye rockfish, suggesting that the detrimental effects of barotrauma increased with depth (Table 2; Figure 3). Logistic regression showed that as depth of capture increased, black rockfish, blue rockfish, and

TABLE 2.—Frequency distribution (numbers of individuals) of composite behavior scores for nine species of Pacific rockfish, by bottom depth at capture. Species with four or more observations in a depth zone are shown.

Species	Total score					All scores combined
	0	1	2	3	4	
12–39 m						
Black rockfish	0	0	0	3	13	16
Blue rockfish	1	2	1	0	13	17
Canary rockfish	0	3	1	4	2	10
40–99 m						
Black rockfish	1	0	6	5	6	18
Blue rockfish	8	3	7	0	0	18
Quillback rockfish	0	1	1	2	1	5
Tiger rockfish	0	0	3	2	0	5
Widow rockfish	2	1	1	2	4	10
Canary rockfish	1	4	5	11	11	32
Yelloweye rockfish	0	2	2	6	9	19
Yellowtail rockfish	0	0	2	2	0	4
109–194 m						
Canary rockfish	0	2	1	2	1	6
Silvergray rockfish	1	2	1	7	1	12
Yelloweye rockfish	2	2	6	3	2	15
Total	16	22	37	49	63	187

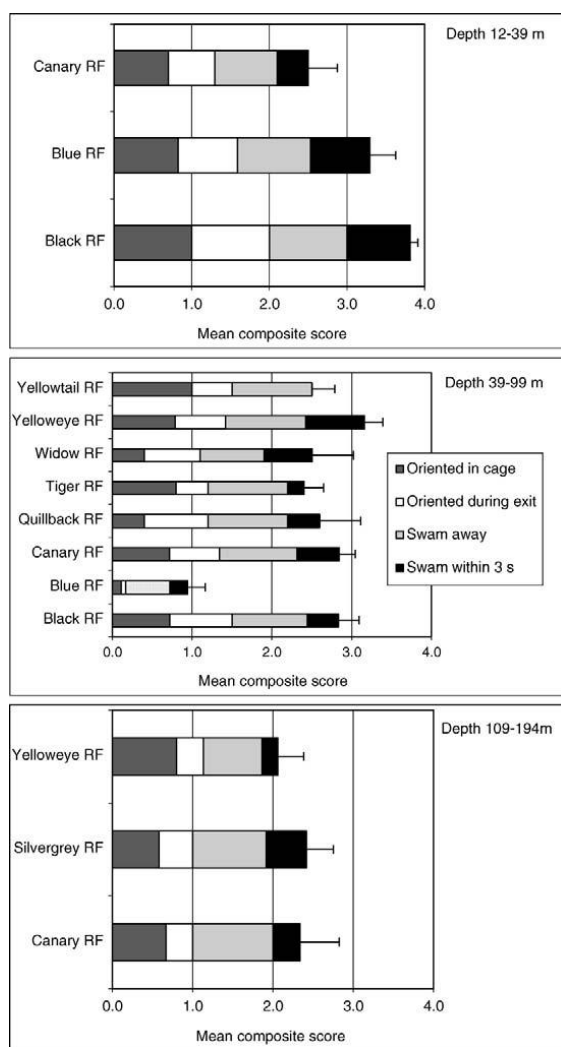


FIGURE 3.—Mean composite release behavior scores for nine species of Pacific rockfish (RF) captured at three depth ranges: 12–39, 39–99, and 109–194 m. The error bars represent the SEs of the mean combined scores for all four behaviors.

yelloweye rockfish were significantly more likely to be behaviorally impaired at time of release ($P < 0.01$; Table 3; Figure 4), while canary rockfish showed no consistent effect of depth of capture on release behavior ($P > 0.05$). Scores on individual behaviors for these three species showed that as depth of capture increased fish were less likely to display vertical orientation ability while exiting the cage and were more sluggish, often taking longer than 3 s to exit (Figure 3). Although many fish of all nine species showed some behavioral impairment when captured at depths greater than 39 m, individuals from most species still received a perfect behavioral score of 4 and a large proportion scored a composite score of 3 suggesting some potential for survival of fish that are released after capture from these depths, providing they can overcome surface buoyancy.

When captured at depths shallower than 40 m canary rockfish, blue rockfish, and black rockfish had different mean behavioral scores ($P < 0.05$; Figure 3), canary rockfish showing the greatest degree of behavioral impairment. Species captured between 40 and 99 m also showed significant differences in mean composite behavioral scores ($P < 0.001$), yelloweye rockfish and black rockfish scoring the highest and blue rockfish scoring well below all of the other species sampled (Figure 3). In the deepest depth zone sampled (100–194 m) there were no significant differences in mean behavioral score between species ($P > 0.05$).

Species showed very different rates of change in the proportion of behaviorally impaired fish as depth of capture increased (Figure 4; Table 2). Most black rockfish and blue rockfish captured at depths shallower than 40 m received a perfect behavioral score of 4 (Table 2). For depths of capture between 40 and 99 m, however, 6 of 18 black rockfish received a perfect behavioral score while none of the 18 blue rockfish captured received a score as high as 3 (Table 2). Behavioral impairment of blue rockfish increased more rapidly with depth and at shallower depths than impairment of black rockfish (Figure 4). Behavioral

TABLE 3.—Results of logistic regression analysis of the proportion of Pacific rockfish showing behavioral impairment at release on depth (m) at capture, by species; NS = nonsignificant.

Species	Independent variable	Coefficient	SE	Likelihood ratio chi-square	<i>P</i> -value
Black rockfish	Constant	-2.522	1.101	6.65	0.0099
	Depth	0.060	0.026		
Blue rockfish	Constant	-16.107	12.145	40.900	0.0001
	Depth	0.479	0.339		
Canary rockfish	Constant			0.154	NS
	Depth				
Yelloweye rockfish	Constant	-1.966	0.862	8.014	0.0046
	Depth	0.020	0.008		

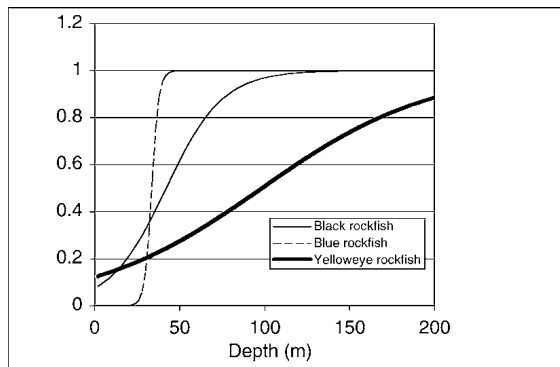


FIGURE 4.—Fitted logistic curves (Table 3) relating the proportions of three species of Pacific rockfish with impaired behavior at time of release (y-axis) to bottom depth at capture site.

impairment of yelloweye rockfish increased even more slowly with depth and at greater depths than black rockfish (Figure 4).

Rockfish species also differed in the ways in which behavior was impaired by barotrauma. For blue rockfish, the most severely impaired species, the ability to orient vertically was greatly diminished (Figure 3). This species rarely showed an ability to orient vertically within the cage, or during exit from the cage, except when captured at depths less than 40 m. Many of the blue rockfish captured between 40 and 99 m appeared to be severely impaired at time of release. Eight of the 18 blue rockfish sampled at these depths (44%) actually failed to swim away at all, but simply drifted off in a sideways or upside down orientation when released. In contrast, all but one of the

18 black rockfish (6%) and all 5 of the tiger rockfish captured at these depths swam off, but most showed a tendency to be delayed beyond 3 s in exiting the cage. At deeper depths all of the species sampled showed a tendency to be more sluggish in exiting the cage and showed less of a tendency to be vertically oriented while exiting (Figure 3). One of the canary rockfish collected in the deepest zone showed what appeared to be evidence of impaired vision. This fish had both “bulging eyes” (exophthalmia) and “gas in the eye” when examined at the surface. After recompression in the cage this fish was observed to repeatedly swim slowly and directly into the cage frame and sides, even though outward signs of barotrauma had been reversed; water clarity was excellent and the cage door was wide open.

The frequency of external barotrauma signs was variable among species (Table 4), the lowest frequencies of the six signs being seen in yellowtail rockfish. The least common sign was gas in the eye, which was not observed in yellowtail or quillback rockfish. Black rockfish, blue rockfish, and yelloweye rockfish showed an increased frequency of barotrauma signs with increased depth of capture (Table 4). The same trend was not observed for canary rockfish with many of the signs being slightly less frequent in fish captured at greater depths. The other species captured were either captured too infrequently (e.g., tiger rockfish) or captured only in a single depth zone, preventing meaningful comparisons of the frequency of external signs across depth.

The differences among species in the frequency and severity of behavioral impairment at time of release

TABLE 4.—Proportions of Pacific rockfish species displaying external barotrauma signs by sign and bottom depth at capture. Species with four or more observations in a depth zone are shown.

Species (sample size)	Tight body	Bulging membrane	Gas in membrane	Bulging eye	Gas in eye	Gut in mouth
12–39 m						
Black rockfish (16)	0.81	0.31	0.19	0.06	0.06	0.38
Blue rockfish (17)	0.41	0.24	0.06	0.06	0.00	0.35
Canary rockfish (10)	0.90	1.00	1.00	0.30	0.20	1.00
40–99 m						
Black rockfish (18)	1.00	0.94	0.78	0.33	0.17	0.94
Blue rockfish (18)	0.56	0.78	0.50	0.17	0.06	0.89
Quillback rockfish (5)	1.00	1.00	1.00	0.60	0.00	0.20
Tiger rockfish (5)	1.00	1.00	1.00	0.20	0.20	0.80
Widow rockfish (10)	0.50	0.90	0.60	0.30	0.10	1.00
Canary rockfish (32)	0.91	1.00	0.97	0.56	0.38	0.88
Yelloweye rockfish (19)	0.84	1.00	0.95	0.42	0.11	0.95
Yellowtail rockfish (4)	0.25	1.00	0.50	0.00	0.00	0.00
100–194 m						
Canary rockfish (6)	0.83	1.00	1.00	0.33	0.17	0.67
Silvergray rockfish (12)	0.92	1.00	1.00	0.83	0.75	1.00
Yelloweye rockfish (15)	1.00	1.00	1.00	0.80	0.53	1.00

were not reflected in differences with respect to external barotrauma signs (Table 4). For example, blue rockfish captured between 40 and 99 m were the most behaviorally impaired species at time of release but showed similar or lower frequencies of external barotrauma signs in comparison with other species captured in that depth range (Table 4). Within some species, however, an increased frequency of certain external barotrauma signs was associated with a higher probability of behavioral impairment at time of release. In blue rockfish the presence of almost any external barotrauma sign was associated with a higher probability of behavioral impairment at release. The presence of “bulging membrane” or “gut in the mouth” was most strongly associated with behavioral impairment in blue rockfish ($P < 0.001$). In black rockfish the presence of bulging membrane or gas in membrane was associated with behavioral impairment ($P < 0.05$). In the yelloweye rockfish sampled, only gas in the eye was associated with behavioral impairment ($P < 0.05$). In contrast, canary rockfish showed no significant associations between the presence of external signs of barotrauma and behavioral impairment at time of release ($P > 0.05$); however, nonsignificant test results must be interpreted cautiously due to the relatively small sample sizes obtained in this study. These differences in the degree of association between the external signs of barotrauma and the degree of behavioral impairment at time of release further support the conclusion that the effects of barotrauma on Pacific rockfishes are highly species specific.

Discussion

Our observations strongly suggest that the effects of barotrauma on Pacific rockfishes are highly species specific and that the condition of different rockfish species at the surface may not be a good indicator of the relative potential for survival after submergence and recompression. Many of the individual rockfish examined in this study did not show severe behavioral impairment after recompression and displayed an ability to maintain vertical orientation and swim away quickly upon release. At the surface, normal movement, even opercular movements, can be impaired by the extreme expansion of the swim bladder and production of blood gases, conditions that are reversed during recompression. Many of these rockfish have some potential, for at least short-term survival, if surface buoyancy can be overcome and the fish is returned to depth quickly. The observation by many anglers that rockfish with severe barotrauma at the surface appear dead is apparently inaccurate.

The potential for longer-term survival and a return to normal wild behavior, however, remains unknown for

most rockfish species. Detailed laboratory studies of decompression injuries in other species are not encouraging. Red snapper (Rummer and Bennett 2005) showed a wide array of displacement and compression injuries from expanded swim bladder gases, including injuries to the digestive system, liver, and heart. Black rockfish can also sustain serious injuries from barotrauma, but have been shown to survive simulated capture from an acclimation depth of 32 m at high rates (97% of 90 fish tested) after 21 d, with all fish resuming normal feeding behavior (Parker et al. 2006). In our study most of the black rockfish captured and released had high behavioral scores, consistent with the high survival rates found in laboratory studies. However, at similar depths of capture most blue rockfish received very low behavioral scores suggestive of low rates of survival.

Observation of release behavior at depth was effective for identifying rockfish with behavioral impairment after capture and associated barotrauma. Behavioral scores revealed gross differences between rockfish species, as well as effects from increased barotrauma associated with greater depth of capture. The video camera–cage provided information that could be very useful in tagging programs designed to study rockfish movements or discard survival, providing quantifiable information on fish condition at time of release but after reversal of external barotrauma signs via recompression. It may be possible to develop more sophisticated behavioral assays for use with the camera–cage system that better test a fish’s ability to see, or to orient and navigate around obstacles or through confined passages, giving even better indications of general postrelease competency. More sophisticated behavioral tests at time of release could provide quantitative data that could better relate to survival potential in the wild, for example, to the ability to detect and evade predatory fish, such as lingcod *Ophiodon elongatus*.

For black, blue, and yelloweye rockfish, increased depth of capture was associated with increased behavioral impairment at time of release and higher incidence of the external signs of barotrauma at the surface. This was expected based on Boyle’s law defining an inverse relationship between gas volume and pressure, which predicted larger increases in swim bladder gas volume during forced ascents from greater acclimation depths. However, data collected for canary rockfish did not follow this pattern. The external signs of barotrauma were not consistently more frequent in canary rockfish captured at greater depths and behavioral impairment was not related to depth of capture, at least in the range of depths we sampled. Moreover, the rates of change in behavioral impairment

as depth of capture increased varied between black, blue, and yelloweye rockfish, suggesting that several factors influence how different rockfish species are affected by barotrauma during capture. For a given bottom depth at capture species or individual fish that have spent significant time above the bottom should become neutrally buoyant at shallower depths, resulting in less barotrauma at capture and potentially less behavioral impairment at release (Parker et al. 2006). While this is one possible explanation for the lack of a depth effect on barotrauma signs and behavior of canary rockfish at release, previous studies do not suggest extensive pelagic feeding for this species (Brodeur and Pearcy 1984). Perhaps the most likely explanation for interspecific differences in the effects of barotrauma is that individual species have differences in anatomy and physiology that alter how and where gas expands and collects and which tissues are damaged when internal pressures reach some critical point. To evaluate this hypothesis more information on the types and extent of internal damage from barotrauma in rockfish is needed, as has been collected for red snapper (Rummer and Bennett 2005). The ability to remove gas from the body during forced ascent may also differ among species. Generally, rockfish are believed to be very slow at removing gas from their swim bladders, requiring days to accomplish significant changes (Parker et al. 2006). However, the rates of acclimation to pressure change differ among species. At one extreme, China rockfish *S. nebulosus* took over 250 h to acclimate to a 4 atmospheres (depth equivalent of 30 m) change in pressure (Parker et al. 2006). At the other extreme, yellowtail rockfish have been reported to expel gases during decompression, greatly reducing the adverse effects of gas expansion (Pearcy 1992). For most of the rockfishes acclimation rates to pressure change have not been studied.

Many of the blue rockfish captured in this study showed behavior indicative of poor survival potential after recompression and release at depth. This finding is consistent with results from earlier blue rockfish tagging studies. Gotshall (1964) tagged blue rockfish in waters off California and reported recoveries by condition at initial capture, separating fish into those tagged without venting, those deflated by venting and those whose "stomachs" had to be pushed back into their gut cavity after venting. Tag recovery rates for the three groups were 2.14, 1.76 and 0.81%, respectively. Gotshall (1964) interpreted these data as evidence that venting fish might be detrimental to survival. More likely though, it is evidence that blue rockfish with more severe barotrauma survive at lower rates, as evidenced by the lower return rates for fish needing

venting and much lower return rates for fish with everted stomachs.

This study focused on release behavior after recompression, separating behavioral issues related to excess buoyancy from those related to injuries from barotrauma. Tagging studies examining postrelease survival of marine fish with excess buoyancy have often focused on measuring survival benefits from venting fish at the surface before release (Gotshall 1964; Collins et al. 1999). Behavioral studies of discarded marine fish with excess buoyancy have focused on the fish's ability to resubmerge, supplying only estimates of maximum potential survival based on condition at the surface (Wilson and Burns 1996; Baker et al. 2004). Our data show that the potential for postrelease survival of Pacific rockfishes is better demonstrated by observations of postrecompression behavior than by methods focusing on the ability of fish to overcome surface buoyancy.

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