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Effectiveness of descending devices to mitigate the effects of barotrauma among rockfishes (*Sebastes spp.*) in California recreational fisheries

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ABSTRACT

Fishes caught from depth often suffer from barotrauma, which can result in high mortality rates (close to 100% for some species) when released at the surface. To mitigate for this, the recreational fishing community proactively developed several different types of descending devices designed to assist unwanted or prohibited fish back toward the bottom for release. Post-release survival using recompression techniques has been documented for some species, which has allowed fisheries managers to begin revising estimates of total fishing mortality in some cases, but the effectiveness of the different commercially-available descending device types has not been quantified. We conducted 24 Commercial Passenger Fishing Vessel charters at 11 sites along the coast of California, and invited volunteer recreational anglers aboard the charters to test the effectiveness of five different commercially available device types, and respond to a survey of their device preferences. During release, all fish were descended either to 46 m (150 ft) depth or directly to the bottom, whichever depth was shallower. While there were some significant differences between device types, all devices were effective for releasing rockfishes back to depth. Initial post-release mortality (defined as all mortality events observable from the vessel while fishing) across all devices was relatively low (7.5%) in capture depths less than 100 m, but increased significantly to 16.4% at capture depths from 100 to 135 m. Our results suggest that rockfishes should be released at least half-way to the bottom (preferably directly to the bottom) for the device to be effective in minimizing post-release mortality. The time required to use the devices averaged under three minutes regardless of device type, meaning that all device types could be used efficiently on deck, but anglers showed a clear preference for the SeaQualizer™. This device produced some of the lowest release error rates and lowest initial post-release mortality of rockfishes aboard the charters, so angler preference coincided with device effectiveness. Collaborating with the recreational fishing community was an extremely important aspect to this study, provided more robust results, and fostered working relationships that can be built upon in future research projects.

1. Introduction

California recreational fisheries have significant economic impacts (Lovell et al., 2013) and have exhibited a range of temporal trends during the last century (Hill and Barnes, 1998; Dotson and Charter, 2003, Bellquist & Semmens 2016). Evidence of population declines are documented for many species, especially those with behavior and life history characteristics that increase susceptibility to overfishing (e.g., MacCall and He, 2002; Butler et al., 2003). However, recent evidence

suggests that some species are now showing signs of recovery following more stringent fisheries management policies since 2001 (Sewell et al., 2013). One such species group, the rockfishes (*Sebastes spp.*), generally exhibit slow growth, long life spans, limited daily movement, and susceptibility to barotrauma, which collectively translate to high vulnerability to overfishing. Indeed, rockfishes showed signs of both population decline and serial depletion from the 1970s to the 1990s due to overfishing (Love et al., 1998; Miller et al., 2014), with the longest lived and slowest growing species among the most heavily impacted (Butler

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et al., 1999, 2003). In response, fisheries managers implemented a progressive suite of regulations beginning in 2001 for both recreational and commercial fisheries, including fishing depth restrictions, offshore marine protected areas (Rockfish Conservation Areas, Cowcod Conservation Areas) in federal waters, networks of coastal MPAs in state waters, species moratoriums, adjusted recreational bag limits for some species, gear restrictions, and open/closed seasons. The depth restrictions (i.e., fishing prohibited deeper than a specified depth), which have been adjusted multiple times since 2001, were among the most impactful because they effectively created the largest statewide marine protected area to date. These depth restrictions were initially implemented in California to reduce fisheries interactions with certain species such as Cowcod (*S. levis*), which were severely impacted at the time. After approximately 18 years under this new management regime, in addition to some years of strong juvenile rockfish recruitment (Love et al., 2012), eight of the original ten species listed as overfished are now declared fully rebuilt (e.g., Field et al., 2010; Sewell et al., 2013; Thorson and Wetzel, 2016). Of the remaining two species, both Cowcod and Yelloweye Rockfish (*S. ruberrimus*) have earlier projected rebuild dates than originally estimated (Dick and MacCall, 2014; Gertseva and Cope, 2018).

Despite their vulnerability to inadequate management and overfishing, the rockfish species complex consistently represents the top ranked recreational fishery in the state by volume (number of fish), with approximately 2 million fish landed aboard Commercial Passenger Fishing Vessels (CPFVs) and private vessels in 2015 alone (CDFW 2016). While the vast majority of rockfishes caught by anglers are kept for consumption, Cowcod, Yelloweye, and Bronzespotted (*S. gilii*) rockfishes must be released by law when caught incidentally, while other species, such as Canary (*S. pinniger*) and Black rockfish (*S. melanops*), have reduced daily bag limits (<https://www.wildlife.ca.gov/Fishing/Ocean/Regulations/Groundfish-Summary#south>). The list of both prohibited and restricted species has changed over the last decade due to improvements in stock status for species such as Bocaccio and Canary rockfishes (<https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=34082&inline=true>). However, rockfishes inhabit a broad range of depths, which can lead to multiple physiological symptoms of barotrauma upon capture with hook-and-line. The primary barotrauma symptoms in rockfishes consist of a generally firm (bloated) body from an expanded swim bladder, emboli under the pharyngo-cleithral membrane (inflated “gill membrane”) indicating the escape of gas into the peritoneal cavity, an everted esophagus and stomach, exophthalmia (“pop-eye”), and ocular emphysema (gas bubbles accumulated under the eye’s cornea). These symptoms, which often co-occur, frequently result in mortality if the fish are released at the surface. Mortality often results from the inability to swim back to depth against their excessive buoyancy, which is typically followed by predation from seabirds or marine mammals, such as California sea lions (*Zalophus californianus*) and harbor seals (*Phoca vitulina*).

Research focusing on different recompression techniques has shown evidence for increased post-release survival of U.S. west coast rockfishes, depending on factors such as depth of capture and severity of barotrauma (Jarvis and Lowe, 2008; Hochhalter and Reed, 2011; Hannah et al., 2012; Pribyl et al., 2012). The recreational fishing industry used these findings to pro-actively develop several different types of descending devices to release excessively buoyant fish. These devices all share the common function of assisting fish either partially or completely back to depths that allow recompression and, hopefully, recovery from barotrauma. To date, there is documented recovery of both vision (Brill et al., 2008; Rogers et al., 2011) and swim bladder function (Parker et al., 2006) following exposure to decompression and rapid recompression in rockfishes. Even large, deepwater groupers can be successfully descended to maximize post-release survival (Runde and Buckel, 2018). This growing body of literature and the increased volunteer usage of descending devices by the recreational fishing community has recently contributed to the relaxation of fishing regulations

in some cases. For example, California groundfish fishing depth restrictions were recently changed from 50 to 60 fathoms (approximately 91–110 m) in the Southern California Management Area (from Point Conception to the U.S.-Mexico border) by the Pacific Fisheries Management Council following evidence of post-release survival for Cowcod (Wegner et al. *in prep*) and other rockfishes when using descending devices (Jarvis and Lowe, 2008; Hannah et al., 2012, http://www.pcouncil.org/wp-content/uploads/D3b_GMT_MAR2014BB.pdf). This opened significantly more nearshore area for recreational bottom fishing.

There are several types of descending devices available on the market, some of which are designed to return fish back to the bottom while others are designed to release fish at specific depths in the water column. Recreational anglers use all device types, but there has been no study to date focusing on the effectiveness of, angler preference for, or use rates of the different device types in California. The Pacific Fisheries Management Council requested this information to allow a more comprehensive integration of descending devices into management decisions.

Our goal was to work collaboratively with the recreational fishing community to test the five most popular devices used by California recreational anglers. We measured device effectiveness based on the overall success rate of fish release, device usage error rates, and the time required to use each device. Each of these metrics affect the amount of time each fish is handled at the surface, which influences their mortality rates during catch-and-release, especially if signs of barotrauma are exhibited (Jarvis and Lowe, 2008). Anglers are also more likely to use easier, faster devices that allow them to return to fishing more quickly. We recorded capture depth and physical barotrauma symptoms to measure how device effectiveness changes with increasing symptoms and severity of barotrauma. We also measured initial post-release mortality (defined as all mortality events observable from the vessel while fishing) relative to descending device type and capture depth. Angler surveys after each trip provided estimates of user preference for and perceived effectiveness of each device type. This collaborative approach with recreational anglers allowed us to integrate quantitative estimates of device effectiveness for releasing protected or unwanted rockfishes, along with angler perceptions of and preferences for different device types.

2. Methods

In collaboration with the recreational fishing community, we conducted fishing charters aboard CPFVs at four sites in southern California and seven sites in central and northern California from May 2015 – Nov 2016 (Fig. 1). Field sites were chosen based on known popular rockfish fishing locations in each of the two regions, and CPFVs were chosen among those that regularly target rockfishes on ½-day and ¾-day fishing trips. Fishing gear consisted of hook-and-line gear legally allowed for state recreational bottom-fishing (typically a lead weight with two baited hooks), and anglers were free to choose from any of the five different descending device types available for testing. This allowed the project results to be representative of typical rockfish fishing trips within the CPFV fleet. Volunteer anglers were recruited for each trip with invites through boat captains and crew, the Sportfishing Association of California, recreational fishing clubs, and our ongoing initiative, the Coastal Angler Tagging Cooperative (www.cooperativefishtagging.org), which is a program that joins anglers, scientists, and managers to conduct field research focused on California fisheries.

Each trip consisted of up to 15 volunteer anglers and 6 data recorders. On each trip, the anglers were introduced to each of the five descending devices (the SeaQualizer™, RokLees™, Shelton Fish Descender™, Blacktip Catch and Release Recompression Tool™, and the inverted, weighted milk crate, see Fig. 2), and trained on their proper use for releasing fishes. Immediately following capture, fishermen brought their rockfish to a tagging station on the back deck, where the

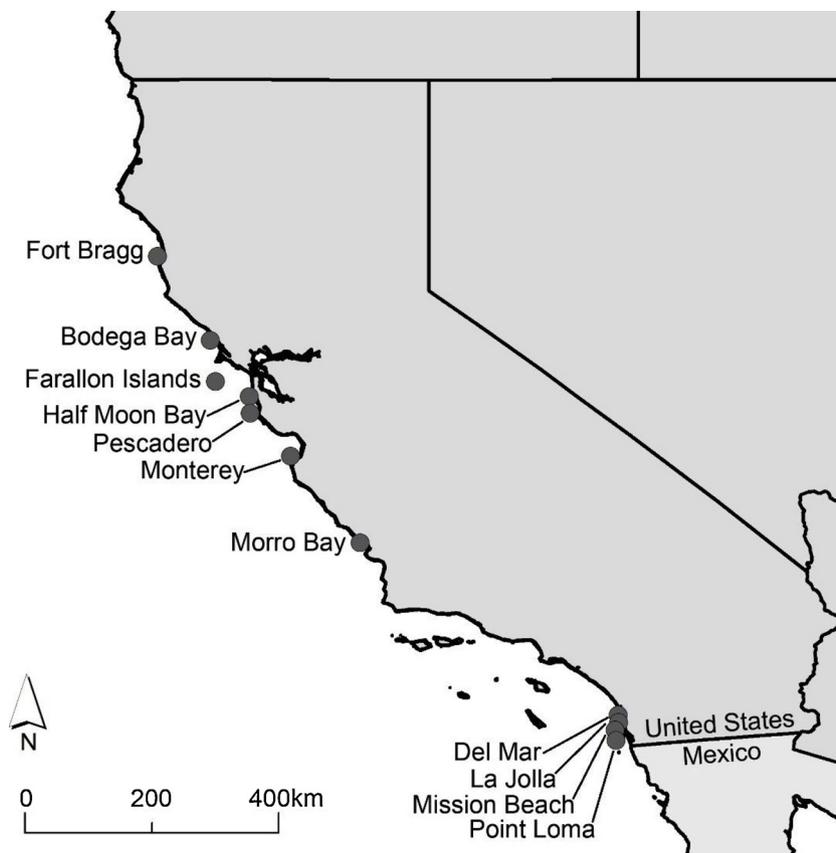


Fig. 1. Site map of the California coast showing 11 sites from Fort Bragg to Point Loma at which rockfish catch-and-release and descending device testing occurred.

fish was identified, measured for fork length (mm), and assessed for five common symptoms of barotrauma: firm body, inflated pharyngo-cleithral (gill) membrane, esophageal eversion, exophthalmia (“pop-eye”), and ocular emphysema (gas bubbles under eye cornea). Each fish was then tagged with a Floy™ FD-94 T-bar anchor ID tag and returned to the fisherman for release using one of the five devices (anglers were encouraged to use each of the five devices to gain hands-on experience and determine which of the devices they preferred). The release depth of 46 m (150 ft) was defined based on the deepest setting available on the standard market version of the SeaQualizer, which is a commonly used device that can be set to three optional release depths (50 ft,

100 ft, or 150 ft). In depths shallower than 46 m (150 ft), fish were descended all the way to the bottom using all five device types, although the SeaQualizer could only be used when the pre-set release depth was very close or equal to the bottom depth. In depths deeper than 46 m, fish were released at a constant 46 m depth, regardless of device type, to maintain consistency across device types. This study is thus designed to be representative of the release methods commonly used by the rockfish angling community. When using devices other than the SeaQualizer, lines were marked at the 46 m depth point to ensure an accurate release depth, although some anglers estimated the 46 m release depth based on prior angling experience. For each rockfish

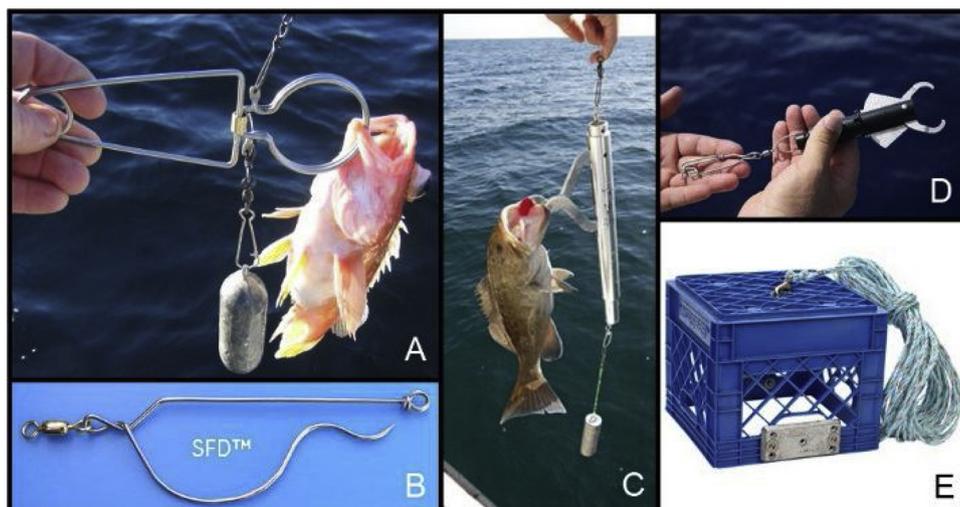


Fig. 2. The five descending devices assessed in this study: the RockLees (a), Shelton Fish Descender (b), Blacktip Catch and Release Recompression Tool (c), SeaQualizer (d), and weighted, inverted milk crate (e).

Table 1

Depth, fishing effort, and catch-per-unit-effort by region and site when targeting rockfishes aboard 24 Commercial Passenger Fishing Vessel (CPFV) trips in southern (17 trips) and central/northern (7 trips) California.

Region	Site	Mean depth and range (m)	Effort (angler-hours)	CPUE (fish/angler-hour)
Southern CA	Del Mar	94 (69-135)	317.80	1.25
	La Jolla	86 (42-152)	165.78	0.62
	Mission Beach	103 (60-147)	510.95	1.20
	Point Loma	91 (75-104)	73.60	0.88
Central CA	Farallon Islands	54 (52-55)	32.99	4.64
	Bodega Bay	46 (44-48)	23.44	6.61
	Pescadero	28 (25-30)	34.10	5.04
	Fort Bragg	26 (15-36)	25.65	1.75
	Half Moon Bay	49 (44-57)	36.67	2.97
	Monterey	59 (44-66)	36.96	2.60
	Morro Bay	53 (19-74)	40.68	3.84

caught, data collectors recorded species, Floy™ tag ID number, fork length (mm), depth of capture, latitude/longitude, descending device type used for release, time (to the second) the fish was out of the water, time it took to load the fish on the selected descending device, total time required to release the fish (time at which the device was retrieved back into the boat), and number of descending device errors (times fish fell off the device either during the transition of the fish to the water or during the descent of the device underwater to depth).

All observed rockfish mortality events were recorded, which allowed us to generate estimates of initial post-release mortality rates. Mortality events occurred when fish succumbed to hooking-related injuries; failed to descend to the release depth due to device user error, device function error, or excessive exhaustion/barotrauma; and/or died from predation by California sea lions, harbor seals, or marine birds. These estimates of initial mortality did not include delayed mortality that was unobservable after fish were successfully released. Floy tag IDs were used to help identify individual mortalities when multiple fish were being released simultaneously by different anglers.

At the end of each trip, each participating volunteer angler completed a short questionnaire. This contained ten questions focused on anglers' perceptions of device effectiveness, ease of use, preference between device types, recommendations to other anglers, and use rates of the devices. Anglers were first asked to rank (1–5) each device type in terms of perceived effectiveness, ease of use, and preference for using aboard both CPFVs and private vessels. Mean ranks (1 = best, 5 = worst) were then used to assess overall perceptions among the anglers regarding use of the devices in different contexts. Each angler also provided information regarding how often they already used devices prior to this study, and which device they might prefer if cost wasn't a factor. This information was expressed in the percentage of anglers responding in favor of each device type. This questionnaire thus allowed us to combine angler preferences and perceived effectiveness of devices with quantitative estimates of device effectiveness measured aboard the charters.

Catch-and-release device effectiveness and angler survey data were assessed for the southern and central/northern California regions both separately and combined. Species other than those from the genus *Sebastes*, such as Pacific Sanddab (*Citharichthys sordidus*) and Lingcod (*Ophiodon elongatus*), were omitted from the catch-and-release analyses as they typically do not exhibit barotrauma symptoms and were released directly at the surface without descending devices. Initial post-release mortality rates and barotrauma symptoms were both analyzed with respect to capture depth across the study region using logistic regression. We also compared effectiveness between devices based on time to load (the amount of time required for each fish to be successfully loaded onto the device and placed in the water), total release time

(the amount of time required to load, release, and retrieve the device), and total time on deck (the amount of time each fish was out of the water). Differences in time to load and total release times between regions were compared using a two-sample *t*-test. Differences between device types in the time to load and total release time were tested using a one-way ANOVA and Tukey's post hoc tests for pairwise comparisons. Frequency distributions of total time on deck were compared using a *t*-test between the central/northern and southern California regions. All analyses were conducted using Statsoft Statistica 13 Academic version.

3. Results

A total of 2275 rockfishes from 32 species (genus *Sebastes*) were caught and released using the five different descending devices tested (the SeaQualizer™, RokLees™, Shelton Fish Descender™, Blacktip Catch and Release Recompression Tool™, and the inverted, weighted milk crate) during 24 CPFV fishing charters at 11 different sites along the California coast. Specifically, 1389 rockfishes from 20 species were caught and released by 192 volunteer anglers aboard 17 CPFV fishing charters at four sites in southern California, and 886 rockfishes from 18 species were caught and released by 60 volunteer anglers at seven sites in central/northern California. Differences in the recreational rockfish fisheries between central/northern and southern California resulted in shallower depths of capture and greater catch-per-unit-effort (CPUE) in central/northern California than in southern California (Table 1). Overall, capture depths in central/northern California ranged from 14 to 74 m, averaging 46 ± 15 m (SD), while capture depths in southern California ranged from 42 to 152 m, averaging 99 ± 15 m (SD). Regional differences in species assemblage were evident, with the top three species in central/northern California consisting of Yellowtail (*S. flavidus*), Canary, and Deacon (*S. diaconus*) rockfishes, while the top three species in southern California were Vermilion (*S. miniatus*), Greenspotted (*S. chlorostictus*), and Greenstriped (*S. elongatus*) rockfishes (Fig. 3).

Initial post-release mortality, defined as mortality events directly observed during the catch-and-release process, was compared between the five device types and across a range of depths. No control group was included (i.e. release of rockfishes without devices at all) because 90% of the rockfishes caught exhibited severe signs of barotrauma, including emboli within the pharyngo-cleithral membrane, esophageal eversion, and/or exophthalmia. Virtually all of these individuals were too buoyant to swim back to depth without the use of a descending device, so it was assumed that these individuals would have died otherwise. The overall initial survival rate for rockfishes being released with descending devices was 91.4 percent. This was associated with initial mortality rates of 4.3%, 11.3%, 9.0%, 8.4%, and 5.4% for the SeaQualizer, Roklees, Shelton, Blacktip, and milk crate, respectively. In southern California, the SeaQualizer resulted in the lowest rate of post-release mortality overall (6%), while the Blacktip resulted in the highest post-release mortality overall (16%, Fig. 4). In central/northern California, where initial post-release mortality was considerably less, the SeaQualizer yielded the best results with only 2% mortality, while the Roklees yielded the highest initial mortality at 6% (Fig. 4). We also compared initial post-release mortality across the entire depth range of our samples (using 5 m depth bins) in both regions. Logistic regression analyses indicated a significant effect of depth on initial post-release mortality in southern California ($X^2 = 5.04$, $df = 1$, $p = 0.025$), but no effect in central California due to the shallower and narrower range of capture depths that resulted in a more limited sample size in this region (Table 1). There was a relatively low average post-release mortality of approximately 7.5% at depths from 20 to 105 m, with an increase in initial mortality at depths from 110 to 130 m, averaging approximately 16.4% (Fig. 5). Relatedly, symptoms of barotrauma increased relatively consistently with depth, with firm body and inflation of the pharyngo-cleithral membrane showing the highest rates of occurrence but no effect of depth ($p = 0.17$ and 0.18 , respectively), followed by

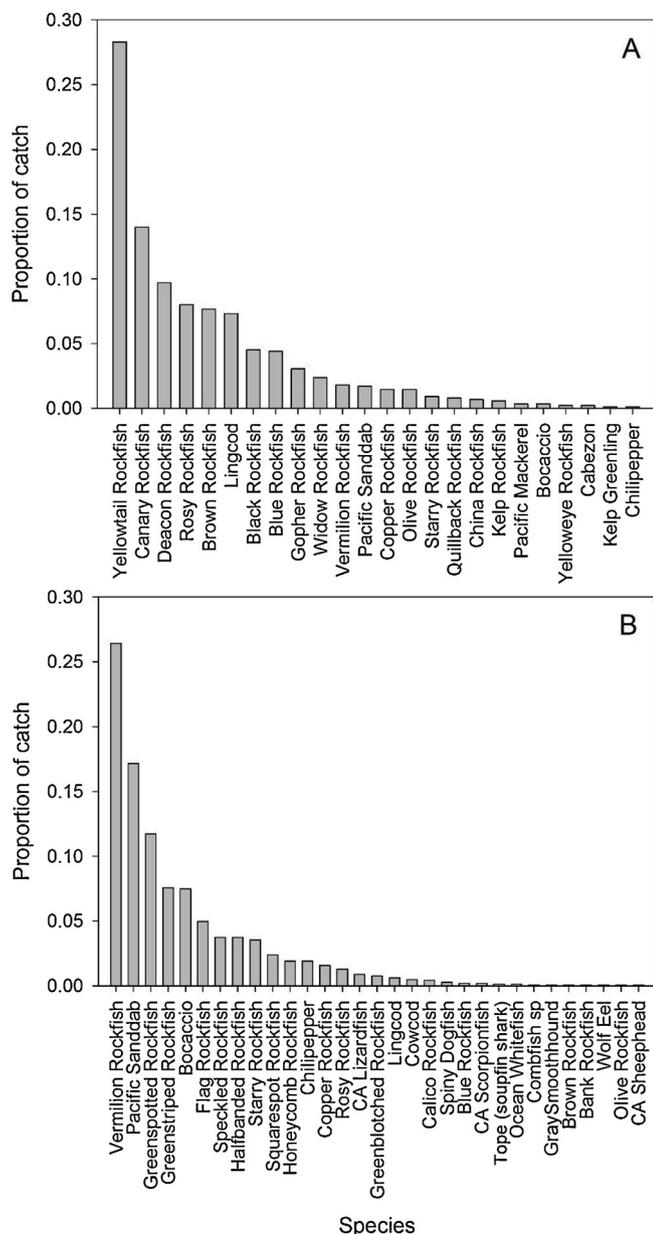


Fig. 3. Proportional species composition aboard Commercial Passenger Fishing Vessel (CPFV) trips targeting rockfishes in central/northern (a) and southern (b) California.

esophageal eversion ($p < 0.01$), exophthalmia ($p < 0.01$), and lastly, ocular emphysema ($p < 0.01$, Fig. 6).

While post-release mortality resulted from multiple factors, both user and device functionality were measured to understand the potential influence of the catch and release process on mortality estimates. The mean total time out of water (time on deck) for each fish averaged $2.43 \text{ min} \pm 1.23 \text{ min}$ (SD). The time fish were held out of water before reaching the devices (i.e., for tagging, measurement, and assessment of barotrauma) was not significantly different between device types ($F = 1.67$, $df = 4$, $p = 0.15$). Following tagging, the fish was returned to the fisherman for release and the time to load and total release time (as defined in the methods section) were recorded. Collectively, the mean total time to load a device was 0.67 ± 0.73 (SD) minutes, and mean total release time was 2.92 ± 1.60 (SD) minutes. However, there were significant differences in total release time ($F = 16.03$, $df = 4$, $p < 0.001$) and time to load ($F = 50.59$, $df = 4$, $p < 0.001$) between the five different device types (Fig. 7). Post hoc pairwise

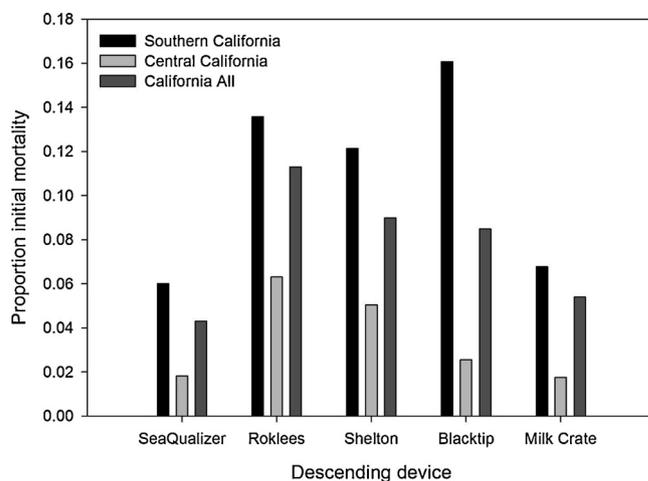


Fig. 4. Initial post-release mortality for all rockfishes separated by descending device type in southern California (black), central California (light gray) and combined across regions (dark gray).

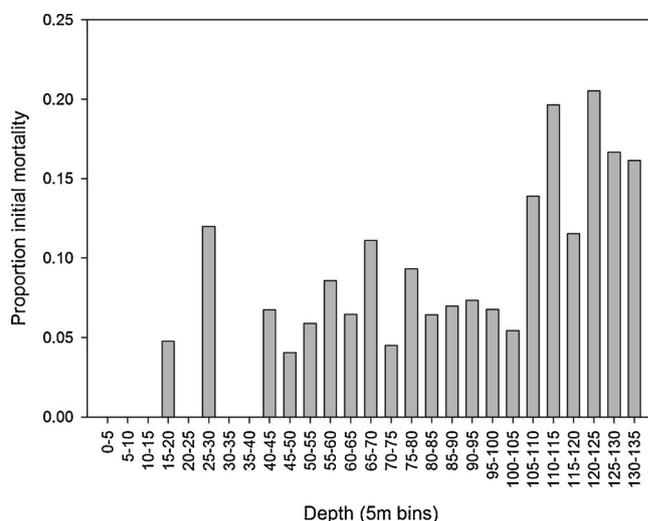


Fig. 5. The proportion of catch exhibiting initial mortality (mortality directly observable while fishing) as a function of catch depth (5m bins). Initial mortality from barotrauma was due to both direct effects (physical injury) and indirect effects (predation and/or angler/descending device error) during release.

comparisons showed significantly greater total release times for the Shelton and weighted milk crate, and greater time to load for the Shelton. Device effectiveness was also measured based on device error rates as well as the overall rate of successful release (Table 2). During the device loading process, fish sometimes fell off the device onto the deck or into the water, and others sometimes came off the device during release and floated back to the surface. These were considered errors that added to the total time required to release each fish. The Shelton Fish Descender had the greatest percentage of errors on deck in both central/northern and southern California (27.1% and 53.8%, respectively), but produced among the lowest percentages of errors during descent. While the devices were slightly more successful overall in central/northern California than in southern California, all devices were still highly successful, and the SeaQualizer produced the highest overall release success percentages in both regions (Table 2).

Angler perceptions of device effectiveness and use were also measured. Overall, 42% of California anglers surveyed ($n = 214$ surveys) stated that they use a descending device (36.4% of anglers in southern California and 46.6% of central/northern California anglers),

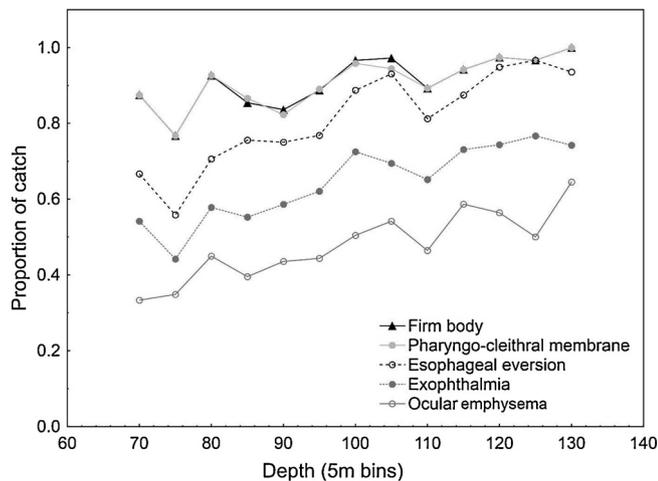


Fig. 6. The proportion of rockfish catch exhibiting each of the five barotrauma symptoms assessed in this study across a depth range of 70–130 m from the southern California sites. Data from less than 70 m depth were not included because these data were collected virtually entirely from the central California region, and physiological signs of barotrauma were recorded differently in this region such that direct comparisons were not possible.

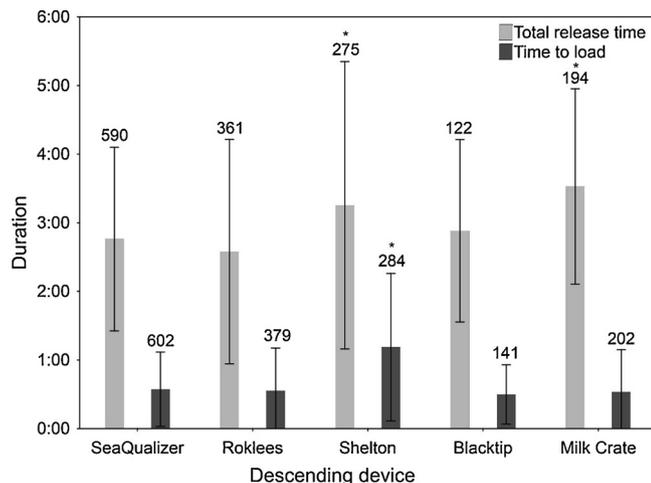


Fig. 7. Mean duration (min) (± SD) required to use each of five different descending devices when releasing individual fish. The light gray bars represent the mean time required to load, deploy, and retrieve each descending device. The dark gray bars represent the mean time required to successfully load each fish onto each device and place it in the water. The numbers above each bar represent sample sizes, and asterisks (*) represent statistical significance for the associated group based on post-hoc tests.

Table 2

The percent occurrence of release errors using each of the five descending devices in central/northern and southern California regions. ‘Error on deck’ refers to instances when fish fell off the device either onto the vessel deck or into the water, and had to be retrieved for re-loading. ‘Error on descent’ refers to instances when the device either released prematurely during descent or the fish shook itself off the device during descent, both of which resulted in a second release attempt after the fish floated back to the surface due to excessive buoyancy. ‘Release success’ refers to the percent of fish that were successfully descended alive with or without user or device errors in the process.

Device Type	Overall California			Central/northern CA			Southern CA		
	Error on deck	Error on descent	Release Success	Error on deck	Error on descent	Release success	Error on deck	Error on descent	Release success
SeaQualizer	4.95	7.42	95.7	4.89	1.78	98.2	5.01	18.75	94.0
Roklees	12.92	16.77	88.7	10.74	10.74	93.7	15.23	21.97	86.4
Shelton	37.54	4.51	91.0	27.07	5.26	95.0	53.76	4.26	87.9
Blacktip	19.21	8.36	91.5	9.38	15.63	97.4	26.79	7.41	83.9
Milk crate	5.59	3.86	94.6	6.67	0.00	98.2	4.52	4.52	93.2

suggesting that the majority of recreational anglers in California do not use descending devices at all. There were significant differences across all four metrics of preference that were reflected in the first four questions of the questionnaire (perceived effectiveness, ease of use, recommended for use aboard CPFVs, and recommended for use aboard private vessels). Anglers showed clear preference for and perceived effectiveness of the SeaQualizer over all other device types ($F = 58.7$, $df = 4$, $p < 0.01$), which was followed in order by the Roklees, Shelton, Blacktip, and the weighted milk crate was the least preferred of all five devices (Table 3). Anglers also recommended the SeaQualizer as the preferred device for both CPFVs and private vessels ($F = 67.78$, $df = 4$, $p < 0.01$), which was followed in order by the Roklees, Shelton, Blacktip, and weighted milk crate. However, despite the evidence that the SeaQualizer was clearly the preferred device type, only 14% of respondents stated that they currently use them.

4. Discussion

This study provides evidence that descending devices are highly successful in releasing rockfishes suffering from barotrauma, even among anglers who were relatively inexperienced with using the devices. Of the 2275 rockfish caught, 2079 were released alive, resulting in a 91.4 percent initial survival rate overall. The majority of the anglers (58%) participating in this study stated that they do not use descending devices regularly, and this was the first time that many of the anglers had used some of the descending devices at all. Our results were thus likely reflective of the private angling community majority that has not yet adopted the regular use of descending devices. This means that our estimate of initial survival could be conservative, as descending devices are gaining in popularity in west coast fishing communities, and increased experience with descending devices could produce an even higher rate of successful releases. It is important to emphasize that only initial (i.e. observable) mortality was measured in this study. Delayed post-release mortality was not included and is likely an important consideration. For example, Lowe et al. (2009) found a 30% mortality rate of rockfishes off southern California during a 6-day period after release with a descending milk crate, and additional mortality may have occurred after this period.

Some important considerations remain regarding the results from this study due to the chance that self-selection of volunteer anglers may have represented a more conservation-oriented segment of the angling population. This could potentially skew results toward higher survival rates if these anglers took more care in the catch-and-release process compared to an ‘average’ angler. The results from this study were based on data from 252 volunteer anglers aboard 24 CPFV charters at 11 coastal sites across a ~1200 km stretch of California coastline, and the opportunity for anglers to participate in the project was advertised through a broad range of outlets, including fishing trade shows, newspapers and magazine articles, tv shows, radio shows, fishing club presentations, and websites. The overwhelming interest from the

Table 3

Angler survey results (n = 214) showing mean scores of perceived effectiveness (with standard deviations in parentheses) and percentage of recreational angler respondents using descending devices while targeting rockfishes in California. Green highlighted cells denote positive results, light green denotes somewhat positive, orange denotes somewhat negative, and red highlighted cells denote negative results for device effectiveness, angler use, and angler preference. For the mean scores, ranks 1, 2, and 3, were assigned green, light green, and orange colors, respectively (there were no mean ranks of 4 or 5 to assign to a red color). For the percentages of respondents, the green, light green, orange, and red colors were assigned to the following categories, respectively: above 30%, 20–30%, 10–20%, and less than 10%.

Metric	Survey question	SeaQualizer	Roklees	Shelton	Blacktip	Milk crate
Mean (SD) score (1–5) 1 = Best 5 = Worst	Most successful	1.40 (0.84)	2.49 (1.14)	3.34 (1.31)	3.19 (1.08)	3.33 (1.35)
	Easiest to use	1.48 (0.82)	2.29 (1.13)	3.51 (1.33)	3.12 (1.07)	3.13 (1.46)
	Preferred for CPFV	1.49 (0.89)	2.34 (1.12)	3.45 (1.28)	3.18 (1.14)	3.24 (1.50)
	Preferred for private boat	1.65 (0.98)	2.30 (1.17)	2.95 (1.48)	3.21 (1.10)	3.51 (1.39)
Percentage of respondents	Currently own (%)	11.7	11.2	11.2	0.9	2.8
	Currently use (%)	14.0	10.7	9.3	3.3	4.7
	Preference if free (%)	68.9	18.2	6.2	5.3	1.4
	Preference if purchasing (%)	42.3	24.5	28.1	2.3	2.8

fishing community to participate resulted in a broad diversity of angling experience, skillsets, backgrounds, motivations for fishing, and outlook on catch-and-release among the volunteer angler participants. This broad outreach effort and the resulting diversity of experience and perspectives among our angler pool maximized the representativeness of the data, but it is still possible that self-selection bias could result from anglers who voluntarily participate in research behaving differently than those who do not.

Another limitation to consider is that this study only included data obtained aboard CPFVs, while the private vessel fleet also represents a large portion of recreational landings in California. However, results from this study may be comparable to the private vessel fleet as well because the descending devices operate similarly regardless of vessel type. When releasing fish with descending devices, the primary difference between the vessel types is with respect to freeboard, or the vertical distance from the waterline to the deck of the vessel. The higher freeboard on CPFVs (1–2 m) vs. typical private vessels (< 1 m) meant that fish needed to be lowered a greater distance to the waterline aboard CPFVs than they would have aboard private vessels. This may translate to higher release errors aboard CPFVs due to fish falling off the device more easily when they had to be lowered a greater distance to the waterline, especially when using devices that require more practice.

Certain devices had higher user error rates that resulted a longer amount of time both to load and release the fish. Release errors can greatly extend release times and the amount of handling, and sometimes add trauma when fish are dropped on the vessel deck, all of which may increase post-release mortality. The Shelton Fish Descender yielded the greatest rates of user error, which was typically associated with fish falling off the device when being transitioned from the boat to the water. These error rates were likely increased due to the high platform (freeboard) of the CPFVs used in this study and the more delicate technique required with this device to transition fish into the water. This device type also had the greatest learning curve with much fewer release errors occurring with subsequent uses of the device. This was evidenced by almost double the error rate for this device in southern California (54%) as opposed to central/northern California (29%) where the Shelton Fish Descender was designed and where anglers are much more familiar with its use. Despite the higher error rates observed in this study, the Shelton was still highly successful in releasing fish (approximately 93% of fish were successfully released alive), is the least expensive device, and is more commonly used by

private vessel operators on smaller boats that are much closer to the water surface allowing for an easier transition of the fish to the water and reduced error rates.

While each device type was associated with certain user errors, virtually all rockfish in this study were returned to the water in less than five minutes following capture. Much of this time prior to release was needed for measuring, assessing barotrauma, and tagging each individual. Following assessment and tagging, the total time to load a fish onto a descending device and return it to the water averaged 0.67 ± 0.73 (SD) minutes, and the mean total time to release the fish and recover the gear was 2.92 ± 1.60 (SD) minutes across devices. These times (plus the added time required for assessing and tagging each fish) are well within the time window needed to avoid increases in post-release mortality. Jarvis and Lowe (2008) tested for effects of multiple factors on survival of southern California rockfishes, and found that surface time was a significant predictor of post-release mortality, but only after at least 10 min out of water.

While release times in this study were relatively short, certain factors, including device type, capture depth, and release depth appeared to influence initial post-release mortality. In terms of the device types, the Roklees, Shelton, and Blacktip each resulted in approximately double the mortality measured with the SeaQualizer. These three devices each had certain errors that translated to greater time required to release. The Roklees sometimes failed to release the fish at depth, so the fish would be brought back to the surface unintentionally; the Shelton required more practice to prevent fish from falling off the device; and the blacktip often opened pre-maturely during conditions of higher wind/swell. Each of these examples required second or sometimes third release attempts, which likely increased likelihood of mortality. However, anglers became proficient after practicing with each device type aboard the fishing charters, which allowed them to recognize device differences and avoid device-specific errors over time. This meant that all device types were ultimately effective, but some had a steeper learning curve than others. Capture depth (which correlates with multiple symptoms of barotrauma) was a second important factor, especially in the context of release depth (which influences the ability of the fish to return to the bottom to recover). For consistency, all fish in this study were released at a depth of 46 m, unless the bottom depth was shallower. We chose this release depth because the stock version of the SeaQualizer has a maximum set release depth of 46 m (150 ft). Fish that were captured at depths less than 46 m were released directly to

the bottom. Fish that were caught at bottom depths greater than 46 m were released at 46 m depth, meaning the fish then needed to swim the remaining distance to the bottom. We observed relatively low initial post-release mortality in depths up to approximately 100 m (7.5%), which more than doubled at depths from 100 to 130 m (16.4%). This suggests that release using descending devices should be done a minimum of half-way to the bottom, although releasing fish all the way to the bottom is ideal.

Angler surveys aboard the charters showed clear preference for and perceived effectiveness of the SeaQualizer in both southern and central/northern California, which was also the device with the lowest error rates. Despite the relatively higher cost of the SeaQualizer (\$59.99), this device was preferred regardless of whether anglers were given the device for free, or if hypothetically purchasing the device themselves. The SeaQualizer was preferred because it can be automatically set to a specific release depth, it is capable of holding large fish, it can be rigged to a separate rod and reel allowing easy retrieval, requires almost no extra deck space, and two fish can be released at once with this device. However, one significant advantage of the other four devices is that they allow anglers to descend fish all the way to the bottom, regardless of depth, which is the best way to maximize post-release survival. Despite the effectiveness of the inverted milk crate, this device received less favorable ratings in the angler survey due primarily to its weight and large profile, requiring added time and exertion to recover it following the release of the fish at depth.

Symptoms of barotrauma showed clear association with depth of capture for rockfishes, which is consistent with the growing base of literature focusing on barotrauma (e.g., Stewart, 2008; Hannah et al., 2008, 2014; Ferter et al., 2015). Virtually all fish exhibited a stiff and bloated body and inflated pharyngo-cleithral membranes indicating the rupture or leakage of gas from the gas bladder into the peritoneal cavity. These symptoms were typically followed by esophageal eversion, exophthalmia, and lastly, ocular emphysema, depending on the depth of capture. The degree to which each of these symptoms influences post-release survival is unclear (Jarvis and Lowe, 2008), but 66% of the rockfishes that died in this study exhibited all five symptoms of barotrauma that we measured, and 73% of dead fish that incurred ocular emphysema also exhibited the other four symptoms. The presence of ocular emphysema may thus be an indication of a lower chance for survival, especially if the other four symptoms are also exhibited.

While some differences in both actual and angler-perceived effectiveness and ease of use were measured between the devices, all devices were highly successful at releasing fish back to depth in very short periods of time. Device choice should thus be based on a condition-specific basis for each angler because device effectiveness can change with several factors, such as boat type, seascape conditions, depth, angler familiarity, catch rates, and target species. For example, some of these devices can release more than one fish at once which could be useful for the CPFV fleet, while others can be rigged to the angler's fishing rod without impacting the fishing rig, and be purchased at a much lower cost. Some common factors to consider in choosing a device are the amount of practice required for successful use, number of fish that can be released at once, device durability, performance during faster vessel drift rates, and required extra deck space onboard the vessel.

Given both the angler preference for and the effectiveness of the SeaQualizer, the Sportfishing Association of California recently voluntarily purchased SeaQualizers for every Commercial Passenger Fishing Vessel (CPFV) in the southern California recreational fleet. This represented a pro-active and significant step toward maximizing conservation of the rockfish fishery, which is especially important given our lessons learned from past declines among this species group (Gunderson, 1998; Love et al., 1998; Mason, 1998). Collaborations between NOAA scientists and the recreational fishing community strengthened the results of this study, informed the adoption of descending device policies by governments in other regions (e.g., the

Canada Department of Fisheries and Oceans in British Columbia), and facilitated broader angling community awareness of the effectiveness of descending devices. Increased usage of descending devices can be facilitated through direct engagement with fishing communities and fisheries management bodies, and awareness in angling communities elsewhere continues to grow.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.fishres.2019.03.003>.

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