Fisheries Research 211 (2019) 212–216

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Technical note

Effects of barotrauma and recompression events on subsequent embryo condition of yelloweye rockfish

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ARTICLE INFO

Handled by George A. Rose

Keywords:
Yelloweye rockfish
Barotrauma
Embryo composition
Reproductive viability

ABSTRACT

Catch-and-release fishing may adversely affect reproduction of rockfishes *Sebastes* spp. due to angling-induced barotrauma. Although yelloweye rockfish (*S. ruberrimus*) have been shown to be reproductively viable following these events, the energetic cost of recovery may negatively affect reproductive fitness through reduced embryo condition. In this study, female yelloweye rockfish from Prince William Sound, Alaska, were recaptured one to two years following their initial capture and recompression using a deepwater-release mechanism (DRM). Embryo composition from these fish was compared to the embryos from females with no previously known capture history to examine embryo oil globule volume (OGV), energy content, and percent lipid content. Capture history, maternal length and age, and developmental stage explained a high proportion of the variability in embryo OGV, but not energy or percent lipid content. For both groups of females, there were declines in OGV and energy content of embryos from early to late developmental stages. However, there were no differences in OGV and energy content between female groups for each embryo developmental stage and there were no differences in lipid content of embryos for either group between and among developmental stages. These results suggest that embryo condition was similar between females, regardless of capture history. As a result, DRM recompression seems to mitigate the negative effects of barotrauma on yelloweye rockfish embryo composition in subsequent spawning seasons.

1. Introduction

Rockfishes *Sebastes* spp. are long-lived, iteroparous marine fishes that have internal fertilization and bear live young (Love et al., 2002). Most rockfishes are matrotrophically viviparous, where eggs are fertilized internally and embryo nutrition comes from the yolk/oil globule and direct maternal energy transfer. Endogenous energy for rockfish embryos from yolk and oil globule lipid reserves is essential during the transition to exogenous feeding, particularly if maternal nutrition is inadequate (Fisher et al., 2007). Maternal attributes play a key role in embryo composition and parturition timing, with older, larger females typically having higher fecundity and producing larger embryos with higher survival probability than younger females (Berkeley et al., 2004; Sogard et al., 2008; Rodgveller et al., 2012).

Because fish condition impacts larval quantity and quality, there is a concern that catch-and-release fishing may adversely affect reproductive success (Meka and McCormick, 2005). This concern is relevant to demersal rockfishes, which often experience barotrauma due to swimbladder morphology and deep capture depths (Love et al., 2002). Unlike fishes with physostomous swimbladders that can rapidly express gases, rockfishes have a physoclistous swimbladder. As a result, fish brought rapidly to the surface experience positive buoyancy and tissue damage (i.e., barotrauma). Due to these injuries and the inability to resubmerge, survival of surface-discarded rockfishes can be low (Jarvis and Lowe, 2008; Hochhalter and Reed, 2011).

Recompression of captured rockfishes using a deepwater-release mechanism (DRM) is an alternative to surface release that can reverse barotrauma symptoms and improve survival (Jarvis and Lowe, 2008; Hochhalter and Reed, 2011). Blain and Sutton (2016) found that recaptured female yelloweye rockfish (*S. ruberrimus*) in Prince William Sound (PWS), Alaska, were gravid or spent, indicating that fish could reproduce after capture-barotrauma-recompression events. However, it is unclear if DRM recompression mitigates barotrauma effects on maternal fitness and how this might impact offspring viability. The objective of this study was to compare embryo condition from female yelloweye rockfish that had undergone at least one capture event, suffered barotrauma, and were released at depth (i.e., recaptures; treatment group) to embryos from females with no known capture

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https://doi.org/10.1016/j.fishres.2018.11.022
Received 3 January 2018; Received in revised form 28 September 2018; Accepted 18 November 2018
Available online 24 November 2018
0165-7836/

Table 1
Biological and capture attributes, barotrauma symptoms (EV = esophageal eversion; EX = exopthalmia; TA = tight abdomen; PC = prolapsed cloaca; CE = corneal emphysema; BP = branchial protrusion; SB = swimbladder rupture/tear), and embryo developmental stage and condition (OGV = oil globule volume) for each female yelloweye rockfish by capture history (R = recaptured fish, N = newly captured fish). For barotrauma symptoms, an "X" indicates that the female was positive for a specific injury type, whereas a "0" indicates that the fish did not exhibit that sign. NR indicates that data were not recorded for a particular fish, and NA means that there was insufficient material to complete the analyses. Summarized data for each capture history type (R or N) includes the number (percentage in parentheses) for barotrauma symptoms and means (standard errors in parentheses) for all other biological, capture, and embryo developmental stage and condition data.

Female capture				Barotrauma symptoms							Age (years)	Embryo			
History	Date	TL (mm)	Depth (m)	EV	EX	TA	PC	CE	BP	SB		Dvpt stage	OGV (mm³)	Caloric content (kcals)	Lipid content (%)
R1	06/16/09	507	39	0	0	X	X	0	0	–	–	–	–	–	–
	08/05/09	507	29	X	0	X	0	0	0	–	–	–	–	–	–
	05/19/10	507	40	0	0	X	0	0	0	X	36	2	0.015	6.06	33.65
R2	06/30/09	501	43	0	0	X	X	0	0	–	–	–	–	–	–
	06/03/10	510	60	0	0	X	0	0	0	X	26	2	0.011	6.00	23.07
R3	06/14/09	365	42	0	0	X	X	0	0	–	–	–	–	–	–
	06/30/10	411	NR	NR	NR	NR	NR	NR	NR	X	17	2	0.018	NA	NA
R4	06/18/08	510	36	NR	NR	NR	NR	NR	NR	—	–	–	–	–	–
	05/21/10	548	31	0	X	0	X	0	0	X	22	1	0.024	6.36	26.10
R5	08/29/08	488	NR	NR	NR	NR	NR	NR	NR	–	–	–	–	–	–
	08/21/09	498	32	X	0	X	0	0	0	–	–	–	–	–	–
	06/29/10	498	40	NR	NR	NR	NR	NR	NR	X	23	3	0.006	5.64	24.63
R6	06/15/09	400	31	0	0	X	X	0	0	–	–	–	–	–	–
	08/20/09	NR	26	0	X	0	0	0	0	–	–	–	–	–	–
	05/21/10	405	31	0	0	X	0	0	0	X	16	1	0.021	6.13	25.73
R7	06/12/08	NR	NR	NR	NR	NR	NR	NR	NR	–	–	–	–	–	–
	06/11/10	460	39	X	0	X	0	0	0	X	15	3	0.012	6.04	33.61
		474	37.07	3	2	10	5	0	0	7	22		0.015	6.05	25.92
		(14)	(2.27)	(25)	(17)	(83)	(42)	(0)	(0)	(100)	(3)		(0.002)	(0.25)	(1.89)
N1	06/25/2010	395	36	0	0	X	0	0	0	X	17	2	0.012	5.64	24.58
N2	05/30/2010	465	37	0	0	X	0	0	0	X	20	1	0.022	5.83	31.24
N3	06/13/2010	431	34	0	0	X	0	0	0	X	21	2	0.018	6.00	33.23
N4	05/19/2010	480	67	X	X	0	0	X	0	X	25	3	0.014	5.59	28.53
N5	06/13/2010	494	42	X	0	X	0	0	0	X	27	3	0.007	6.06	20.65
N6	06/24/2010	470	56	X	0	X	0	0	X	X	27	3	0.014	6.26	23.19
N7	06/24/2010	500	39	0	X	X	0	0	0	X	27	1	0.021	6.06	29.80
N8	06/01/2010	566	37	0	0	X	X	0	0	0	30	2	0.016	6.10	23.32
N9	06/12/2010	480	53	0	0	X	0	0	0	X	31	3	0.014	5.99	26.53
N10	06/24/2010	508	35	0	0	X	0	0	0	X	31	3	0.011	6.11	29.59
N11	05/22/2010	555	33	0	0	X	0	0	0	X	32	2	0.020	6.29	24.78
N12	06/03/2010	505	37	X	0	X	X	0	0	X	33	1	0.035	6.00	29.10
N13	06/24/2010	575	39	0	X	0	0	0	0	X	34	3	0.011	6.06	31.94
		494	41.92	4	3	11	2	1	1	12	27		0.017	5.99 (0.06)	27.42
		(14)	(2.85)	(31)	(23)	(85)	(15)	(8)	(8)	(92)	(2)		(0.002)		(1.08)

history (i.e., new captures; control group).

2. Material and methods

Yelloweye rockfish were collected by angling from May through June 2008–2010 at a reef in Port Gravina, PWS, Alaska. For each individual, capture depth (m) and time to capture, deck processing, and release were recorded (minutes), total length (TL) was measured (mm), and fish were examined for t-bar anchor and passive integrated transponder (PIT) tags. If present, tag numbers were recorded and, if not, a PIT tag (TX1411SST; length = 12.5 mm, diameter = 2.07 mm, mass = 0.10 g; Biomark Inc., Boise, Idaho) was implanted at the pectoral fin base and a t-bar anchor tag (Model #FD-94; Floy Tag & Mfg., Inc., Seattle, Washington) was inserted beneath the dorsal fin. All fish were released at their capture site using a DRM in 2008 and 2009 (see Hochhalter and Reed, 2011), while all females were retained in 2010. At capture, females were examined for external macroscopic signs of barotrauma (see Jarvis and Lowe, 2008) and for embryos. Swimbladder condition was examined for euthanized fish, and whole ovaries were removed from females and stored at -80 °C. Sagittal otoliths were removed and aged using the crack-and-burn method. Annuli were identified by two separate readers, and discrepancies were resolved with a concert read.

Microscopic evaluation was used to identify embryo development stages using modified criteria from Yamada and Kusakari (1991) for Korean rockfish *S. schlegeli* and Sewall and Rodgveller (2008) and Rodgveller et al. (2012) for quillback rockfish *S. maliger*. Using these criteria, three embryo developmental stages were identified: (1) stage-1 embryos were at early stages of development, with no eye or body development and yolk was present; (2) stage-2 embryos had optic cups but minimal retinal pigmentation and body development; and (3) stage-3 embryos had darker retinal pigment, a developing body, and melanophores along the notochord.

Two samples of embryos (1.0 g each) from each female were weighed before counting the number of embryos in each sample. While three ovary samples per female have been used in similar studies (Daugherty et al., 2008; Dupuis and Sutton, 2011), results from our study indicated that variability in embryo composition between samples for each female was low (< 0.5%). Embryo oil globule volume (OGV) was estimated by photographing 20 embryos from each female using a Leica DM 1000 compound microscope and a Leica DFC420C digital camera (Leica, Wetzlar, Germany) at 4X magnification. After imaging, two perpendicular measurements of oil globule diameter (μm) were made using Leica Application Suite software (version 3.3.0) and averaged before calculating OGV as the volume of a sphere (Berkeley et al., 2004; Sewall and Rodgveller, 2008). The coefficient of variation for OGV among embryos for each female was ≤ 5%.

Additional embryo samples (1.0 g each) from each female were freeze dried, homogenized, and stored dry for energy and percent lipid content. A Parr Automatic Bomb Calorimeter (Model 1281; Parr

Instrument Company, Moline, Illinois) was used to measure energy content (kcals) by combusting two 0.5-g samples per female following Pierce et al. (1980). Lipid was extracted from two additional 0.5-g samples from each female using a 2:1 chloroform-methanol solution (Schlechtriem et al., 2003). Percent lipid for each sample was calculated as: ([initial weight (mg) – extracted weight (mg)]/initial weight (mg)) x 100.

A Kruskal-Wallis rank sum test was used to determine if capture depth, maternal age, and TL differed between recaptured and newly captured females. To detect differences in embryo composition and maternal age between developmental stages within and between the two female groups, data were analyzed using a Kruskal-Wallis rank sum test. If significant differences were found, a Dunn's multiple comparison test was used to separate medians. Multiple linear regression was used to describe relationships between embryo composition (dependent variable; OGV, energy content, percent lipid content) and maternal attributes (independent variables) separately for each composition variable. Female capture history was given a binary code (recapture [1] or new capture [0]), which allowed for the evaluation of continuous (i.e., maternal length and age) and categorical (i.e., female capture history, embryo developmental stage) independent variables on embryo composition. Pairwise correlations were examined between predictor variables to assess multicollinearity among independent variables (no variables were excluded from analyses). Dependent variables were transformed (ln[embryo composition variable] + 0.25) prior to analyses, and all statistical analyses were significant at $\alpha = 0.05$.

3. Results

There were no differences in yelloweye rockfish TL, capture depth, or age between female groups (TL: $H = 3.05$, $p = 0.08$; depth: $H = 0.38$, $p = 0.54$; age: $H = 0.19$, $p = 0.66$, respectively; Table 1). Similarly, there were no differences in female age within and among stages of embryo development ($H = 0.65$, $p = 0.72$). Multiple linear regression results showed that capture history, maternal length and age, and development stage explained a high proportion of the variability in embryo OGV ($r^2 = 0.59$, $F = 7.10$, $p < 0.01$), but not energy ($r^2 = 0.34$, $F = 1.66$, $p = 0.22$) or percent lipid ($r^2 = 0.03$, $F = 0.11$, $p = 0.75$) content. Significant declines in OGV and energy content were detected from early to late development stages ($H = 13.74$, $p = 0.001$; $H = 12.002$, $p < 0.003$, respectively); however, there were no differences among development stages for lipid content ($H = 0.61$, $p = 0.73$; Fig. 1). Oil globule volume, energy content, and percent lipid content did not differ between female groups (OGV: $H = 0.025$, $p = 0.87$; energy: $H < 0.002$, $p = 0.97$; lipid: $H = 0.031$, $p = 0.86$).

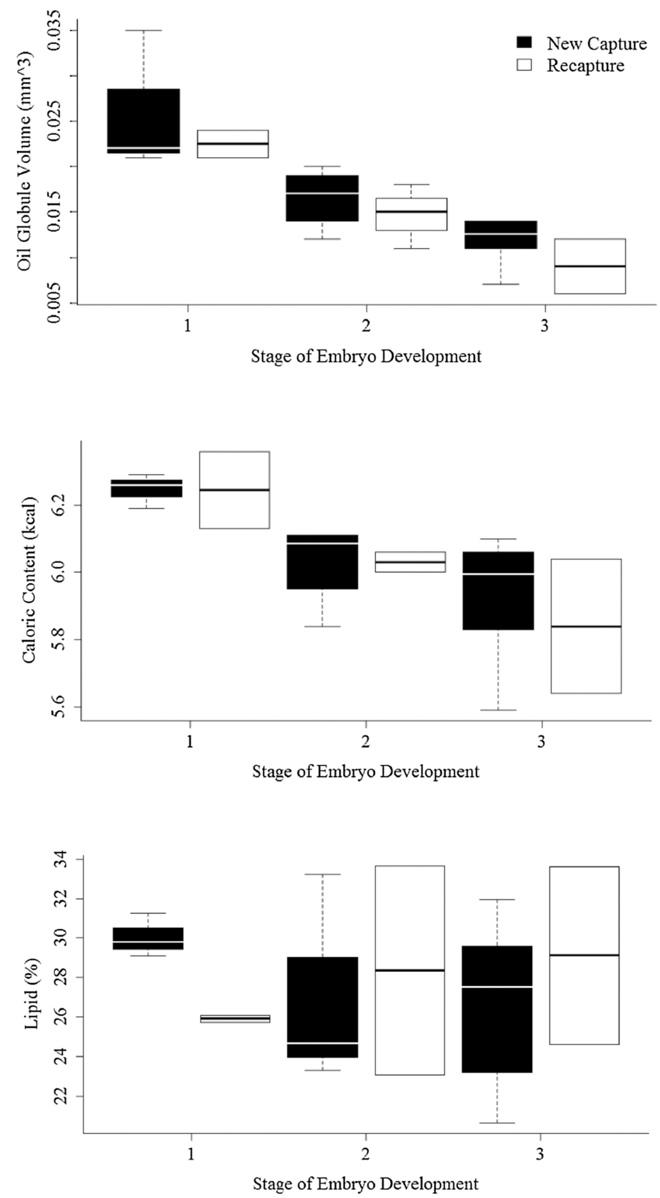

Fig. 1. Median oil globule volume (OGV), energy (caloric) content, and percent lipid content for each stage of yelloweye rockfish embryo development by capture history (newly captured and recaptured fish).

4. Discussion

Yelloweye rockfish in our study exhibited macroscopic external barotrauma injuries, likely due to gases escaping from the swimbladder into the body cavity and moving in an anterio-dorsal direction during rapid ascension as the fish were brought to the surface from depth by angling as have been shown in other studies (Hannah et al., 2008; Jarvis and Lowe, 2008). No recaptured fish in our study had a fully ruptured swimbladder, while two new captures exhibited fully ruptured their swimbladder. In most cases, the swimbladder was expanded and likely on the verge of rupturing, with gases trapped in the body cavity. Although previous studies have found that rockfish are capable of reversing the signs of barotrauma (Hannah et al., 2008; Pribyl et al., 2011; Hochhalter and Reed, 2011), there is a limited amount of energy available to repair these injuries. If energy is reallocated to heal injuries and tissue repair is protracted in duration, it is possible that there will be less energy available for reproductive development and embryo nutrition during gestation. However, reduced embryo composition for yelloweye rockfish was not observed during our study, suggesting that previous barotrauma and recompression effects were not transferred to developing embryos.

The current study found no difference in embryo OGV, energy, and lipid content between newly captured and recaptured yelloweye rockfish, regardless of maternal length and age or embryo developmental stage indicating that previous DRM recompression events for known recaptured rockfish mitigated negative potential impacts of barotrauma on embryo composition. Fish egg composition in subsequent spawning seasons can change during development due to adverse physiological events (e.g., barotrauma, starvation, etc.) and the metabolic demands of the eggs (Weigand, 1996). Because the oil globule acts as an energy store during the early stages of larval feeding, it is a critical resource during times of inadequate food supply (Boehlert and Yoklavich, 1984). Berkeley et al. (2004) found that larval black rockfish with larger oil globules exhibited growth and survival rates more than three and two times faster, respectively, than individuals with smaller oil globules. Further, female body size and age have been shown to be positively related to OGV and offspring success (Berkeley et al., 2004; Sogard et al., 2008; Rodgveller et al., 2012). These results demonstrate the importance of the maternal contribution to offspring success, particularly OGV for developing embryos and larvae.

For yelloweye rockfish in our study, both embryo OGV and energy content declined from early to late development stages, indicating that developing embryos were utilizing this energy source. In contrast, embryo lipid content did not differ significantly among development stages. Sewall and Rodgveller (2008) and Rodgveller et al. (2012) observed similar declines in OGV from early to late embryo developmental stages for quillback rockfish. However, studies involving quillback, yellowtail (*S. flavidus*), and shortbelly (*S. jordani*) rockfishes detected lower lipid mass for embryos at later stages (MacFarlane and Norton, 1999; Eldridge et al., 2002). These authors concluded that lipid was metabolized more rapidly and contributed a larger portion of the energy required for development than the other measured composition variables. While Sewall and Rodgveller (2008) noted that OGV was strongly related to total lipid content of developing quillback rockfish embryos, Berkeley et al. (2004) did not detect a relationship between these composition variables for black rockfish embryos at parturition. The relationship between OGV and lipid content for yelloweye rockfish embryos in our study more closely matched Berkeley et al. (2004). These differences illustrate the potential diversity of energy-use patterns and changes in body composition that may occur among rockfish species and the need examine each species separately given their variable life-history and biochemical composition.

The yelloweye rockfish in our study experienced lower rates of barotrauma symptoms than have been reported previously for this species. For example, esophageal eversion rates ranged from 65 to 100% in other studies (Hannah and Matteson, 2007; Hannah et al., 2014; Blain and Sutton, 2016; Rankin et al., 2017), whereas these rates were 25 and 31%, respectively, for recaptured and newly captured females in our study. These studies also reported higher rates for other barotrauma symptoms, such as exophthalmia and corneal/ocular emphysema, relative to our study. Although the causal mechanism(s) for these differences are unclear, they might be related to the shallower capture depths for yelloweye rockfish in our study (29–67 m) relative to these other studies (46–174 m). Rankin et al. (2017) noted that yelloweye rockfish caught at depths ≥ 100 m exhibited physical signs associated with extreme expansion and retention of swimbladder gas (pronounced barotrauma), which occurred at a greater frequency than for fish caught at shallower depths (Hannah and Matteson, 2007; Hochhalter and Reed, 2011; Hannah et al., 2014; Blain and Sutton, 2016). Additional research is needed for yelloweye rockfish caught at deeper depths to better understand the effects of barotrauma and recompression using a DRM on reproductive success of females and the condition of developing embryos.

A caveat of our study was the low sample sizes of female yelloweye rockfish examined for embryo composition among development stages. This was a greater concern for recaptured fish where sample sizes consisted of either two or three females per development stage relative to new captures (4–6 fish per development stage). Sewall and Rodgveller (2008) reported similar sample sizes for their rockfish embryo composition study (three to four fish for OGV and lipid mass for each developmental stage). Female rockfish sample sizes examined for each development stage were 21 and 22 fish for Eldridge et al. (2002) and Boehlert and Yoklavich (1984), respectively, and ranged from 1 to 21 fish for MacFarlane and Norton (1999). Although our sample sizes were low, they were within the ranges reported for similar rockfish studies. In addition, our embryo composition data were comparable to results reported in these studies. However, our sample sizes prevented us from including additional embryo development stages as in Yamada and Kusakari (1991); Sewall and Rodgveller (2008), and Rodgveller et al. (2012).

This study found no differences in embryo composition for female yelloweye rockfish subjected to angling-induced barotrauma and DRM recompression relative to individuals with no known capture history. Results from embryo composition analyses corroborated previous rockfish studies (Berkeley et al., 2004; Sewall and Rodgveller, 2008). Females not only survived one or more barotrauma and DRM-recompression events, but could also reproduce and produce embryos in subsequent years. Based on the results of our study, DRMs should continue to be a valuable conservation tool for rockfishes, particularly long-lived demersal species such as yelloweye rockfish. However, our fish examined did not suffer extensive barotrauma as has been observed in other studies, possibly because they were caught at shallower depths than in previous research (Hannah et al., 2014; Rankin et al., 2017). Additional research is needed on individuals caught throughout the depth range that this species is targeted at for recreational purposes to state with confidence that embryo quality is not affected by recompression events and that the use of DRMs helps to mitigate the impacts associated with barotrauma.

Acknowledgements

We would like to thank S. Hochhalter, D. Bosch, C. Brazil, K. Dunker, B. Marston, S. Meyer, S. Nehl, L. Horstmann, S. Heppell, R. Swor, and B. Failor for field collections and/or laboratory sample processing. All project procedures were approved by the UAF Animal Care and Use Committee (assurance 159435). Funding was provided by the ADF&G Division of Sport Fish, with partial funding from the Federal Aid in Sport Fish Restoration Act, Alaska Cooperative Fish and Wildlife Research Unit, and the UAF School of Fisheries and Ocean Sciences.

References

Berkeley, S.A., Chapman, C., Sogard, S.M., 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85, 1258–1264.
Blain, B.J., Sutton, T.M., 2016. Reproductive status and blood-plasma indicators of sex and gonad maturation status for yelloweye rockfish following barotrauma and recompression events. Trans. Am. Fish. Soc. 145, 1234–1240.
Boehlert, G.W., Yoklavich, M.M., 1984. Reproduction, embryonic energetics, and the maternal-fetal relationship in the viviparous genus *Sebastes* (Pisces: Scorpaenidae). Biol. Bull. 167, 354–370.
Daugherty, D.J., Bacula, T.D., Sutton, T.M., 2008. Reproductive biology of blue sucker in the Wabash River, Indiana. J. Appl. Ichthyol. 24, 297–302.
Dupuis, A.W., Sutton, T.M., 2011. Reproductive biology of female humpback whitefish in the Chatanika River, Alaska. J. Appl. Ichthyol. 27, 1365–1370.
Eldridge, M.B., Norton, E.C., Jarvis, B.M., MacFarlane, R.B., 2002. Energetics of early development in the viviparous yellowtail rockfish. J. Fish Biol. 61, 1122–1134.
Fisher, R., Sogard, S.M., Berkeley, S.A., 2007. Trade-offs between size and energy reserves reflect alternative strategies for optimizing larval survival potential in rockfish. Mar. Ecol. Prog. Ser. 344, 257–270.
Hannah, R.W., Matteson, K.M., 2007. Behavior of nine species of Pacific rockfish after hook-and-line capture, recompression, and release. Trans. Am. Fish. Soc. 136, 24–33.
Hannah, R.W., Parker, S.J., Matteson, K.M., 2008. Escaping the surface: the effect of depth of capture on submergence success of surface-released Pacific rockfish. N. Am. J. Fish. Manag. 28, 694–700.
Hannah, R.W., Rankin, P.S., Blume, M.T.O., 2014. The divergent effect of capture depth and associated barotrauma on post-recompression survival of canary (*Sebastes pinniger*) and yelloweye rockfish (S. ruberrimus). Fish. Res. 157, 106–112.
Hochhalter, S.J., Reed, D.J., 2011. The effectiveness of deepwater release at improving the survival of discarded yelloweye rockfish. N. Am. J. Fish. Manag. 31, 852–860.
Jarvis, E.T., Lowe, C.G., 2008. The effects of barotrauma on the catch-and-release survival of southern California nearshore and shelf rockfish (Scorpaenidae, *Sebastes* spp.). Can. J. Fish. Aquat. Sci. 65, 1286–1296.
Love, M.S., Yoklavich, M., Thorsteinson, L., 2002. The Rockfishes of the Northeast Pacific. University of California Press, Berkeley.
MacFarlane, R.B., Norton, E.C., 1999. Nutritional dynamics during embryonic development in the viviparous genus *Sebastes* and their application to the assessment of reproductive success. Fish. Bull. 97, 273–281.
Meka, J.M., McCormick, S.D., 2005. Physiological response of wild rainbow trout to angling: impact of angling duration, fish size, body condition, and temperature. Fish. Res. 72, 311–322.
Pierce, R.J., Wissing, T.E., Jaworski, J.G., Givens, R.N., Megrey, B.A., 1980. Energy storage and utilization patterns of gizzard shad in Acton Lake, Ohio. Trans. Am. Fish. Soc. 109, 611–616.
Pribyl, A.L., Kent, M.L., Parker, S.J., Schreck, C.B., 2011. The response to forced decompression in six species of Pacific rockfish. Trans. Am. Fish. Soc. 140, 374–383.
Rankin, P.S., Hannah, R.W., Blume, M.T.O., Miller-Morgan, T.J., Heidel, J.R., 2017. Delayed effects of capture-induced barotrauma on physical condition and behavioral competency of recompressed yelloweye rockfish, Sebastes ruberrimus. Fish. Res. 186, 258–268.
Rodgveller, C.J., Lunsford, C.R., Fujioka, J.T., 2012. Effects of maternal age and size on embryonic energy reserves, developmental timing, and fecundity in quillback

rockfish (*Sebastes maliger*). Fish. Bull. 110, 35–45.
Schlechtriem, C., Focken, U., Becker, K., 2003. Effects of different lipid extraction methods on δ^{13}C of lipid and lipid-free fractions of fish and different fish feeds. Isotopes Environ. Health Stud. 39, 135–140.
Sewall, F.F., Rodgveller, C.J., 2008. Changes in body composition and fatty acid profile during embryogenesis of quillback rockfish (*Sebastes maliger*). Fish. Bull. 107, 207–220.
Sogard, S.M., Berkeley, S.A., Fisher, R., 2008. Maternal effects in rockfishes *Sebastes* spp.: a comparison among species. Mar. Ecol. Prog. Ser. 360, 227–236.
Weigand, M.D., 1996. Composition, accumulation and utilization of yolk lipids in teleost fish. Rev. Fish Biol. Fish. 6, 259–286.
Yamada, J., Kusakari, M., 1991. Staging and the timing course of embryonic development in kurosoi, Sebastes schlegeli. Environ. Biol. Fish. 30, 103–110.