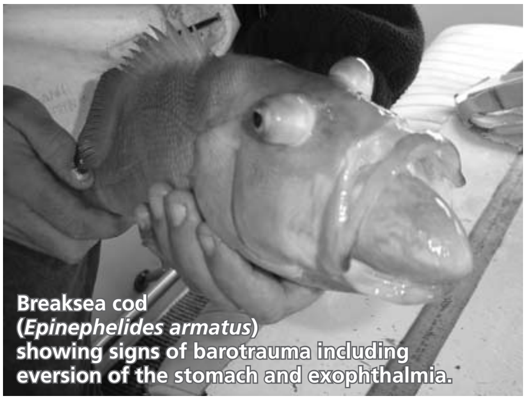
**FEATURE:**
FISHERIES MANAGEMENT



Breaksea cod (*Epinephelides armatus*) showing signs of barotrauma including eversion of the stomach and exophthalmia.

RECFISHWEST AUSTRALIA.

# Does Venting Promote Survival of Released Fish?

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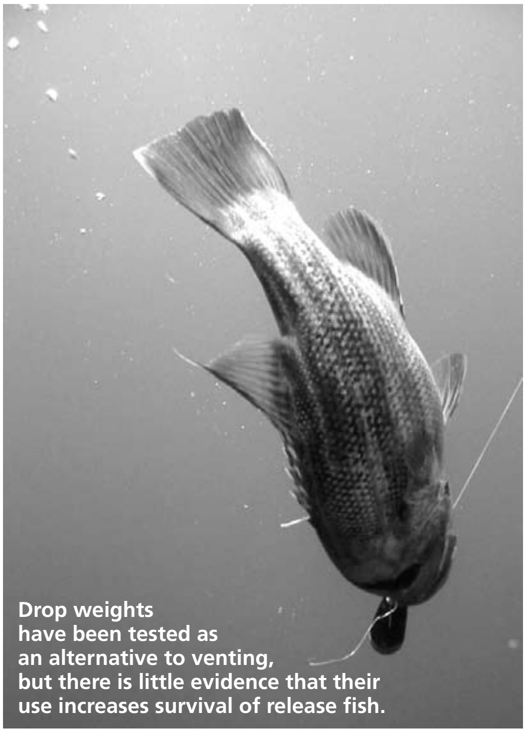
**ABSTRACT:** Fishes captured and brought to the surface by commercial and recreational fishers may suffer a variety of injuries that collectively are referred to as barotrauma. To relieve barotrauma symptoms, particularly those associated with an expanded swim bladder, some anglers deflate, or vent, the swim bladder (or body cavity when the swim bladder has ruptured) of fishes before releasing them. I compiled 17 studies that assessed the potential benefits of venting in 21 fish species and 1 composite group. These studies provided 39 sample estimates that compare survival ($N = 18$) and recapture rates ($N = 21$) of vented and unvented fish. I used relative risk to summarize results of individual studies, which allowed me to combine results from experimental and capture-recapture studies. Overall, there was little evidence that venting benefited fish survival. Venting was equally ineffective for freshwater and marine fishes and its efficacy was unaffected based on whether venting was performed by fishery biologists or anglers. The effects of venting did vary with capture depth: venting was slightly beneficial to fish captured from shallow waters, but appeared to be increasingly harmful for fish captured from progressively deeper waters. The available evidence suggests that venting fish should not only be discouraged by fishery management agencies, but given the possibility that venting may adversely affect survival of fish captured from deep water, this practice should be prohibited, rather than required by regulation.

# La maniobra de descarga en peces liberados promueve su supervivencia?

**RESUMEN**: Los peces que son capturados y llevados a la superficie por parte de los pescadores recreativos y comerciales pueden sufrir una variedad de lesiones que genéricamente se conocen como barotraumas. Para aliviar los síntomas del barotrauma en peces, particularmente aquellos asociados a la expansión de la vejiga natatoria, algunos pescadores la desinflan o descargan (o la propia cavidad corporal cuando la vejiga está rasgada) antes de regresarlos al agua. Se copilaron 17 estudios que evalúan los beneficios potenciales de la maniobra de descarga en 21 especies de peces y un grupo compuesto. En estos estudios se presentan 39 estimaciones muestrales que comparan la supervivencia ($N = 18$) y tasas de recaptura ($N = 21$) en peces a los que se les practicó y no se les practicó la maniobra de descarga. Se utilizó el riesgo relativo para resumir los hallazgos de cada trabajo, lo que permitió combinar los resultados tanto de los estudios experimentales como de los de captura-recaptura. En general hubo poca evidencia de que la maniobra de descarga beneficiara la supervivencia de los peces. La maniobra fue igualmente inefectiva en peces marinos y de agua dulce y su eficacia no dependió de si era realizada por un biólogo pesquero o un pescador. Los efectos de la maniobra de descarga sí variaron con la profundidad de captura: la maniobra fue ligeramente más benéfica para los peces de aguas someras pero más perjudicial a medida que aumentaba la profundidad de captura. La evidencia disponible sugiere que la maniobra de descarga es una práctica que no solo debe desalentarse en las agencias de manejo de pesquerías sino que dado que puede afectar de manera adversa la supervivencia de los peces que se capturan en aguas profundas, esta práctica más que requerir una regulación, debe prohibirse.



Drop weights have been tested as an alternative to venting, but there is little evidence that their use increases survival of release fish.

RECFISHWEST AUSTRALIA

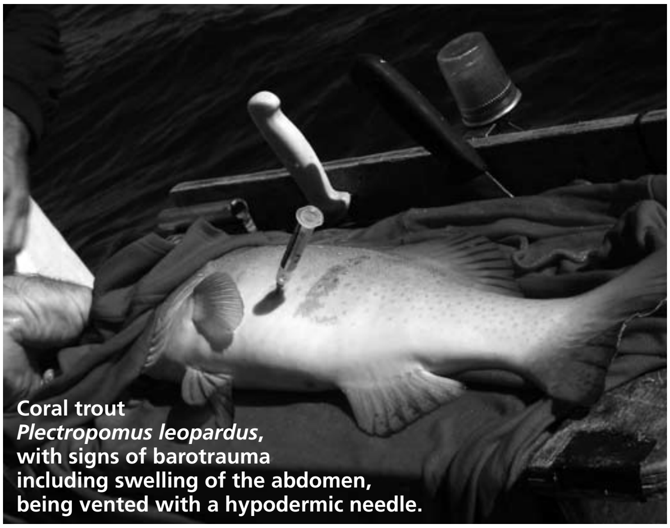
## INTRODUCTION

Fishes captured and brought to the surface by commercial and recreational fishers may suffer a variety of injuries that collectively are referred to as barotrauma. Although typically thought of as an affliction of physoclistous fishes, those having swim bladders lacking a direct connection to the digestive tract, barotrauma can affect any fish that experiences rapid depressurization. As a captured fish is brought to surface, it experiences a progressive decrease in ambient pressure, which in turn results in an increase in the partial pressure of dissolved gases within the blood and tissues as described by Boyle's Law. As the blood and tissues become supersaturated, gases may leave solution and form bubbles (emboli) in the blood, and various tissues and organs, including the eyes, brain, heart, arteries, gills, spleen, fins, musculature, and the dermis beneath the scales (Feathers and Knable 1983; Parrish and Moffitt 1993; Brown et al. 2007). These emboli may occlude the heart and arteries, affecting circulation to the heart and gills (Beyer et al. 1976). Fish with physoclistous swim bladders may suffer additional injuries as the swim bladder expands, causing compaction and displacement injuries to, as well as hemorrhage and hematoma of, the eyes, heart, liver, kidneys, and other internal organs (Gotshall 1964; Rummer and Bennett 2005; Phelan 2008). These injuries are so widespread among fishes afflicted with barotrauma that Rummer and Bennett (2005) suggested they could be aptly described as a syndrome. Physiological effects of barotrauma include changes in plasma concentrations of proteins that affect coagulation (Casillas et al. 1975), and lysis of red blood cells and an increase in concentration of enzymes indicative of tissue damage (Morrissey et al. 2005). The prevalence and severity of physical (Rogers et al. 1986; St. John and Syers 2005; Hannah et al. 2008) and physiological (Casillas et al. 1975) affects of barotrauma progressively increase with increased capture depth.

To relieve barotrauma symptoms, particularly those associated with an expanded swim bladder, some anglers deflate, or vent or "fizz," the swim bladder of fish showing obvious signs of barotrauma. Fish are vented in a variety of ways, but this is most commonly accomplished by inserting a wide-bore hypodermic needle into the swim bladder (or body cavity if the swim bladder has ruptured), thereby allowing it to deflate. Venting is considered to be "controversial" (Rummer and Bennett 2005; Jarvis and Lowe 2008) because the apparent benefits of venting vary widely among studies, with some suggesting this practice is beneficial (W. Fable, National Marine Fisheries Service, Panama City, Florida, unpublished data; Collins et al. 1999; Sumpton et al. 2008) or without adverse effect (Lee 1992), whereas others suggest that venting is ineffective as a means of increasing survival of released fish (Render and Wilson 1996). Bartholomew and Bohnsack (2005) conducted a simple "vote counting" meta-analysis (see Gurevitch and Hedges 1999 for limitations of this method) of four experimental studies that assessed the efficacy of venting. They found no significant excess in the proportion of positive versus negative results, but concluded that the available evidence suggested venting, if performed properly, was an effective means of increasing survival of released fish.

At present, most Canadian provincial and many U.S. state fishery management agencies discourage anglers from venting released fish because improper venting may result in additional, occasionally fatal, injuries (Kerr 2001). Nevertheless, despite the conflicting evidence in support of venting, various individual investigators, some U.S. fishery management agencies (see Kerr 2001), and numerous marine fishery extension services and angler groups advocate this practice in pamphlets (e.g., FSG 1999) and on their websites. The Australian National Strategy for the Survival of Released Line Caught Fish recently endorsed venting as has, in effect, the U.S. National Marine Fisheries Service, which now requires offshore anglers in U.S. territorial waters in the Gulf of Mexico to have venting devices in their possession (NMFS 2008).

Studies that have assessed the potential benefits of venting fish released by anglers have been of two basic designs, survival experiments and capture-recapture studies. In survival experiments, fish are captured by angling or exposed to rapid depressurization in the lab, held in cages, aquaria, etc., and the survival of vented and unvented fish then is compared. In capture-recapture studies, vented and unvented fish are captured, tagged, and released. Subsequent recaptures then are used to assess the recapture rates of vented and unvented fish, based on the assumption that recapture rates are surrogate measures of survival (see Sumpton et al. 2008). Herein, I conduct a meta-analysis of published and unpublished studies that assess the potential survival benefits of venting fish to relieve the symptoms of barotrauma. I use relative risk (Sutton et al. 2000), which is widely used in the medical and epidemiological literature in the analysis of binary data, to summarize results of individual studies that assess the efficacy of venting fish. This approach allows me to combined survival estimates from experimental and capture-recapture studies. I specifically sought to determine whether:



**Coral trout *Plectropomus leopardus*, with signs of barotrauma including swelling of the abdomen, being vented with a hypodermic needle.**

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1. There is any difference in survival rate between fish that have their swim bladders vented and those that do not,
2. There is any difference in the survival benefits of venting between freshwater and marine fishes,
3. There is any difference in survival benefits between fish vented by anglers versus those vented by fishery biologists, and

4. There is a relationship between capture depth and the survival benefits of venting.

## METHODS

I compiled studies that compared survival or recapture rates of vented and unvented fish. I obtained comparative results from tables, figures, or text of the cited sources. Burns et al. (2002) presented tagging results compiled during two overlapping periods, October 1998 to December 2001 and 1990 through February 2002; I used results from the latter, more inclusive, period. I made no distinction among studies based on the type of device used to vent fish (e.g., hypodermic syringe, ice pick, knife, etc.). Most survival and recapture studies conducted by fishery biologists explicitly comment on the venting device; however, studies that used angler-supplied capture-recapture data include fish vented with a variety of devices for which no quantification was provided. I included only studies that allow direct comparisons of vented and unvented fish. For example, Bruesewitz et al. (1993) assessed survival of vented burbot (*Lota lota*), but they did not assess survival of unvented fish. Although survival of vented burbot was high, there is no way to determine whether this was attributable to venting. Similarly, Lee (1992) compared recapture rates of three groups of tournament-caught largemouth bass (*Micropterus salmoides*): those that showed no sign of barotrauma, of which some were released unvented and others vented, and those that possessed distended abdomens, an indicator of barotrauma, and were vented prior to release. Lee (1992) did not include fish that showed distended abdomens but which were not vented prior to release; therefore, no proper control group is available with which to assess the potential effects of venting on survival.

Among studies that compared different venting devices (e.g., Fable unpublished data; Collins et al. 1999), I combined data for all vented fish and made no distinction on this basis. Similarly, Keniry et al. (1996) assessed survival of three groups of fish: unvented and untagged, unvented and tagged, and vented and tagged. I used the combined results of the first two groups as control (unvented) fish. Some studies presented results for more than one trial, conducted in different seasons (Gitschlag and Renaud 1994) or years (Fable unpublished data); I combined data across seasons or years into a single sample for each study. In studies that examined multiple species, I treated each species as a separate sample. Similarly, among studies that examined one or more species using different protocols (experimental and tag-recapture), I treated data collected using each protocol as a separate observation.

Several studies presented experimental or capture-recapture results for vented and unvented fish captured from discrete depths or various depth ranges. To assess the relationship between potential survival benefits of venting and depth, I tabulated results separately for each depth or depth range reported. If samples were collected from a range in depth, e.g., 10 to 20 m, I used the midpoint of that range. When results for fish collected from an indefinite depth range were presented, such as 100+ m, I used the shallower depth of that range (i.e., 100 m) as the nominal capture depth.

If venting has no effect on survival or recapture, then vented and unvented fish should survive or be recaptured at equal rates. Therefore, I used relative risk to assess the efficacy of venting fish. Relative risk is the probability of an event (survival or recapture) in a treatment group (vented fish) divided by the probability of that event in a control group (unvented fish). I added 0.5 to all cells to accommodate those with zero values, as recommended by Sutton et al. (2000), and calculated relative risk as:

$$\text{relative risk} = S_v / (S_v + NS_v) / S_{nv}/(S_{nv} + NS_{nv})$$

where $S_v$ is the number of vented fish that survived in experimental studies or that were recaptured, $NS_v$ is the number of vented fish that did not survive or that were not recaptured, $S_{nv}$ is the number of unvented fish that survived experimental studies or that were recaptured, and $NS_{nv}$ is the number of unvented fish that did not survive or that were not recaptured. A value of 1.0 for the risk ratio implies no effect of venting; values greater than 1.0 imply that venting increases survival and recapture rates. The natural log of relative risk, ln(RR), has a sampling distribution that is approximately normal, with variance:

$$\text{Var}\ (\ln(RR)) = 1 / S_v\text{-}1 / (S_v + NS_v) + 1 / S_{NV}\text{-}1 / (S_{NV} + NS_{NV})$$

I used variances calculated according to equation (2) to estimate 95% confidence intervals about ln(RR) using the equation:

$$\ln(RR) \pm 1.96 \times \text{sqrt}(\text{Var}(\ln(RR)))$$

Herein, I report values of relative risk and its confidence interval that have been back-transformed to the linear scale; consequently, the confidence intervals reported herein are asymmetrical about the mean.

I used MetaWin 2.0 (Rosenberg et al. 2000) to calculate relative risk and its variance for each sample. I used Cochran's Q (Rosenberg et al. 2000), which is distributed as a $\chi^2$ statistic with *n*-1 df, where *n* is the number of groups being compared, to assess whether there was significant heterogeneity in relative risk among samples. In all cases, there was significant ($P < 0.05$) heterogeneity among samples, so I performed random effects meta-analyses of relative risk among species grouped across all species combined, by habitat type (freshwater versus marine), and by study type (experimental versus tagging). To assess the relationship between relative risk and capture depth, I performed a random effects meta-analysis with depth as a continuous covariate (Lipsey and Wilson 2001). This is, essentially, a weighted regression of ln(RR) on depth, in which each sample is weighted by the inverse of its variance. All analyses presented herein were performed with MetaWin 2.0 (Rosenberg et al. 2000).

## RESULTS

I located 17 studies (Table 1), which provided a total of 39 samples, that compared survival ($N = 18$) or recapture rates ($N = 21$) of vented and unvented fish in 21 species and 1

**Table 1.** A summary of experimental (exp) and capture-recapture (cap-recap) studies that assessed the survival benefits of venting fishes showing external signs of barotrauma. Relative risk, and 95% confidence intervals (CI), is the ratio of survival (or recapture) in vented fish divided by survival of unvented fish: values greater than 1.0 indicate that venting has a positive survival affect. Angler participation in capture-recapture studies is indicated by Y—yes or N—no.

| Species | Habitat | Study type | Anglers in study | Relative risk | Lower 95% CI | Upper 95% CI | Source |
|---|---|---|---|---|---|---|---|
| Black crappie *Pomoxis nigromaculatus* | fresh | exp | N | 1.03 | 0.44 | 2.41 | Childress (1987) |
| Black sea bass *Centropristis striata* | marine | exp | N | 1.19 | 1.08 | 1.31 | Collins et al. (1999) |
| Blue rockfish *Sebastes mystinus* | marine | cap-recap | N | 0.82 | 0.55 | 1.23 | Gotshall (1964) |
| Coral trout *Plectrodomus maculatus* | marine | exp | N | 1.03 | 0.87 | 1.22 | Brown et al. (2008) |
| Coral trout *Plectrodomus maculatus* | marine | cap-recap | Y | 0.74 | 0.44 | 1.23 | Brown et al. (2008) |
| Coral trout *Plectrodomus maculatus* | marine | cap-recap | Y | 1.16 | 0.32 | 4.18 | Sumpton et al. (2008) |
| Coral trouts *Plectrodomus spp.* | marine | cap-recap | Y | 1.80 | 0.47 | 6.83 | Brown et al. (2008) |
| Crimson snapper *Lutjanus erythropterus* | marine | exp | N | 0.99 | 0.86 | 1.13 | Brown et al. (2008) |
| Crimson snapper *Lutjanus erythropterus* | marine | cap-recap | Y | 1.34 | 1.02 | 1.76 | Brown et al. (2008) |
| Crimson snapper *Lutjanus erythropterus* | marine | cap-recap | Y | 2.36 | 0.66 | 8.45 | Sumpton et al. (2008) |
| West Australian dhufish *Glaucosoma hebraicum* | marine | exp | N | 1.00 | 0.67 | 1.50 | St John and Syers (2005) |
| Gag *Mycteroperca microlepis* | marine | cap-recap | Y | 1.83 | 1.49 | 2.25 | Burns et al. (2002) |
| Grass emperor *Lethrinus laticaudis* | marine | cap-recap | Y | 1.28 | 0.45 | 3.67 | Brown et al. (2008) |
| Grass emperor *Lethrinus laticaudis* | marine | cap-recap | Y | 4.35 | 0.85 | 22.39 | Sumpton et al. (2008) |
| Gray snapper *Lutjanus griseus* | marine | cap-recap | Y | 2.06 | 1.00 | 4.24 | Burns et al. (2002) |
| Largemouth bass *Micropterus salmoides* | fresh | exp | N | 1.00 | 0.82 | 1.22 | Shasteen and Sheehan (1997) |
| Pacific cod *Gadus macrocephalus* | marine | cap-recap | N | 0.74 | 0.53 | 1.03 | Forrester and Ketchen (1955) |
| Pink snapper *Pagrus auratus* | marine | cap-recap | N | 1.03 | 0.87 | 1.23 | Willis and Babcock (1998) |
| Red emperor *Lutjanus sebae* | marine | exp | N | 1.00 | 0.95 | 1.05 | Brown et al. (2008) |
| Red emperor *Lutjanus sebae* | marine | cap-recap | Y | 0.76 | 0.42 | 1.36 | Brown et al. (2008) |
| Red emperor *Lutjanus sebae* | marine | cap-recap | Y | 1.72 | 0.89 | 3.31 | Sumpton et al. (2008) |
| Red grouper *Epinephelus morio* | marine | cap-recap | Y | 0.63 | 0.56 | 0.72 | Burns et al. (2002) |
| Red snapper *Lutjanus campechanus* | marine | cap-recap | Y | 0.23 | 0.17 | 0.31 | Burns et al. (2002) |
| Red snapper *Lutjanus campechanus* | marine | exp | N | 1.52 | 0.58 | 3.95 | Gitschlag and Renaud (1994) |
| Red snapper *Lutjanus campechanus* | marine | exp | N | 0.97 | 0.80 | 1.19 | Render and Wilson (1994) |
| Red snapper *Lutjanus campechanus* | marine | exp | N | 1.03 | 0.97 | 1.09 | Render and Wilson (1996) |
| Redthroat emperor *Lethrinus miniatus* | marine | exp | N | 0.93 | 0.80 | 1.08 | Brown et al. (2008) |
| Redthroat emperor *Lethrinus miniatus* | marine | cap-recap | Y | 1.97 | 0.61 | 6.35 | Brown et al. (2008) |
| Saddletail snapper *Lutjanus malabaricus* | marine | exp | N | 1.42 | 0.91 | 2.19 | Brown et al. (2008) |
| Saddletail snapper *Lutjanus malabaricus* | marine | cap-recap | Y | 1.30 | 0.88 | 1.93 | Brown et al. (2008) |
| Saddletail snapper *Lutjanus malabaricus* | marine | cap-recap | Y | 1.06 | 0.49 | 2.29 | Sumpton et al. (2008) |
| Spangled snapper *Lethrinus nebulosus* | marine | exp | N | 1.06 | 0.61 | 1.82 | Brown et al. (2008) |
| Spangled snapper *Lethrinus nebulosus* | marine | cap-recap | Y | 0.34 | 0.02 | 6.97 | Brown et al. (2008) |
| Vermilion snapper *Rhomboplites aurorubens* | marine | cap-recap | Y | 2.05 | 0.12 | 36.07 | Burns et al. (2002) |
| Vermilion snapper *Rhomboplites aurorubens* | marine | exp | N | 0.77 | 0.58 | 1.02 | Fable, W. (unpublished data) |
| Vermilion snapper *Rhomboplites aurorubens* | marine | exp | N | 1.10 | 1.00 | 1.20 | Collins et al. (1999) |
| Walleye *Sander vitreus* | fresh | exp | N | 85.00 | 5.31 | 1360.58 | Insley, D. (Ohio Department of Natural Resources, unpublished data) |
| Walleye *Sander vitreus* | fresh | exp | N | 0.84 | 0.70 | 1.01 | RL&L (1995) |
| Yellow perch *Perca flavescens* | fresh | exp | N | 1.28 | 1.20 | 1.36 | Keniry et al. (1996) |

composite group (coral trout *Plectrodomus* spp.). My analyses include results for 4 freshwater and 17 marine species or groups. Relative risk ranged from 0.23 (95% confidence interval = 0.17 to 0.31) in red snapper (*Lutjanus campechanus*) to 85.00 (95% confidence interval = 5.31 to 1360.58) in walleye (*Sander vitreus*) that were captured in a fishing tournament and held in live wells before being vented and released.

Venting had no effect on fish survival in 32 of 39 individual samples (Table 1). In 2 samples, red grouper (*Ephinephelus morio*) and red snapper, upper 95% confidence intervals for relative risk were less than 1.00, which suggests that venting significantly ($P < 0.05$) reduced survival of these species. In 5 samples, black sea bass (*Centropristis striata*), crimson snapper (*L. erythropterus*), gag (*Mycteroperca microlepis*), walleye, and yellow perch (*Perca flavescens*), the lower 95% confidence intervals for relative risk exceeded 1.00, which suggests that venting significantly ($P < 0.05$) increased survival of these species. Among the 7 species that showed a significant response to venting, multiple samples were available for 3 (red snapper, crimson snapper, and walleye), none of which showed more than 1 significant ($P < 0.05$) response to venting. Similarly, none of the 10 species for which multiple estimates of survival were available showed a significant ($P < 0.05$) overall response to venting (Table 2).

Pooling relative risk estimates across all species and studies showed there was no evidence that venting affected fish survival (relative risk = 1.01, 95% confidence interval = 0.92 to 1.11). There was no evidence ($X^2 = 0.2821$, df = 1, $P = 0.595$) that venting affected fish survival differentially in freshwater (relative risk = 1.07, 95% confidence interval = 0.75 to 1.54) versus marine fishes (relative risk = 1.00, 95% confidence interval = 0.90 to 1.11). Relative risk did not differ ($X^2 = 0.758$, df = 1, $P = 0.384$) among studies based on design (experimental studies relative risk = 1.04, 95% confidence interval = 0.92 to 1.18; capture-recapture studies relative risk = 0.96, 95% confidence interval = 0.82 to 1.12). Finally, among tagging studies, there was no evidence ($X^2 = 0.476$, df = 1, $P = 0.490$) that survival differed based on whether fish were tagged and vented by fishery biologists (relative risk = 0.86, 95% confidence interval = 0.18 to 4.05) or anglers (relative risk = 1.13, 95% confidence interval = 0.78 to 1.65). The wider confidence interval observed in studies conducted by fishery biologists is, presumably, due to the smaller number of such studies ($N = 3$) compared with those in which anglers participated ($N = 18$).

The effects of venting varied with capture depth particularly in capture-recapture studies Figure 1), which are most sensitive to delayed effects of capture and release. Relative risk decreased significantly with capture depth ($P = 0.044$), indicating that venting was slightly beneficial for fish captured from shallow waters, but was potentially harmful to fish captured from progressively deeper depths. The relationship between relative risk and capture depth was more pronounced in capture-recapture studies ($P = 0.001$) than in experimental studies ($P = 0.781$). There are two possible explanations for this. Capture-recapture studies assess the long-term consequences of capture, venting, and release, and fishes captured in these studies were frequently captured at greater depth than those used in experimental studies.

## DISCUSSION

The available information provides virtually no support for the practice of venting as a means of increasing survival of captured and released fish. This result is consistent across a variety of experimental and field study protocols, within and among various species of fish, including species captured in freshwater and in saltwater, and from various depths. Nevertheless, this result is counterintuitive because fish that are unable to submerge after release have poor survival prospects. Fish that cannot submerge are subject to predation (Collins 1996; Keniry et al. 1996; Overton et al. 2008), stress from high surface water temperatures (Shasteen and Sheehan 1997; Bettoli and Osborne 1998), and injury due to sun exposure (Keniry et al. 1996) and being struck by boats (Gravel and Cooke 2008). Although fish that can swim away or submerge commonly are considered to have survived catch and release (e.g., Gitschlag and Renaud 1994), this assumption is largely untested and there is some evidence that the ability to swim away is unrelated to survival (Bettoli and Osborne 1998; St. John and Syers 2005). Additionally, fish suffering barotrauma often exhibit atypical behavior (Gotshall 1964; Hannah and Matteson 2007; Gravel and Cooke 2008), which can adversely affect survival. It is, perhaps, the counterintuitive nature of this result, along with some wishful thinking, that has perpetuated the practice of venting.

Both experimental studies, which assess short-term affects of venting, and capture-recapture studies, which assess long-term effects, failed to provide support for venting. Failure to

**Table 2.** Composite estimates of relative risk, and 95% confidence intervals (CI), in species for which there were multiple assessments of the survival benefits of venting.

| Species | Number of estimates | Relative Risk | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| Coral trout | 3 | 0.93 | 0.24 | 3.56 |
| Crimson snapper | 3 | 1.27 | 0.35 | 4.59 |
| Grass emperor | 2 | 1.97 | 0.00 | 2431.05 |
| Red emperor | 3 | 1.07 | 0.31 | 3.73 |
| Red snapper | 4 | 0.71 | 0.33 | 1.55 |
| Redthroat emperor | 2 | 1.14 | 0.01 | 151.34 |
| Saddletail snapper | 3 | 1.27 | 0.35 | 4.62 |
| Spangled snapper | 2 | 0.95 | 0.00 | 525.66 |
| Vermilion snapper | 3 | 0.96 | 0.25 | 3.72 |
| Walleye | 2 | 1.25 | 0.01 | 307.55 |

properly deflate swim bladders by anglers participating in capture-recapture studies could contribute to the observed inefficacy of venting. Indeed, many fishery management agencies (see Kerr 2001), extension services (e.g., Theberge and Parker 2005), and researchers (Keniry et al. 1996; Render and Wilson 1996) discourage anglers from venting fish because poor technique can result in injuries to internal organs, causing potentially fatal wounds. However, there has been no demonstration that fishery biologists are more knowledgeable concerning barotrauma or more skilled at venting than are anglers. For example, Gitschlag and Renaud (1994) repeatedly state that they vented the everted "gas bladders" (i.e., everted stomachs) of red snapper. The available information shows that, on average, fish captured, vented, and released by anglers fare no worse than those that are vented by fishery biologists. Thus, the observed inefficacy of venting in capture-recapture studies cannot be attributed to angler technique.

As an alternative to venting, several devices have been developed, recommended by fishery biologists, and used by anglers to return fish to the depth from which they were captured. These devices include baskets or cages in which fish are placed and lowered to some depth, usually the bottom, and shot weights (e.g., Theberge and Parker 2005). Brown et al. (2008) provide the only available assessment of the survival benefits of shot weights compared with venting. Among six species of Australian reef fish showing signs of barotrauma, Brown et al. (2008) found that survival was similar among control (unvented) fish, vented fish, and fish that were returned to depth using shot weights. Thus, there was no evidence that shot weights increased survival of released fish. There has been no assessment of the efficacy of baskets or cages in promoting survival of released fish.

The inefficacy of venting, and apparently drop weights, in promoting survival of released fish may be due to the severity of the injuries sustained as a result of barotrauma. Virtually every organ in the body of a fish is affected by barotrauma (e.g., Feathers and Knable 1983; Rummer and Bennett 2005; Phelan 2008), regardless of the presence of a swim bladder (e.g., Brown et al. 2007). Notably, Rummer and Bennett (2005) identified over 70 different injuries that resulted from overexpansion of the swim bladder alone. Venting fish, or returning them to their capture depth by any other means, has the potential benefit of relieving some symptoms of barotrauma (St. John and Syers 2005; Parker et al. 2006; Jarvis and Lowe 2008). However, the physiological effects of barotrauma are not remediated simply by returning the fish to its capture depth (Morrissey et al. 2005) and many barotrauma injuries are unaffected by recompression. Eversion and prolapse of the stomach and intestine are irreversible in some species and ultimately can result in death (Rogers et al. 1986; Phelan 2008). Similarly, torsion and volvulus of the stomach and intestines, which commonly are observed in fishes suffering barotrauma (Render and Wilson 1996; Rummer and Bennett 2005; Jarvis and Lowe 2008), are potentially fatal and are unlikely to resolve following recompression (Rummer and Bennett 2005; Phelan 2008). Hemorrhaging of the liver, heart, and other organs (e.g., Rummer and Bennett 2005; Parker et al. 2006; Phelan 2008) does not necessarily cease, nor do hematomas caused by this bleeding spontaneously resolve, upon recompression. Severe exophthalmia, such as occurs following rupture of the swim bladder and the consequent accumulation of gases in orbital cavities, can result in extreme stretching of the optic nerve, causing permanent impairment or loss of vision (Fable unpublished data; Rogers et al. 2008). Gravel and Cooke (2008) suggested there was a need to find alternatives to venting as a means for recompression of fishes suffering barotrauma. Any such alternative would have to provide relief from a number of serious injuries to be effective.

Several studies have shown that survival of released fish is inversely related to capture depth (Rogers et al. 1986; Gitschlag and Renaud 1994; St. John and Syers 2005). In particular, Render and Wilson (1994) hypothesized that survival decreased exponentially with capture depth and, consequently, that the potential benefits of venting would increase with capture depth. My summaries and analyses do not address variation in the magnitude of survival, or its relationship

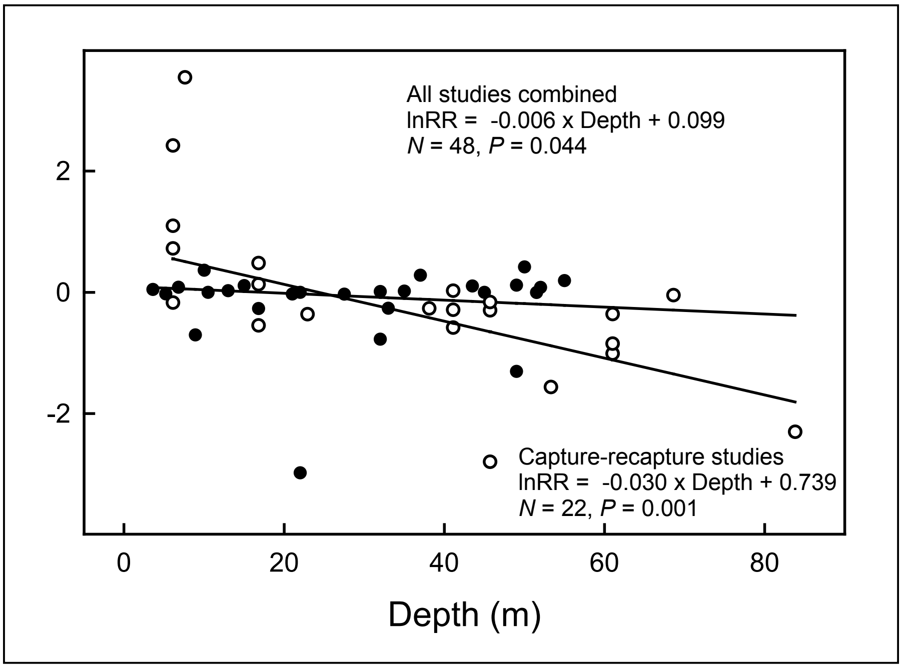

**Figure 1.** The natural log of relative risk (lnRR) was negatively related to capture depth, which indicates that venting may be beneficial for fishes captured from shallow waters, but becomes less beneficial, possibly harmful, for fish captured at greater capture depths. The upper line and regression statistics are for combined samples from experimental (solid circles) and capture-recapture studies (open circles). The lower line and regression statistics are for capture-recapture studies (open circles) only.

with depth; however, they are inconsistent with Render and Wilson's (1994) hypothesis and, instead, show that the survival of vented fish, compared with those that are not vented, actually decreases with depth of capture.

The observed negative relationship between relative risk for venting and capture depth can arise in either of two slightly different ways. First, venting might be beneficial to fish captured from shallow waters, but becomes progressively less beneficial as capture depth increases. Hannah et al. (2008) concluded that venting had no effect on the survival of released fish that were unable to submerge on their own. They suggested that such fish failed to submerge not because of their expanded swim bladders, but because they already were fatally stressed or injured and, thus, were incapable of submerging. Because the prevalence and severity of barotrauma injuries increase with depth of capture (Rummer and Bennett 2005; St. John and Syers 2005; Hannah et al. 2008), one would expect greater survival among vented (as well as unvented) fish captured from shallow waters compared with those captured from deeper waters. This could result in the observed relationship. Alternatively, venting may be of no benefit to fish captured from shallow waters, but it then becomes increasingly harmful as capture depth increases. This could result if venting was without effect, except as one additional stressor to which captured fish are subjected, and survival of fish captured from progressively deeper waters, which arguably are more stressed than those captured from shallower waters, is reduced because of the stress of venting and associated handling. The available data do not allow one to distinguish between these two alternatives; however, both have important fishery management implications.

High release mortality and the potential for permanent injuries in fishes suffering barotrauma led Rummer and Bennett (2005) and St. John and Syers (2005) to question the effectiveness of minimum length limits in the management of fisheries for red snapper and West Australian dhufish (*Glaucosoma hebraicum*), respectively. These authors proposed eliminating minimum length limits and requiring that all captured fish, up to the bag limit, be kept (Rummer and Bennett 2005), or enacting seasonal or spatial restrictions on demersal fishing when and where undersized fish were concentrated (St. John and Syers 2005). As an alternative to minimum length limits, Wilde et al. (2003) suggested that restrictions on the size of lures and baits used by anglers could be used to reduce catches of undersized fish in fisheries with high release mortality. Any alternative to the use of minimum length limits will disaffect some portion of the angling community, but the inefficacy of venting provides a compelling need to consider and enact these alternatives. Capture depth was recognized by Muoneke and Childress (1994) as an important determinant of survival of released fish and, hence, fishery quality. Fifteen years later, barotrauma and the means for mitigating it remain among the most important unresolved issues in fishery management (Arlinghaus et al. 2007).

There is an additional reason to pursue alternatives to the management status quo in fisheries affected by a high incidence of barotrauma. Fishes suffering barotrauma experience a wide range of serious, permanent, and potentially debilitating injuries. Although there is ongoing debate as to whether, and to what extent, fish feel pain (e.g., Rose 2002; Sneddon 2006), there is growing concern within the fishery management community for the welfare of fishes captured and released by anglers (Davie and Kopf 2006; Huntingford et al. 2006; Cooke and Sneddon 2007). Indeed, Arlinghaus et al. (2007) argue convincingly that this concern cannot be ignored and, in the future, will directly impact fishery management. Responsible fishery management requires such actions as are necessary to reduce mortality attributable to barotrauma. Ethical fisheries management similarly requires such actions as are necessary to minimize catches of undersize and nontarget fishes and minimize injuries resulting from barotrauma.

## CONCLUSION AND RECOMMENDATION

The available evidence fails to demonstrate that venting fishes exhibiting symptoms of barotrauma promotes post-release survival. In fact, it is possible that this practice decreases survival of fish captured from deeper waters, presumably because of the greater severity of their barotrauma symptoms. Venting fish should not only be discouraged by fishery management agencies (e.g., Kerr 2001), but given the possibility that venting adversely affects survival of released fish, this practice should be prohibited, rather than mandated (i.e., NMFS 2008).

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