The effect of rapid decompression on barotrauma and survival rate in swallowtail seaperch (Anthias anthias): Defining protocols for mitigating surfacing mortality

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\section{Introduction}

Fish barotrauma is associated with rapid decompression that may occur during fishing operations (Wilson and Burns, 1996; Burns and Restrepo, 2002; Lenanton et al., 2009; Butcher et al., 2012), lifting fish cultured in oceanic sea-cages (Korsøen et al., 2010; Ferter et al., 2015), or fish passing hydroelectric facilities (Colotelo et al., 2012; Richmond et al., 2014). It is defined as a physical trauma resulting from a rapid decrease in ambient pressure, and is common amongst fish captured from depth (Rummer and Bennett, 2005; Nichol and Chilton, 2006).

Barotrauma is common in fish with a closed swimbladder (physoclistous), which regulates buoyancy over depth changes by secreting and reabsorbing swimbladder gases (Jones, 1952; Parker et al., 2006). As gas secretion and reabsorption are relatively slow processes, the “free vertical range” that the fish can swim and compensate is restricted to the extent and speed of the changes in depth and time taken to adjust to a new pressure (Jones and Scholes, 1985; Stensholt et al., 2002). In physoclistous fish, a rapid compression or decompression of individuals can be harmful or lethal, as a result of the rapid compression or expansion of gases (Burns and Restrepo, 2002; Hannah and Matteson, 2007; Korsøen et al., 2010).

Fish suffering from decompression barotrauma usually exhibit characteristic symptoms (Rummer and Bennett, 2005). Expanded gases can cause swimbladder distension or rupture which, in some cases,
includes compression injuries to organs, eversion of the esophagus or stomach, or intestinal protrusions from the anus. Exposure to barotrauma can also cause exophthalmia, embolism and hemorrhaging in almost all body tissues, such as gills, heart, liver and brain (Gitschlag and Renaud, 1994; Rummer and Bennett, 2005; Parker et al., 2006; Hannah and Matteson, 2007; Gravel and Cooke, 2008; Jarvis and Lowe, 2008; Wilde, 2009).

Several studies have been conducted in order to understand the range of depths and pressure changes relative to neutral buoyancy in physoclistous fish. Godü and Michalsen (2000) and Stensholt et al. (2002) indicate that the free vertical range of cod, Gadus morhua, corresponds to no more than a 50% pressure reduction in depth, relative to neutral buoyancy. Korsøen et al. (2010) recommend that lifting steps of cages in farmed cod should be lower than 40%, while maintaining a slower rate, to enable the recovery of cod. Although barotrauma is a common issue in the capture of live fish for the public aquaria industry, it has been rarely addressed. Barotrauma has prevented deep water fish to be exhibited in public aquaria and therefore limiting environmental awareness activities related to deep-sea ecosystems. Holding live fish in sea cages and performing optimal decompression profiles may help overcoming barotrauma problems in fish captured in deeper waters and allow deep water fish to be exhibited in public aquaria.

The swallowtail seaperch, Anthias anthias (Linnaeus 1758), is a physoclistous fish very popular in the public aquaria industry worldwide, mainly because of its unique appearance and striking coloration. This species displays gregarious behavior, inhabiting rocky substrates and submarine caves commonly at depths between 30 and 200 m (Paglialonga et al., 2001; Micarelli and Barlettani, 2005; Espino et al., 2007), and is subject to barotrauma and high mortality rates associated with rapid decompression if an appropriate decompression profile is not used (Paglialonga et al., 2001; Micarelli and Barlettani, 2005). Internal or external signs of barotrauma have not yet been described for any Anthinidae species and reliable protocols for mitigating ascendance injury and mortality have not been developed.

Therefore, the objective of this study was to develop a protocol for mitigating surfacing mortality in swallowtail seaperch, while assessing its resilience to changes in pressure during ascendance to the surface. We aimed specifically at i) assessing fish condition state of swallowtail seaperch subject to different pressure changes and acclimation times during decompression; ii) quantifying post-decompression fish condition state and recovery rates; and iii) determine an optimum decompression protocol that reduces mortality and increases long-term survival of swallowtail seaperch.

2. Materials and methods

2.1. Study location and fish collection

This study was conducted in Faial Island, Azores in 2012. Capture and decompression trials were conducted in Baía da Garça (38°31’N; 028°37’W) due to its proximity to the harbor and easy access by boat. This bay is relatively sheltered throughout the year and large schools of A. anthias are usually found. Fish were collected by a team of 3 to 5 divers at depths varying from 33 to 40 m. To do this, a knotless seine net (2.5 cm stretched mesh size) was adapted to be operated underwater. This stationary net had a floatline along the top and a leadline with sinkers along the base, keeping the floats from lifting the net from the bottom and forming a vertical wall with approximately 4 m wide x 2.5 m high. When schools of A. anthias were detected, the fish were huddled and driven by the divers towards the net. Fish were then captured with hand nets, handled very gently and placed in custom designed decompression containers. These consisted of 15L polypropylene cylindrical shape containers, with an acrylic window on top to allow the observation of fish behavior during decompression. The containers had holes around which allowed for water flow and keeping the pressure inside and outside the container equal. Fish densities were kept constant at 5 fish per container whenever possible. In total, 83 A. anthias were collected.

2.2. Decompression experimental design

After collection, A. anthias were maintained in decompression containers at 30 m depth for at least 24 h to allow them to recover from any possible stress caused by capture. A decompression line was set consisting of a polypropylene cable anchored at 30 m depth with a dead weight of approximately 100 kg connected to a subsurface buoy that ensured the cable was permanently under tension. The cable was marked at the multiple depths at which different treatments would make a decompression stop. At each decompression step containers were well secured with strong elastic straps.

To test behavioral responses and survival rates due to pressure reduction, a series of container lifting steps were conducted. Four different treatments (i.e. changes in pressure rates) were tested, corresponding to 15%, 25%, 35% and 45% reductions in pressure from the initial depth of 30 m (i.e. 4 ATA, absolute atmospheres) or previous lifting step. The number of lifting steps and at which depth they occurred was variable and is illustrated in Fig. 1. Decompression using this procedure was done with two different acclimation durations.
between each pressure change: 12 and 24 h (Fig. 1). Each lifting to a
new depth was conducted by the same diver at a standardized ascension
rate of 4 m·min⁻¹. In summary, 8 different treatments of percentage of
pressure reduction x acclimation time were tested: 15% x 12 h (n = 10),
15% x 24 h (n = 10), 25% x 12 h (n = 14), 25% x 24 h (n = 5), 35% x
12 h (n = 10), 35% x 24 h (n = 13), 45% x 12 h (n = 5), and 45% x
24 h (n = 11). Uneven sample sizes resulted from difficulties in cap-
turing a sufficient number of fish in each fishing event.

2.3. Assessing fish condition state

Assessment of the behavior of the animals based on swimming
speed, tail beat and swimming angle, were used to assign a fish con-
dition state. The fish condition states used in this study were:

i. Moribund with positive buoyancy: fish floating at the surface or top
of the decompression container with apparent tight abdomen
symptom and lacking the ability to swim to the bottom or sink;
ii. Positively buoyant: fish with downward compensatory swimming
(head down/caudal fin up) displaying accelerated and powerful tail-
beating and swimming speed;
iii. Neutrally buoyant: fish that were able to maintain a horizontal
position with minimal movement;
iv. Negatively buoyant: fish displaying compensatory swimming (head
up/caudal fin down) with accelerated tail-beating in order to keep
off the bottom;
v. Moribund with negative buoyancy: fish on the bottom showing very
little activity and with no reaction of stimulus;
vi. Dead.

Neutrally buoyant fish (iii) were considered to be in the best con-
dition, immediately followed by positively buoyant fish (ii), which were
believed to have the swimbladder slightly inflated but with a high
probability for gas resorption. Negatively buoyant fish (iv) were be-
lieved to have suffered rupture of the swimbladder with moderate
probability for recovering. Moribund with positive and negative
buoyancy (i and v) were believed to be in the worst condition state and
with the lowest probability for surviving (Alexander, 1966; Stevens,
2011).

2.4. Assessing fish condition during decompression

Fish condition state was evaluated during the ascendance to surface
i) immediately after each lifting step (C₁), to identify the immediate
response to pressure reduction; and ii) after two different acclimation
durations (C₂) following each pressure reduction, to identify the re-
covery response after 12 and 24 h.

The control group was brought to the surface directly from 30 m
depth corresponding to a 75% pressure reduction. This procedure was
performed by the same diver and also at the standardized rate of
4 m·min⁻¹. A diver’s safety stop at 5 m for 3 min was always respected.
During the ascension of the control group, the diver observed the
depths at which: (i) individuals went from neutral to positively
buoyant; (ii) intestinal eversion occurred; (iii) swim bladder rupture
occurred as observed by the release of gas bubbles from the anus. All
fish were brought to the surface individually to allow for easier ob-
servations (n = 5).

2.5. Assessing fish condition during post-decompression

Once at the surface, the animals were kept on land-based tanks for
approximately 14 days. During this period, all fish were monitored and
assessed closely, to identify behavioral effects and survival rates: (i)
short-term; measured after 24 h (C₂₁₄); at surface; (ii) medium term;
measured after 72 h (C₂₇₂); at the surface (iii) long-term; measured after
14 days (C₂¹₄). Similarly to the decompression evaluation, post-
decompression evaluation used the same 6 fish condition state (see
above).

A. anthias were held in 1200 L cylindrical polyethylene tanks, each
divided in 8 equal sections containing the different decompression
treatments with the respective replicates as well as the control group.
Initial fish densities were 5 fish per tank section in most cases. The
tanks were equipped with mechanical filtration in a semi-closed re-
circulating system, with 100% water changes daily. New water was
pumped directly from the nearby shore, as the staging facility was lo-
cated inside Horta’s harbor. Water from tanks parameters were mon-
tored every day to ensure optimal water quality: temperature
(20.5 ± 2.3 °C; range 17.1–24.7 °C), ammonia (0.001 mg L⁻¹; range
0–0.027 mg L⁻¹), pH (8.1 ± 0.1; range 8.0–8.2), dissolved oxygen
(91 ± 7%; range 60–100%) and salinity (36 PSU). Twenty-four hours
after arrival fish were fed with frozen shrimp and food pellets. Food was
then offered to satiation every second day. Fish were provided with PVC
pipes with multiple diameters, positioned in the bottom of the tank, to
provide shelter and reduce stress.

2.6. Data analysis

Data did not meet the normality and homoscedasticity assumptions,
even after transformation, and a PERMANOVA multivariate analysis of
variance test (unrestricted permutation of raw data) was therefore ap-
plied (Anderson et al., 2008). This statistical analysis is a powerful non-
parametric approach that uses a permutational technique to enable
significance tests for small sample sizes to be conducted (Walters and
Coen, 2006) and was used to test the effect of pressure reduction and
acclimation time on the fish condition state and recovery rates. The
analyses were conducted using the software PRIMER 6 & PERMANOVA
using a resemblance matrix based on Euclidean and treatments as fixed
effects. The PERMANOVA was run using 9999 permutations to produce
p values using the Monte Carlo (MC) method. When the main test
produced a significant result (p < .05), a pairwise test was conducted
to identify the individual differences between treatments.

3. Results

3.1. Assessing fish condition state during decompression

Overall, the average proportion of neutrally buoyant fish im-
mediately after each pressure reduction was higher at lower pressure
change rates and longer acclimation duration (Fig. 2a). However, the
PERMANOVA with Monte Carlo test showed significant differences
between pressure changes (p (MC) < 0.0001), no significant differ-
ences between acclimation time (p (MC) = 0.9776), and the interaction of the
two factors was not significant (p (MC) = 0.067) Table 1.

After acclimation time at each depth, the proportion of neutrally
buoyant fish was also higher at lower pressure change rates but did not
show a marked trend with acclimation duration (Fig. 2b). The PERM-
ANOVA with Monte Carlo test showed significant differences between
pressure changes (p (MC) = 0.035), no significant differences between
acclimation time (p (MC) = 0.556), and the interaction of the two factors was not significant (p (MC) = 0.367). The higher proportion of
neutrally buoyant fish arriving to the surface occurred in 24 h accli-
mation durations in the 15%, 25%, 35% and 45% pressure change
treatments with 0.90, 1, 0.85 and 0.91 of neutrally buoyant fish, re-
spectively. The control group, subjected to a 75% pressure reduction,
revealed that only 0.40 of fish arrived to the surface neutrally buoyant.
The 12 h acclimation period was, on average, sufficient for the recovery
of fish subject to a pressure change of 15%, 25% and 35% but appar-
ently not enough for those individuals subjected to a 45% pressure
change.

During the decompression steps, as fish were being lifted, the pro-
portion of neutrally buoyant decreased as the number of positively
buoyant fish increased, which is caused by the reduction in pressure
Condition fidecompression (C24 h, C72 h and C14 d). 

Cropsied, and barotrauma symptoms were identified in the decompression trials, both of which related to barotrauma. One at the second lift of the 35% x 12 h treatment and another one during the third lift of the 25% x 12 h treatment. The former death was also necropsied, and barotrauma symptoms were identified, such as tight abdomen and several internal hemorrhages. The latter death displayed, upon necropsy, formation of gas bubbles in the pharyngo-cleithral membrane.

3.2. Assessing fish condition state post-decompression trials

The fish condition state post-decompression trials were assessed in the short-term (24 h), medium term (72 h) and long-term (14 days). Twenty four hours after arriving to the surface, the proportion of neutrally buoyant A. anthias post-decompression trial, was higher for all 24 h treatments when compared to the 12 h treatments (Fig. 4). There was no clear trend on the effect of the pressure change in the condition of fish 24 h after arriving to the surface. Accordingly, the PERMANOVA with Monte Carlo test showed significant differences between acclimation time (p (MC) < 0.010), but no significant differences between pressure changes (p (MC) = 0.573), or the interaction of the two factors (p (MC) = 0.477).

Medium term monitoring indicated higher proportion of neutrally buoyant fish in 35% x 24 h, 15% x 24 h and 35% x 24 h treatments (Fig. 4). However, PERMANOVA with Monte Carlo test showed no significant differences between acclimation time (p (MC) = 0.416), pressure changes (p (MC) = 0.721), or the interaction of the two factors (p (MC) = 0.985).

Long term monitoring after 14 days demonstrated a similar scenario, where the same higher proportions of neutrally buoyant fish were observed (Fig. 4). Similarly, the PERMANOVA with Monte Carlo test showed no significant differences between acclimation time (p (MC) = 0.525), pressure changes (p (MC) = 0.844), or the interaction of the two factors (p (MC) = 0.965). The general condition states of A. anthias after 14 days of acclimation were generally very good in all treatments. The results also showed that, with the exception of 25% pressure reduction rate, all treatments had a higher proportion of neutrally buoyant fish in 24 h acclimation time. The 25% treatment was the only displaying an equal proportion of neutrally buoyant fish for both 12 h and 24 h. The control group after 14 days revealed the lowest proportion of neutrally buoyant fish in 35% x 24 h, 15% x 24 h and 35% x 24 h treatments (Fig. 4).

3.3. Evaluation of the control group

The evaluation of the control group showed that the average of depth at which fish became positive buoyant was at 18.4 ± 1.4 m (Fig. 5), corresponding to a 29% pressure reduction. Intestinal protrusion occurred in four fish at 4.7 ± 2.1 m (Fig. 5 a - d), corresponding to a 63% pressure reduction, from initial depth. Additionally,
Swimbladder ruptures were observed in four fish, occurring at 1.9 ± 0.87 m (Fig. 5a - d), corresponding to a 70% pressure reduction from initial depth. Three fish were moribund positive when arrived at the surface, with swollen abdomen symptom while floating at the top of the decompression container (Fig. 5b, c, d). The other two individuals displayed typical positive buoyant behavior with a fast-compensatory downward swimming. The post-decompression trial revealed that after 24 h in the tanks there were four fish positively buoyant and one with negative buoyancy. After 72 h two fish were negatively buoyant, and three fish apparently regained their neutral buoyancy.

4. Discussion

Although this study encompasses some limitations, such as reduced (n = 83) and uneven samples size (not always 15 per treatment), or the reduced number of acclimation times (12 and 24 h), it successfully addressed the effect of different decompression profiles on barotrauma and behavior responses to pressure changes in A. anthias. Changes in pressure rates tested in this protocol were within the ranges at which some physoclistous fish can recover and restore neutral buoyancy (Godù and Michalsen, 2000; Stensholt et al., 2002; Korsøen et al., 2010). It is known that the capacity of a physoclistous fish to adapt to a range of depths is mainly related to its natural behavior, in terms of daily vertical migrations, as the swimbladder can restrict these movements (Jones and Scholes, 1985; Pribyl et al., 2009).

As with other species, e.g. cod G. morhua (Jones and Scholes, 1985; Korsøen et al., 2010), visually examining the behavioral responses in A. anthias subjected to pressure reduction, proved to be an effective method. Similar behavior was observed in positively buoyant fish during the decompression and post-decompression trials. After lifting events, positive buoyancy was compensated with a downward fast compensatory swimming, with continuous strong tail beats and showing a head down/tail up position relative to horizontal. In the post-decompression trial, positively buoyant fish were constantly looking for shelter inside PVC tubes to avoid emerging and reduce the energy loss caused by constant downward swimming.

Although the experimental protocol wasn't designed to understand the exact duration necessary to adapt to a certain pressure change, our results suggest that 24 h acclimation time in a new depth can benefit fish health, compared to an acclimation time of 12 h. In all four pressure reduction rates tested, the proportion of neutral individuals at the surface was always higher in the 24 h acclimation time.

The cumulative effect observed, where in deeper lifting steps the proportion of neutrally buoyant fish was higher compared to shallower steps, could be explained by the pressure that occurs in deeper water compared to those in shallower water. Jones (1952) and Fänge (1983) described similar results for cod, Gadus morhua, where the rate of gas resorption increased with the pressure to which the fish were adapted from. These results indicate that in different magnitude ascensions, involving the same proportional pressure reductions, the time taken to

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**Fig. 3.** Proportion of neutrally buoyant fish during decompression steps; a – d) for the four pressure reductions rates with 12 h acclimation time; e - h) for the four pressure reductions with 24 h acclimation time. Red indicates lower proportion of neutrally buoyant fish or bad condition state while blue indicate higher proportions of neutrally buoyant fish or good condition state. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Fig. 4.** Proportion of neutrally buoyant A. anthias during post-decompression trials assessed in the short-term (C24h), medium term (C72h), and long-term (C14d).
adjust to a new pressure in an ascension, will be lesser in deeper than in shallower water. Thus, as described by Jones and Scholes (1985) and Korsøen et al. (2010) for G. morhua, the resorption of gases in the swimbladder near the surface is lower compared to deeper waters.

During the post-decompression trial, three fish - despite being neutrally buoyant for a period of time - regained their positive buoyancy. This unusual behavior could be due to internal injuries, induced during the decompression phase that could have affected the fish. Internal injuries caused by decompression may not be visible with external inspection. However, they may affect long-term fish health. The expansion of gases in the swimbladder can lead to compression injuries of internal vital organs and emboli can cause internal hemorrhaging that may affect long-term fitness (Gitschlag and Renaud, 1994; Rummer and Bennett, 2005; Parker et al., 2006; Butcher et al., 2012). Goolish (1992) showed that killifish, Fundulus heteroclitus, subjected to artificial lift required a minimum of 7–8 days to restore their neutral buoyancy, in order to completely reabsorb gases in the swimbladder. This author also observed high variability amongst individuals, with some fish being unable to decrease swimbladder volume below 60–70% of its normal state. Similarly to the killifish, A. anthias regained neutral buoyancy after 8 days in the 25% - 12 h (in two fish), and after 13 days in the 15%-12 h (in one fish).

Assessing the effects of decompression on A. anthias has proven to be valuable. The average pressure reduction rate at which fish became positively buoyant was 29% pressure reduction from the initial depth of 30 m, which could indicate an approximate value of the free vertical range of this species in ascending situations. This value was similar to the 25% pressure reduction observed by Jones and Scholes (1985) while following individual cod in the sea, suggesting this was the safe limit for cod to maintain its buoyancy. Moreover, the free vertical range should correspond to < 50% pressure reduction, for cod, in natural habitats, and < 25% in pressure tank experiments. Intestinal protrusion occurs at a depth slightly below and the swimbladder ruptures at 63 and 70% of pressure reduction, respectively. Interestingly Jones and Scholes (1985) suggested similar values for wild cod at which, pressure reductions above 60% can cause swimbladder rupture.

There were two unexpected results in the control group that deserve scrutiny. Two individuals - after 24 and 48 h - went from positive to negative buoyancy.

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**Fig. 5.** Phenomena occurring during decompression and post-decompression trials of the A. anthias control group (n = 5, a-e). The x-axis indicate the buoyancy of fish (Moribund negative – M(−); negative - (−); neutral - (0); positive - (+); Moribund positive - M(+) ). The y-axis show the decompression ascendance (negative values), and post-decompression (positive values); Red cross (•) indicate change from neutral to positive buoyancy; Red square (■) Intestinal protrusion; Red X (x) swimbladder rupture. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
negative buoyancy in the post-decompression trial (Fig. 5 a and b). In both cases there was occurrence of swimbladder rupture during the ascendance, which was observed by the release of gas bubbles from the anus. Despite this fact, both individuals arrived to the surface positively buoyant (one individual was positive buoyant and the second was moribund positive). Moreover, as described above, after 48 h both fish were negatively buoyant contrarily to what was expected. We therefore hypothesized the following: during the ascendance, with the sudden decompression, the gases in the swim bladder expand, therefore compressing internal organs (Rummer and Bennett, 2005); such compression can provoke intestinal protrusion, at which point the intestine (or a small portion of the intestine) is pushed out of the abdominal cavity. If the ascension is too fast for the fish to reabsorb the excess of gas in the swim bladder, the gas overexpands, leading to swimbladder rupture (Jones and Scholes, 1985; Rummer and Bennett, 2005; Colotelo et al., 2012). As the anus is obstructed with the intestine, the gas released from the swimbladder gets trapped in the abdominal cavity. The release of small gas bubbles from the anus, observed during the ascendance, may indicate that there should be a lag between the depth recorded for swimbladder rupture, and the real depth at which this event occurred. Moreover, the observed phenomena of intestinal protrusion can be a consequence of swimbladder rupture, where the air trapped in the abdominal cavity forces the intestine evert from the anus. Consequently, the air is forced to escape from the abdominal cavity through micro-fissures in the everted intestine. We could therefore assume that swimbladder rupture could have occurred between 63 and 70% of pressure reduction. The air of the abdominal cavity escaped completely after 24 and 48 h respectively, at which point fish became negatively buoyant in the tank due to previous swimbladder rupture.

In two other fish, the same phenomena could have occurred, with a slight difference: after 24 h post-decompression, the two positively buoyant fish regained their neutral buoyancy (Fig. 5 c and d). Since fish have the ability to heal damaged swimbladder rapidly (Burns and Restrepo, 2002; Brown et al., 2010), it is possible that time needed to completely relieve the trapped gas from the abdominal cavity (approximately 24 h) was the time to heal the swimbladder, and consequently these two fish became neutrally buoyant. Burns and Restrepo (2002) found that red grouper, Epinephelus morio, and red snapper, Lutjanus campechanus, are able to heal the swimbladder sufficiently to be functional in four days. Shasteen and Sheehan (1997) reported that largemouth bass, Micropterus salmoides, are capable of healing their swimbladders within 17 h from a 0.5 cm hole. The fact that these two individuals required ten and eleven days to regain their positive buoyancy suggests the intensity of the rupture. Nichol and Chilton (2006) showed that ruptured swimbladders in Pacific cod when sufficiently small, the healing process is very fast but not entirely deflating the swimbladder.

In order to maintain healthy A. anthias individuals at the surface, for public aquarium exhibiting purposes, the framework of this study was to define a protocol for mitigating surface mortality while increasing healthy individuals in the long term. Our study suggests the need for a balance between the rate of pressure reduction and total amount of time required for surfacing the animals. Trapping the fish for a long period can induce stress behavior by spatially restricting fish movement and potentially affecting recovery (Hannah et al., 2012), as stress leads to an ionic/osmotic disturbance that can limit gas transport in blood (McDonald and Milligan, 1997). The lower pressure changes tested (15% and 25%) with longer acclimation duration (24 h) required the fish to spend 9 and 6 days in the decompression containers, respectively, while in the 35% x 24 h and 45% x 24 h the amount of days in the decompression containers were 4 and 3 days, respectively. Our work suggests that decompression profiles should not be longer than 4 days in total.

5. Conclusions

The results of this experiment were not completely clear, as far as selecting an optimum decompression profile. However, it seems plausible to combine two decompression profiles used in this experiment, at which proportion of neutrally buoyant fish were greater, both deeper and shallower steps, and the required surfacing time remained within safe limits. This profile has a total duration of 84 h and comprises 4 lifting steps with 35% reduction in the first step with 12 h acclimation, changing to 35% x 24 h in the second step. An even more conservative profile in shallower water, changing to 25% reduction in the two subsequent steps, with acclimation duration of 24 h (Fig. 6), is also advisable. It should be noted that the suggested decompression profile was based built limited information and was not tested during this study, therefore, it should be applied with caution. In addition, the protocol developed to mitigate surface mortality was designed for conditions where oceanic cages or containers can be lifted gradually. Also, decompression of the animals should be done in dark containers to reduce possible stress. Future work on the effect of different decompression profiles on barotrauma and behavior responses to pressure changes in A. anthias. Should analyze the effect of fish density in traps, fish size, and water temperature on fish condition.

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Conflict of interest
The authors declare that they have no conflict of interest.

Ethical approval
The experiments comply with the current laws of the country in which they were performed. All applicable national and international guidelines for the handling, collecting and care of animals were followed. All fish were caught and handled through noninvasive methods. The species collected is not protected throughout its range.

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