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# Trawl capture of Port Jackson sharks, *Heterodontus portusjacksoni*, and gummy sharks, *Mustelus antarcticus*, in a controlled setting: Effects of tow duration, air exposure and crowding

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ABSTRACT

Delayed effects of fisheries capture on the physiology and condition of sharks are poorly understood, but information on the post-release fate of sharks that have been incidentally captured, handled, and released is important to elaborate effective fisheries management measures for by-catch shark species. By-catch is often substantial during commercial trawling operations, and fish are exposed to a multitude of different stressful stimuli during trawl capture. We subjected Port Jackson sharks, *Heterodontus portusjacksoni,* and gummy sharks, *Mustelus antarcticus,* to trawl capture in a controlled setting to investigate effects of tow duration, exposure to air, and crowding in the codend, and monitored their condition via repeated blood sampling during a 72-h recovery period subsequent to the capture event. Port Jackson sharks experienced a low degree of physiological disturbance in response to our capture treatments and no mortality was observed during or after any experiments. Conversely, homeostatic balance of gummy sharks was severely disrupted by trawl capture, and immediate and delayed mortality was substantial (up to 87%) during some experiments. Moribund gummy sharks showed significantly increased blood lactate (>15 mmol/L) and potassium levels (>8 mmol/L) compared with surviving sharks, but these differences did not become evident until 6–12 h after the capture event. There was no strong evidence for an increase in physiological disturbance with increasing tow duration in either species. Extended periods of air exposure (>10 min) following a capture event may lead to additional physiological stress, but simulated crowding as performed in the present study did not result in increased physiological stress compared with trawl capture of individual animals. The results of this study suggest that trawl capture may lead to significant immediate and delayed mortality in gummy sharks, and that extended air exposure on deck may further exacerbate the deleterious effects of capture stress.



## 1. Introduction

Fishing pressure is a major factor contributing to rapidly declining shark populations worldwide. Many shark species are captured incidentally during commercial fishery operations as unwanted by-catch and are subsequently discarded (Stevens et al., 2000). Reliable estimates of discard mortality are important for an accurate assessment of fish stocks and their management (Hueter et al., 2006). However, little is known about the proportion of sharks that are discarded alive, but then perish post-release due to injuries or physiological stress suffered during the capture event (e.g. Skomal, 2007; Frick et al., 2010). Physiological changes in response to capture stress are reflected in the blood of sharks, but these changes often do not become apparent until hours after the capture event (e.g. Cliff and Thurman, 1984; Frick et al., 2010; Van Rijn and Reina, 2010). Consequently, collecting data on the post-release condition of discarded sharks in the wild is associated with considerable logistical challenges, and publications providing much needed information on delayed effects of fisheries capture on the physiology and survival of sharks are scarce.

Trawling is one of the least selective of all commercially used fishing methods and by-catch is usually substantial during trawling operations. In the Southern and Eastern Australian Scalefish and Shark Fishery, for example, 88% of the annual catch of ~50,000 t is caught by demersal trawl and ~47% of the trawl catch of shark is discarded (Walker and Gason, 2007). Fish are exposed to a multitude of stressors during trawl capture, including physical exhaustion, injury, and a low-oxygen environment in the overcrowded trawl codend (see Chopin and Arimoto, 1995; Suuronen, 2005). Furthermore, depending on the fishing depth and location, they experience

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a rapid change of water temperature and pressure during haul-back, and are exposed to air on deck for extended periods of time while the catch is sorted (see Davis, 2002). Each individual stressor has been shown to increase capture-related mortality (e.g. Olla et al., 1997; Davis and Olla, 2001; Suuronen, 2005), and a combination of several or all of these stressors may result in cumulative effects (see Davis, 2002). We previously employed experimental gill-net and longline capture of sharks in a controlled setting, and found that Port Jackson sharks, *Heterodontus portusjacksoni*, were highly resilient to our capture treatments, whereas gummy sharks, *Mustelus antarcticus*, experienced severe, and sometimes irreversible, disruptions to their homeostatic balance in response to a controlled capture event (Frick et al., 2010).

Here, we used a similar approach to investigate effects of three components of trawl capture stress on the physiology and survival of two shark species. We exposed Port Jackson sharks and gummy sharks to varying durations of trawl capture in a controlled setting, placed multiple sharks in our experimental capture gear to simulate overcrowding, and kept sharks out of water for 10 min following a capture event to assess the impact of air exposure on deck. The post-capture condition of sharks was monitored via repeated blood sampling during a 72-h recovery period subsequent to the capture event. Based on our previous findings on effects of gill-net and longline capture on these two species, we hypothesized that Port Jackson sharks would be less affected by our experimental treatments than gummy sharks. We further expected that tow duration would not have a major effect on the degree of physiological disturbance experienced by the sharks, but that crowding and exposure to air would result in increased physiological stress.

## 2. Methods

### 2.1. Collection and husbandry of sharks

Port Jackson sharks were caught in Mallacoota (Victoria, Australia) by a commercial fisherman using gill-nets. Gummy sharks were caught in Mallacoota (Victoria, Australia) and Western Port Bay (Victoria, Australia) by commercial fishermen using longlines. Sharks of both species were transported to the laboratory facilities in Queenscliff (Victoria, Australia) in a 4000-L truck-mounted fish transport tank. Animal holding facilities and feeding regime are described in Frick et al. (2009, 2010). Ambient water temperature ranged 13.2–16.1 °C during Port Jackson shark experiments, and 10.4–13.2 °C during gummy shark experiments; oxygen saturation was >90%. Each animal was only used for a single experiment and was examined by a veterinarian after experimentation prior to release into the wild.

### 2.2. Trawling methods

Trawling was simulated by creating a current in a circular 19,000 L fiberglass tank and placing Port Jackson sharks and gummy sharks in stationary monofilament mesh net bags (Fig. 1). Water current was produced by a rotating PVC panel (200 cm width × 100 cm height), which was powered by a 240 Volt three-phase electric motor (750 Watt; gear reduction 25:1) mounted on a galvanized steel frame above the centre of the tank. The PVC panel was rotating at 12 rpm, creating a water current of ~0.6 m/s in front of the net bag. The electrical field of the operating motor was shielded with a rubber-insulated connection between the motor shaft and the PVC panel to avoid potential electromagnetic disturbance of sharks during experimentation. Monofilament net bags (stretched mesh diameter 10.2 cm (4 in.); length 110 cm) replicating the codend of trawling gear were fastened to powder-coated steel hoops (diameter 70 cm), which were attached to the steel frame. Monofilament netting (as opposed to multifilament netting commonly used for commercial trawling gear) was used to reduce water resistance, and thus ensure appropriate water flow through the net bags. The forward opening of the net bags was closed by a mesh flap during operation.

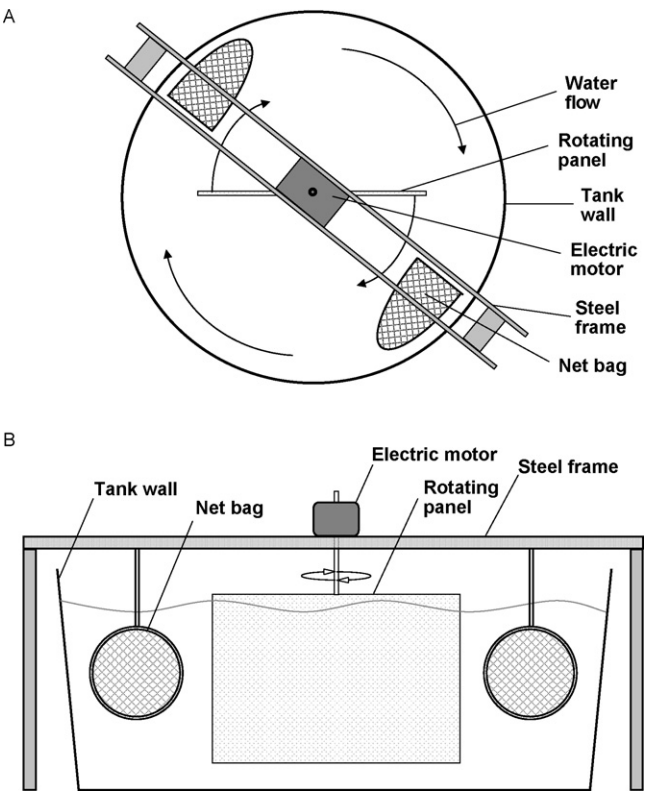


**Fig. 1.** Diagram of the trawl capture apparatus and tank (not to scale): (A) top view (tank diameter 4.7 m); and (B) vertical section. Rotating PVC panel was powered by a 240 Volt three phase motor (750 Watt; gear reduction 25:1). Frame was galvanized steel, net hoops were powder-coated steel (diameter 0.7 m). Stretched mesh diameter was 10.2 cm (4 inch), length of net bags was 1.1 m.

### 2.3. Experimental treatments and blood sampling

Port Jackson sharks and gummy sharks were transferred from their holding tank by hand and placed in a net bag. To assess the effects of tow duration, Port Jackson sharks ($n = 8$ animals for each of three experimental groups; overall total length (TL) = 98 ± 2 cm (mean ± SE)) and gummy sharks ($n = 8$ animals for each of three experimental groups; overall TL = 89 ± 1 cm) were subjected to three different trawl capture durations. Tow durations for Port Jackson sharks were 30 min, 120 min and 360 min, and tow durations for gummy sharks were 30 min, 60 min and 120 min. To investigate the effects of air exposure following a capture event, individual Port Jackson sharks ($n = 8$ animals; TL = 100 ± 2 cm) and gummy sharks ($n = 8$ animals; TL = 96 ± 2 cm) were subjected to a trawl capture event of 120 min and 60 min, respectively, and were subsequently placed in an empty plastic bin for 10 min before the first blood sample was taken. To assess the effects of crowding in the codend during a trawl, Port Jackson sharks ($n = 12$ animals; TL = 100 ± 2 cm) and gummy sharks ($n = 9$ animals; TL = 93 ± 2 cm) were subjected to a trawl capture event of 120 min and 60 min, respectively, with three sharks in the codend at a time. Noteworthy qualitative observations were recorded during and after the capture event. At the end of the predetermined capture duration, a blood sample (1.0–1.5 ml) was taken via caudal venipuncture with a heparinized needle (1.2 × 38 mm (18-gauge, 1.5 in.)) and plastic syringe