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2-Phenoxyethanol as anaesthetic in removing and relocating 102 species of fishes representing 30 families from Sea World to uShaka Marine World, South Africa

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ABSTRACT

VAUGHAN, D.B., PENNING, M.R. & CHRISTISON, K.W. 2008. 2-Phenoxyethanol as anaesthetic in removing and relocating 102 species of fishes representing 30 families from Sea World to uShaka Marine World, South Africa. *Onderstepoort Journal of Veterinary Research*, 75:189–198

2-Phenoxyethanol was used as an anaesthetic to translocate 102 species of fishes representing 30 families from the Sea World aquarium on Durban's beachfront to uShaka Marine World. Most fishes responded well to a final anaesthetic concentration of 0,150 mℓ/ℓ and there were no mortalities.

Keywords: Anaesthetic, fishes, 2-Phenoxyethanol, public aquarium, translocation

INTRODUCTION

The South African Association for Marine Biological Research, incorporating Sea World, Oceanographic Research Institute and the Dolphinarium relocated from their old premises of 46 years on Durban's beach front in March and April 2004 to the new Point Development's marine theme park, uShaka Marine World in Durban, South Africa. Netting of fishes from the large exhibits could cause physical damage to struggling fishes, increasing the risk of opportunistic secondary bacterial infections (Inoue, dos Santos Neto & Morales 2004) which could not be treated in time for the opening of uShaka Marine World on 30 April 2004. An ideal method to facilitate the removal of fishes from exhibits would be the use of a general anaesthetic. Characteristics of a suitable anaesthetic for this purpose would include ease of administration and stability, rapid recovery of anaesthetised fishes once re-introduced into untreated water and the dependency of anaesthetic duration upon concentration (Dunn & Koester 1985). "2-Phenoxyethanol" (MercK Laboratories, Johannesburg) was selected to facilitate the removal of fishes from the two main aquarium exhibits, the open ocean exhibit, housing the highest diversity of fishes (Table 1), and the shark tank housing two large adult Zambezi sharks, *Carcharhinus leucas* Valenciennes, 1839, eight adult Spotted ragged-tooth sharks, *Carcharias taurus* Rafinesque, 1810, and several sympatric teleost species (Table 2). 2-Phenoxyethanol is relatively inexpensive and remains viable in long-term exposure (Kaiser & Vine 1998) and is also available in bulk in South Africa. Deacon, White & Hecht (1997) recommend 2-Phenoxyethanol as a highly suitable anaesthetic for repeatedly exposed fishes. 2-Phenoxyethanol also showed a more notable sedation than MS-222 in an experiment on Gilthead sea bream, *Sparus aurata* (Molinero & Gonzalez 1995) and is considered a desirable anaesthetic for the transportation of fishes by Yanar & Kumlu (2001).

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Pole syringe anaesthetic technique using ketamine hydrochloride and xylazine hydrochloride was not feasible for facilitating translocation of the *C. leucas,* and *C. taurus*, weighing in excess of 170 kg each because of the restriction in dart-syringe size and therefore efficient dosage administration. Repeated darting could not guarantee successful induction or the safety of the operator. Each exhibit of fishes was moved separately on different days.

MATERIAL AND METHODS

The shark tank was first to have its animals relocated on 13 April 2004. The fishes in the open ocean exhibit were relocated 2 days later. Incoming seawater supplies and filtration systems were shut down. Aeration of both exhibits was maintained for circulation and sustaining desirable dissolved oxygen levels during the procedure. The shark tank and the open ocean exhibit volumes were calculated at 386 400 ℓ and 850 500 ℓ, respectively. Temperature, dissolved oxygen and pH levels were monitored using a YSI 85 hand-held temperature, dissolved oxygen, conductivity and salinity meter, and a Cyberscan pH and ORP meter.

2-Phenoxyethanol was thoroughly mixed with tap water in 450 ℓ plastic drums alongside the exhibits and poured directly into the water. Concentration increments of 0.050 mℓ/ℓ, equating to 19.32 ℓ of 2-Phenoxyethanol, were added every 30 min to the shark tank to a final concentration of 0.150 mℓ/ℓ. The initial concentration for the open ocean exhibit was 0.030 mℓ/ℓ equating to 25 ℓ of 2-Phenoxyethanol. After 30 min, increments of 0.006 mℓ/ℓ (5 ℓ of 2-Phenoxyethanol) were added every 15 min until the concentration of 0.150 mℓ/ℓ was obtained. The concentration was increased to 0.250 mℓ/ℓ only to anaesthetise the last fish species, Cobia, *Rachycentron canadum* Linnaeus, 1776, once all other fishes had been removed. Small concentration increments spread over a longer period of time in the open ocean exhibit enabled specific species of fishes of a higher diversity than the shark tank to be removed upon their potential differences in reaction to concentrations and exposure times to 2-Phenoxyethanol.

Excitation events were recorded and the fishes were removed according to their effective induction to anaesthesia upon loss of equilibrium. The Zambezi sharks were guided into PVC stretchers upon the first signs of anaesthesia, after which the Spotted ragged-tooth sharks were similarly removed, to prevent physical injury to themselves through collision with tank walls and viewing panels. All other anaesthetised fishes were collected in transparent PVC bags by a team of divers. They were removed to awaiting transport tanks containing 2 000 ℓ, 4 000 ℓ or 8 000 ℓ volumes of seawater on the back of two flatbed trucks to be delivered in relay to the new aquarium exhibits. All the transport tanks except one of 2 000 ℓ capacity, contained a 2-Phenoxyethanol concentration of 0.100 mℓ/ℓ. The untreated transport tank was reserved for potentially sensitive species to the affects of the 2-Phenoxethanol, so that they could be revived quickly to prevent possible mortalities. All transport tanks were separately filtered using diatom cartridge filters on pump-recirculation, and oxygenated using medical-grade oxygen diffused directly into the water via airstones and flexible gas tubing. After transporting and delivery of two loads of fishes to the new aquarium, all the seawater in the transport tanks was drained and replaced and re-dosed with 2-Phenoxyethanol at the same concentration.

RESULTS/OBSERVATIONS

Water quality parameters throughout the exercise for both exhibits were similar and relatively stable. Temperatures for both exhibits remained unchanged at 22.6 °C, and 22.9 °C for the open ocean exhibit and shark tank, respectively, with a stable pH for each exhibit at 7.77 and 7.86 throughout the exercise. Dissolved oxygen levels were measured at the anaesthetic induction time per species. One hundred and two species of fishes representing 30 families were successfully anaesthetised using 2-Phenoxyethanol (Tables 1 and 2). Both Zambezi sharks displayed excitation at 0.100 mℓ/ℓ at 50 min, characterised by a marked increase in swimming speed, and became disorientated at 0.150 mℓ/ℓ at 72.9 % dissolved oxygen and 70 min, when they were removed promptly to avoid injury. None of the Spotted Ragged-tooth sharks showed any changes in behaviour throughout the procedure and were removed from the shark tank after both *C. leucas* were removed. The remaining fishes were removed by the team of divers from the shark tank after all the sharks had been removed.

All species of the family Carangidae (Kingfishes) from the shark tank displayed excitation (Table 2), yet this was completely absent in all the carangid species in the open ocean exhibit anaesthetised at the same final concentration of 0.150 mℓ/ℓ (Table 1). The Crocodile needlefish, *Tylosurus crocodilus crocodilus* Peron & LeSueur, 1821, from the open ocean

TABLE 1 Fishes anaesthetised and removed from the open ocean exhibit at Sea World

Scientific names	English names	Numbers	Excitation level	Anaesthetic level/induction time
Family: Albulidae (Bonefishes)				
Albula vulpes Linnaeus, 1758	Bonefish	5	None observed	0.150 mℓ/ℓ; 330 min
Family: Belonidae (Needlefishes)				
Tylosurus crocodilus crocodilus Peron & LeSueur, 1821	Crocodile needlefish	1	0.048 mℓ/ℓ; 75 min	0.048 mℓ/ℓ; 75 min
Family: Serranidae (Rockcods)				
Cephalopholis sonnerati Valenciennes, 1828	Tomato rockcod	1	None observed	0.150 mℓ/ℓ; 330 min
Epinephelus caeruleopunctatus Bloch, 1790	Whitespotted rockcod	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Haemulidae (Rubberlips and Grunters)				
Plectorhinchus chubbi Regan, 1919	Dusky rubberlips	3	None observed	0.150 mℓ/ℓ; 330 min
Plectorhinchus gibbosus Lacepede, 1802	Harry hotlips	1	None observed	0.150 mℓ/ℓ; 330 min
Plectorhinchus playfairi Pellegrin, 1914	Whitebarred rubberlips	3	None observed	0.150 mℓ/ℓ; 330 min
Pomadasys commersonnii Lacepede, 1801	Spotted grunter	55	None observed	0.150 mℓ/ℓ; 330 min
Pomadasys kaakan Cuvier, 1830	Javelin grunter	2	None observed	0.150 mℓ/ℓ; 330 min
Pomadasys maculatum Bloch, 1797	Saddle grunter	2	None observed	0.150 mℓ/ℓ; 330 min
Pomadasys multimaculatum Playfair, 1866	Cock grunter	1	None observed	0.150 mℓ/ℓ; 330 min
Pomadasys striatum Gilchrist & Thompson, 1908	Striped grunter	5	None observed	0.150 mℓ/ℓ; 330 min
Family: Lutjanidae (Snappers)				
Lutjanus bohar Forsskal, 1775	Twinspot snapper	2	None observed	0.150 mℓ/ℓ; 330 min
Lutjanus gibbus Forsskal, 1775	Humpback snapper	8	None observed	0.150 mℓ/ℓ; 330 min
Lutjanus kasmira Forsskal, 1775	Bluebanded snapper	77	None observed	0.150 mℓ/ℓ; 330 min
Lutjanus russellii Bleeker, 1849	Russell's snapper	7	None observed	0.150 mℓ/ℓ; 330 min
Family: Sparidae (Seabreams)				
Acanthopagrus berda Forsskal, 1775	Riverbream	2	None observed	0.150 mℓ/ℓ; 330 min
Chrysoblephus puniceus Gilchrist & Thompson, 1908	Slinger	19	None observed	0.150 mℓ/ℓ; 330 min
Diplodus cervinus hottentotus Smith, 1844	Zebra	14	None observed	0.150 mℓ/ℓ; 330 min
Diplodus sargus capensis Smith, 1844	Black tail	17	None observed	0.150 mℓ/ℓ; 330 min
Pachymetopon grande Gunther, 1859	Bronze bream	4	None observed	0.150 mℓ/ℓ; 330 min
Pagellus bellottii natalensis Steindachner, 1902	Red tjor-tjor	7	None observed	0.150 mℓ/ℓ; 330 min
Polysteganus praeorbitalis Gunther, 1859	Scotsman	2	None observed	0.150 mℓ/ℓ; 330 min
Rhabdosargus halubi Steindachner, 1881	Cape stumpnose	2	None observed	0.150 mℓ/ℓ; 330 min
Rhabdosargus sarba Forsskal, 1775	Natal stumpnose	6	None observed	0.150 mℓ/ℓ; 330 min

TABLE 1 *continued*

Scientific names	English names	Numbers	Excitation level	Anaesthetic level/induction time
Family: Lethrinidae (Emperors)				
Gnathodentex aureolineatus Lacepede, 1802	Glowfish	2	None observed	0.150 mℓ/ℓ; 330 min
Lethrinus crocineus Smith, 1959	Yellowfin emperor	1	None observed	0.150 mℓ/ℓ; 330 min
Lethrinus hypselopterus Bleeker, 1873	Mozambique emperor	4	None observed	0.150 mℓ/ℓ; 330 min
Lethrinus nebulosus Forsskal, 1775	Blue emperor	10	None observed	0.150 mℓ/ℓ; 330 min
Lethrinus sanguineus Smith, 1955	Cutthroat emperor	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Coracinidae (Galjoens)				
Coracinus multifasciatus Pellegrin, 1914	Banded galjoen	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Kyphosidae (Sea chubs)				
Kyphosus bigibbus Lacepede, 1801	Grey chub	4	None observed	0.150 mℓ/ℓ; 330 min
Family: Ephippidae (Batfishes)				
Platax pinnatus Linnaeus, 1758	Dusky batfish	34	None observed	0.060 mℓ/ℓ; 105 min
Family: Monodactylidae (Moonies)				
Monodactylus falciformis Lacepede, 1800	Cape Moony	14	None observed	0.150 mℓ/ℓ; 330 min
Family: Mullidae (Goatfishes)				
Parupeneus macronema Lacepede, 1801	Band-dot goatfish	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Pomacanthidae (Angelfishes)				
Apolemichthys trimaculatus Lacepede, 1831	Threespot angelfish	3	None observed	0.150 mℓ/ℓ; 330 min
Pomacanthus imperator Bloch, 1787	Emperor angelfish	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Chaetodontidae (Butterflyfishes)				
Chaetodon auriga Forsskal, 1775	Threadfin butterflyfish	1	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon guttatissimus Bennett, 1823	Gorgeous gussy	2	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon lunula Lacepede, 1803	Halfmoon butterflyfish	4	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon unimaculatus Bloch, 1787	Limespot butterflyfish	1	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon kleinii Bloch, 1790	Whitespotted butterflyfish	1	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon madagaskariensis Ahl, 1923	Pearly butterflyfish	1	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon marleyi Regan, 1921	Doublesash butterflyfish	3	None observed	0.150 mℓ/ℓ; 330 min
Chaetodon vagabundus Linnaeus, 1758	Vagabond butterflyfish	1	None observed	0.150 mℓ/ℓ; 330 min
Forcipiger flavissimus Jordan & McGregor, 1898	Longnose butterflyfish	2	None observed	0.150 mℓ/ℓ; 330 min
Heniochus monoceros Cuvier, 1831	Masked coachman	1	None observed	0.150 mℓ/ℓ; 330 min

TABLE 1 *continued*

Scientific names	English names	Numbers	Excitation level	Anaesthetic level/induction time
Family: Oplegnathidae (Knifejaws)				
Oplegnathus robinsoni Regan, 1916	Natal knifejaw	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Carangidae (Kingfishes)				
Carangoides caeruleopinnatus Ruppell, 1830	Coastal kingfish	2	None observed	0.150 mℓ/ℓ; 330 min
Carangoides fulvoguttatus Forsskal, 1775	Yellowspotted kingfish	4	None observed	0.150 mℓ/ℓ; 330 min
Caranx sexfasciatus Quoy & Gaimard, 1825	Big-eye kingfish	1	None observed	0.150 mℓ/ℓ; 330 min
Megalaspis cordyla Linnaeus, 1758	Torpedo scad	12	None observed	0.150 mℓ/ℓ; 330 min
Pseudocaranx dentex Bloch & Schneider, 1801	White kingfish	1	None observed	0.150 mℓ/ℓ; 330 min
Trachinotus africanus Smith, 1967	Southern pompano	32	None observed	0.150 mℓ/ℓ; 330 min
Trachinotus botla Shaw, 1803	Large spot pompano	10	None observed	0.072 mℓ/ℓ; 135 min
Family: Rachycentridae (Cobia)				
Rachycentron canadum Linnaeus, 1776	Prodigal son	1	None observed	0.250 mℓ/ℓ; 400 min
Family: Cirrhitidae (Hawkfishes)				
Cirrhitichthys oxycephalus Bleeker, 1855	Spotted hawkfish	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Pomacentridae (Damselfishes)				
Abudefduf notatus Day, 1869	Dusky damsel	5	None observed	0.150 mℓ/ℓ; 330 min
Abudefduf vaigiensis Quoy & Gaimard, 1825	Sergeant major	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Labridae (Wrasses)				
Bodianus bilunulatus Lacepede, 1801	Saddleback hogfish	9	None observed	0.150 mℓ/ℓ; 330 min
Bodianus diana Lacepede, 1801	Diana's hogfish	1	None observed	0.150 mℓ/ℓ; 330 min
Bodianus perditio Quoy & Gaimard, 1834	Goldsaddle hogfish	1	None observed	0.150 mℓ/ℓ; 330 min
Cheilinus trilobatus Lacepede, 1801	Tripletail wrasse	1	None observed	0.150 mℓ/ℓ; 330 min
Coris gaimard africana Smith, 1957	African coris	2	None observed	0.150 mℓ/ℓ; 330 min
Halichoeres iridis Randall & Smith, 1982	Rainbow wrasse	3	None observed	0.150 mℓ/ℓ; 330 min
Hemigymnus fasciatus Bloch, 1792	Barred thicklip	1	None observed	0.150 mℓ/ℓ; 330 min
Hologymnosus doliatus Lacepede, 1801	Ringed wrasse	1	None observed	0.150 mℓ/ℓ; 330 min
Family: Scaridae (Parrotfishes)				
Scarus ghobban Forsskal, 1775	Bluebarred parrotfish	1	None observed	0.150 mℓ/ℓ; 330 min
Scarus rubroviolaceus Bleeker, 1847	Ember parrotfish	1	None observed	0.150 mℓ/ℓ; 330 min

TABLE 1 *continued*

Scientific names	English names	Numbers	Excitation level	Anaesthetic level/induction time
Family: Mugilidae (Mullets)				
Mugil cephalus Linnaeus, 1758	Flathead mullet	2	None observed	0.150 mℓ/ℓ; 330 min
Family: Acanthuridae (Surgeonfishes)				
Acanthurus triostegus Linnaeus, 1758	Convict surgeon	9	None observed	0.150 mℓ/ℓ; 330 min
Acanthurus dussumieri Valenciennes, 1835	Pencilled surgeon	6	None observed	0.150 mℓ/ℓ; 330 min
Acanthurus nigrofuscus Forsskal, 1775	Brown surgeon	11	None observed	0.150 mℓ/ℓ; 330 min
Acanthurus tennenti Gunther, 1861	Lieutenant surgeon	3	None observed	0.150 mℓ/ℓ; 330 min
Acanthurus thompsoni Fowler, 1923	Chocolate surgeon	4	None observed	0.150 mℓ/ℓ; 330 min
Acanthurus xanthopterus Valenciennes, 1835	Yellowfin surgeon	6	None observed	0.150 mℓ/ℓ; 330 min
Ctenochaetus striatus Quoy & Gaimard, 1825	Striped bristletooth	5	None observed	0.150 mℓ/ℓ; 330 min
Ctenochaetus strigosus Bennett, 1828	Spotted bristletooth	6	None observed	0.150 mℓ/ℓ; 330 min
Naso brevirostris Valenciennes, 1835	Spotted unicorn	4	None observed	0.150 mℓ/ℓ; 330 min
Naso lituratus Schneider, 1801	Orange-spine unicorn	2	None observed	0.150 mℓ/ℓ; 330 min
Naso unicornis Forsskal, 1775	Bluespine unicorn	2	None observed	0.150 mℓ/ℓ; 330 min
Paracanthurus hepatus Linnaeus, 1776	Palette surgeon	1	None observed	0.150 mℓ/ℓ; 330 min
Zebrasoma scopas Cuvier, 1829	Twotone tang	2	None observed	0.150 mℓ/ℓ; 330 min
Family: Siganidae (Rabbitfishes)				
Siganus sutor Valenciennes, 1835	Whitespotted rabbitfish	3	None observed	0.150 mℓ/ℓ; 330 min
Family: Scombridae (Tunas)				
Sarda orientalis Temminck & Schlegel, 1844	Striped bonito	13	None observed	0.150 mℓ/ℓ; 330 min
Euthynnus affinis Cantor, 1849	Eastern little tuna	24	0.102 mℓ/ℓ; 210 min	0.150 mℓ/ℓ; 330 min
Family: Balistidae (Triggerfishes)				
Balistoides conspicillum Bloch & Schneider, 1801	Clown triggerfish	1	None observed	0.150 mℓ/ℓ; 330 min
Balistoides viridescence Bloch & Schneider, 1801	Dotty triggerfish	1	None observed	0.150 mℓ/ℓ; 330 min
Pseudobalistes fuscus Bloch & Schneider, 1801	Rippled triggerfish	1	None observed	0.150 mℓ/ℓ; 330 min
Sufflamen bursa Bloch & Schneider, 1801	Boomerang triggerfish	1	None observed	0.150 mℓ/ℓ; 330 min

TABLE 2 Fishes anaesthetised and removed from the shark tank at Sea World

Scientific name	English name	Numbers	Excitation level	Anaesthetic level/induction time
Family: Carcharhinidae (Requiem sharks)				
Carcharhinus leucas Valenciennes, 1839	Zambezi shark	2	0.100 mℓ/ℓ; 50 min	0.150 mℓ/ℓ; 70 min
Family: Odontaspididae (Ragged-tooth sharks)				
Carcharius taurus Rafinesque, 1810	Spotted ragged-tooth	8	None observed	0.150 mℓ/ℓ; 70 min
Family: Caesionidae (Fusiliers)				
Caesio teres Seale, 1906	Beautiful fusilier	2	0.050 mℓ/ℓ; 30 min	0.050 mℓ/ℓ; 30 min
Family: Sparidae (Seabreams)				
Diplodus sargus capensis Smith, 1844	Black tail	< 20	None observed	0.150 mℓ/ℓ; 70 min
Lithognathus mormyrus Linnaeus, 1758	Sand steenbras	< 150	None observed	0.150 mℓ/ℓ; 70 min
Rhabdosargus thorpei Smith, 1979	Bigeye stumpnose	6	None observed	0.100 mℓ/ℓ; 47 min
Family: Monodactylidae (Moonies)				
Monodactylus falciformis Lacepede, 1800	Cape Moony	< 15	None observed	0.150 mℓ/ℓ; 70 min
Family: Chaetodontidae (Butterflyfishes)				
Chaetodon blackburnii Desjardins, 1836	Brownburnie	1	None observed	0.150 mℓ/ℓ; 70 min
Family: Carangidae (Kingfishes)				
Alepes djedaba Forsskal, 1775	Shrimp scad	< 200	0.150 mℓ/ℓ; 70 min	0.150 mℓ/ℓ; 70 min
Carangoides caeruleopinnatus Ruppell, 1830	Coastal kingfish	< 20	0.150 mℓ/ℓ; 70 min	0.150 mℓ/ℓ; 70 min
Caranx sexfasciatus Quoy & Gaimard, 1825	Bigeye kingfish	< 10	0.150 mℓ/ℓ; 70 min	0.150 mℓ/ℓ; 70 min
Decapterus macrosoma Bleeker, 1851	Slender scad	< 100	0.100 mℓ/ℓ; 30 min	0.150 mℓ/ℓ; 70 min
Seriola rivoliana Valenciennes, 1833	Longfin yellowtail	1	0.150 mℓ/ℓ; 70 min	0.150 mℓ/ℓ; 70 min
Trachinotus africanus Smith, 1967	Southern pompano	< 200	0.100 mℓ/ℓ; 45 min	0.150 mℓ/ℓ; 70 min
Trachinotus botla Shaw, 1803	Largespotted pompano	< 14	0.150 mℓ/ℓ; 70 min	0.150 mℓ/ℓ; 70 min
Family: Echeneidea (Remoras)				
Remora remora Linnaeus, 1758	Remora	6	None observed	0.150 mℓ/ℓ; 70 min
Family: Pomacentridae (Damselfishes)				
Abudefduf vaigiensis Quoy & Gaimard, 1825	Sergeant major	< 40	None observed	0.150 mℓ/ℓ; 70 min
Plectroglyphidodon leucozonus Bleeker, 1859	Sash damsel	< 10	None observed	0.150 mℓ/ℓ; 70 min

Total numbers given as estimations are approximate numbers of individuals per shoal removed

TABLE 2 *continued*

Scientific name	English name	Numbers	Excitation level	Anaesthetic level/induction time
Family: Labridae (Wrasses)				
Thalassoma hebraicum Lacepede, 1801	Goldbar wrasse	< 10	None observed	0.150 mℓ/ℓ; 70 min
Thalassoma lunare Linnaeus, 1758	Crescent-tail wrasse	< 10	None observed	0.150 mℓ/ℓ; 70 min
Family: Mugilidae (Mullets)				
Liza richardsonii Smith, 1846	Southern mullet	< 100	None observed	0.150 mℓ/ℓ; 70 min
Family: Acanthuridae (Surgeonfishes, Unicornfishes)				
Acanthurus triostegus Linnaeus, 1758	Convict surgeon	< 40	None observed	0.150 mℓ/ℓ; 70 min

Total numbers given as estimations are approximate numbers of individuals per shoal removed exhibit was the most sensitive of all fishes to 2-Phenoxyethanol. Excitation was brief yet violent, followed by a sudden and complete loss of equilibrium at 0.048 mℓ/ℓ and 83.2 % dissolved oxygen after 75 min after the introduction of the initial increment, and was removed to the untreated transport tank where it made a full recovery. Beautiful fusilier, *Caesio teres* Seale, 1906 displayed a short period of excitation at 0.050 mℓ/ℓ before losing equilibrium at 81.6 % dissolved oxygen and 30 min. Dusky batfish, *Platax pinnatus* Linnaeus, 1758 became anaesthetised at 0.060 mℓ/ℓ and 78 % dissolved oxygen and 105 min without excitation. Largespotted pompano, *Trachinotus botla* Shaw, 1803, from the open ocean exhibit became anaesthetised at 0.072 mℓ/ℓ and 71.9 % dissolved oxygen and 135 min, and at 0.150 mℓ/ℓ in the shark tank at 72.9 % dissolved oxygen and 70 min. Bigeye stumpnose, *Rhabdosargus thorpei* Smith, 1979, became anaesthetised at 0.100 mℓ/ℓ at 79.8 % dissolved oxygen and 47 min without displaying excitation. Excitation was evident in the Little Eastern tuna, *Euthynnus affinis* Cantor, 1849, at 0.102 mℓ/ℓ and 210 min, but they only became anaesthetised at 0.150 mℓ/ℓ at 71.9 % dissolved oxygen and 330 min. All other fishes except the Cobia, *R. canadum,* became anaesthetised at 0.150 mℓ/ℓ and 71.9 % dissolved oxygen and 330 min without excitation, and were easily removed from the exhibits. The Cobia was the last fish to be removed from the open ocean exhibit after increasing the dosage to 0.250 mℓ/ℓ, at 89.6 % dissolved oxygen and 430 min.

No mortalities resulted from the use of 2-Phenoxyethanol on any of the fishes during anaesthesia or transport to uShaka Marine World.

DISCUSSION

Hseu, Yeh, Chu & Ting (1998) outlined a drawback in the use of 2-Phenoxyethanol, in that it requires high anaesthetic concentrations in comparison to MS-222 (Argent Chemical Laboratories) and Quinaldine (SIGMA-ALDRICH) in fishes, and that the effective concentration for most fishes is 0.200 mℓ/ℓ to 0.600 mℓ/ℓ. Recently, Velíšec, Wlasow, Gomulka, Svobodova & Novotny (2007) indicated that 2-Phenoxyethanol also has a relatively low therapeutic index, reported as 1:2.6.

The majority of fishes anaesthetised throughout their translocation of fishes from Sea World to uShaka Marine World showed optimal anaesthesia at the concentration of 0.150 mℓ/ℓ, with some species effectively anaesthetised at lower dosages, and one species (*R. canadum*) requiring additional anaesthetic to facilitate successful removal.

Yanar & Kumlu (2001) and Velíšec *et al.* (2007) indicated that the effective concentration of an anaesthetic leading to induction in fishes varied according to their sex, age, water quality parameters, overall biomass and physiological state, and the duration of the exposure. All *T. botla* from the shark tank were juveniles of less than 20 cm in length. Those from the open ocean exhibit were adults of approximately 50 cm in length. Velíšec & Svobodova (2004a) indicated that juvenile rainbow trout, *Oncorhynchus mykiss* Walbaum, 1792, are more sensitive to 2-Phenoxyethanol than adults. This could explain the difference in effective induction of *T. botla* from the shark tank and open ocean exhibit, where more than double the dosage of 2-Phenoxyethanol for the adult fish from the open ocean exhibit was required for the same anaesthetic effect. Once the desired level of anaesthesia had been reached in both exhibits, several hours passed before all fishes were eventually removed. Their anaesthetic state remained stable and did not progress with time.

Velíšec & Svobodova (2004a); Velíšec *et al.* (2007) also consider that sensitivity to anaesthetics is influenced by the enhancement of decreasing or low dissolved oxygen concentration, but the most important factor affecting the anaesthetic efficiency of 2-Phenoxyethnol is temperature, where higher temperatures produce better anaesthetic efficiency (Velíšec & Svobodova 2004b). Dissolved oxygen levels dropped slightly in each exhibit from the beginning of the exercise to first induction, but remained stable at 71.9 % and 72.9 % for the open ocean exhibit and shark tank, respectively. This initial drop is thought to be the result of shutting down the filtration processes and incoming make-up water just prior to the introduction of the first anaesthetic increment. The last dissolved oxygen reading for the open ocean exhibit was taken at induction of the last remaining individual fish, *R. canadum,* and was notably higher at 89.6 % after the removal of all other fishes, which indicates that the stable dissolved oxygen levels observed reflect the equilibrium between biomass and maintained artificial aeration. Aeration is therefore recommended for similar future exercises.

Yanar & Kumlu (2001) stated, following an experiment with European seabass, *Dicentrarchus labrax* Linnaeus, 1758, that an increase in anaesthetic concentration decreased the induction time. This is evident in comparing the time to induction at 0.150 mℓ/ℓ, obtained at 330 min and 70 min for the open ocean exhibit and shark tank respectively, but excitation was displayed in all carangids in the shark tank but not in those from the open ocean exhibit. It is therefore possible that time to anaesthetic concentration, and not necessarily the concentration alone could have played an important role in controlling the onset of excitation in this family of fishes.

Molinero & Gonzalez (1995) consider that reactions of fishes to 2-Phenoxyethanol and MS-222 include a change in respiratory rate and pigmentation. Tytler & Hawkins (1981) suggested that retaining fishes in an anaesthetic bath for too long leads to the fading of respiration and finally complete respiratory and cardiac failure, but Hajec, Kłyszejko & Dziaman (2006) confirmed that lower effective concentrations of the anaesthetic clove oil provided longer periods of general anaesthesia with respiration being maintained. Although fishes in both exhibits became increasingly less responsive to external stimuli, such as sudden movements and the presence of divers in the water through the progression of concentration increments and time, no obvious pigmentation changes or notable changes in respiration rates for the entire duration of the exercise were observed. Shoaling species such as Southern pompano, *Trachinotus africanus* Smith, 1967, Shrimp scad, *Alepes djedaba* Forsskal, 1775, and Coastal kingfish, *Carangoides caeruleopinnatus* Ruppell, 1830, assumed tight shoals until just prior to anaesthesia when they became disorientated, and dispersed throughout the water column before losing equilibrium.

No information is available in which the successful use of 2-Phenoxyethanol to anaesthetise adult *C. leucas,* and *C. taurus,* is outlined. Both these species reacted favourably to this anaesthetic, allowing safe anaesthesia without risk of injury to the sharks or handlers, at the concentration of 0.150 mℓ/ℓ and 72.9 % dissolved oxygen, and 70 min.

The translocation of all fishes from one public aquarium to another is a rare occurrence, and one which requires careful planning. The use of 2-Phenoxyethanol as a reliable and stable anaesthetic was paramount to the successful and relatively stress-free procedure which included transportation by road.

REFERENCES

DEACON, N., WHITE, H., & HECHT, T. 1997. Isolation of the effective concentration of 2-Phenoxyethanol for anaesthesia in the spotted grunter (*Pomadays commersonnii*), and its effect on growth. *Aquarium Sciences and Conservation*, 1: 19–27.

DUNN, R.F. & KOESTER, D.M. 1985. Anesthetics in elasmobranchs: A review with emphasis on halothane-oxygen-nitrous oxide. *Journal of Aquariculture and Aquatic Sciences*, 5:44–52.

HAJEK, G.J., KLYSZEJKO, B. & DZIAMAN, B. 2006. The anaesthetic effect of clove oil on common carp (*Cyprinus carpio* L.). *Acta Ichthyologica et Piscatoria*, 36:93–97.

HSEU, J., YEH, S., CHU, Y. & TING, Y. 1998. Comparison of efficacy of five anesthetics in Goldlined Sea Bream (*Sparus sarba*). *Acta Zoologica Taiwanica*, 9:35–41.

INOUE, L.A.K.A., DOS SANTOS NETO, C. & MORALES, G. 2004. Standardization of 2-phenoxyethanol as anaesthetic for juvenile *Brycon cephalus* (Gunther, 1867): the use in field procedures. *Ciência Rural* (Santa Maria), 34:563–565.

KAISER, H. & VINE, N. 1998. The effect of 2-Phenoxyethanol and transport packing density on the post-transport survival rate and metabolic activity in the goldfish (*Carassius auratus*). *Aquarium Sciences and Conservation*, 2:1–7.

MOLINERO, A. & GONZALEZ, J. 1995. Comparative effects of MS 222 and 2-Phenoxyethanol on gilthead sea bream (*Sparus aurata* L.) during confinement. *Comparative Biochemistry and Physiology*, 111:405–414.

TYTLER, P. & HAWKINS, A.D. 1981. Vivisection, anesthetics and minor surgery, in *Aquarium systems*, edited by A.D. Hawkins. New York: Academic Press.

VELÍŠEK, J. & SVOBODOVA, Z. 2004a. Anaesthesia of Rainbow Trout (*Oncorhynchus mykiss*) with 2-phenoxyethanol: Acute toxicity and biochemical blood profile. *Acta Veterinaria Brno*, 73:379–384.

VELÍŠEK, J. & SVOBODOVA, Z. 2004b. Anaesthesia of Common Carp (*Cyprinus carpio* L.) with 2-phenoxyethanol: Acute toxicity and effects on biochemical blood profile. *Acta Veterinaria Brno*, 73:247–252.

VELÍŠEK, J., WLASOW, T., GOMULKA, P., SVOBODOVA, Z. & NOVONTY, L. 2007. Effects of 2-Phenoxyethanol anaesthesia on sheatfish (*Silurus glanis* L.). *Veterinarni Medicina*, 52: 103–110.

YANAR, M. & KUMLU, M. 2001. The anaesthetic effects of quinaldine Sulphate and/or Diazepam on Sea Bass (*Dicentrarchus labrax*) juveniles. *Turk Veterinerlik ve Hayvancilik Dergisi*, 25:185–189.