PROCEEDINGS

Fish Veterinary Journal (2007) (9) 22–37

Buoyancy disorders of ornamental fish: a review of cases seen in veterinary practice

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Abstract

In veterinary practice, buoyancy disorders are common in goldfish, often having a sudden onset and present floating at the surface or lying on the bottom. Fifty eight affected fish were examined in detail over a period of 11.5 years, of which 47 were goldfish: there were almost equal numbers of short-bodied and long-bodied goldfish. In many cases, there were no external lesions and no consistent environmental factors could be identified. Radiography was performed in 49 fish and proved the most useful investigative approach. Several radiographic abnormalities were found in goldfish including over-inflation (44%), displacement (22%), fluid accumulation (12%) and rupture (2%) of the swim bladder and intestinal tympany (6%). Post mortem and histological examinations were performed on 35 goldfish: findings included systemic granulomatous disease (23%), abnormal fluid in the swim bladder (23%), polycystic kidney disease (17%) and several other internal diseases (20%). However, 17% of goldfish had no identifiable pathology and no consistent radiographic features. Pathological findings in other species were varied and only rupture of the swim bladder in orfe and a renal tumour in oscars were significant. Most cases were euthanased on initial examination due to advanced disease but a quarter were treated conservatively. There was a very poor response to treatment and several environmental, medical and surgical approaches are discussed.

In fish, buoyancy is controlled by the amount and distribution of gas within the body. This is primarily enclosed within a gas-filled buoyancy organ, the swim bladder. In some fish, physostomes, there is a patent duct that connects the swim bladder to the anterior oesophagus, which permits air to be swallowed and forced into the swim bladder. In other fish, physoclists, there is no patent connection and the swim bladder is inflated by the release of gas from arterial blood by a vascular rete in the wall of the swim bladder: this also occurs in some physostomes.

Buoyancy disorders are common in ornamental fish and goldfish (*Carassius auratus*) in particular (Lewbart 2000). Affected fish often present following a sudden onset and are found lying on the bottom of the tank or pond, or floating at the surface. Most are solitary cases and they often deteriorate due to skin damage through desiccation from exposure to air if at the surface or trauma from contact with the substrate. Few cases ever improve but despite the poor prognosis owners often want some investigation and treatment, particularly if they are emotionally attached to their pet. There are very few references in the scientific literature. Tanaka and others (1998) investigated buoyancy disorders in goldfish and there are several individual case reports (Tocidlowski and Harms 1998, Hobbie and others 2002, Britt and others 2005, Lewbart and others 2005, Matysczak 2005) and a brief discussion of the subject (Reyes 2005). However, there is much comment and speculation in the hobby literature (Andrews and others 2002) and on several Internet web sites, which most call 'swim bladder disease'. Poor genetics, poor water quality, poor nutrition, a rapid drop in water temperature and constipation are often cited as the underlying cause.

This paper reviews cases investigated by the author and several aspects relating to the environment, clinical history and pathology were examined in an attempt to find some common factors.

Materials and methods

Fifty eight fish exhibiting abnormal buoyancy were examined between May 1994 and December 2005. Cases were recorded following a routine investigation of the clinical history and physical examination under anaesthesia using tricaine methane sulphonate (MS222®, Sandoz). Radiographs were taken in 49 cases, most of which were taken in the second half of the study period after the author had developed a good radiographic technique. Ultrasonography was performed in only a few cases. Some fish (26%) were given treatment at the owner's request, most of which subsequently died and were unavailable for further investigations. Fish were euthanased with an overdose of tricaine methane sulphonate. Post mortem examinations were carried out immediately on most fish and routine samples of several tissues including the brain were sent for histological examination.

Clinical results

Records over a four year period to December 2005 indicated that 13.5% of phone calls from fish keepers involved buoyancy disorders. About 25% of these were presented for examination in contrast to 10% that present with other fish health problems. In the 11.5 year study period, 58 cases of abnormal buoyancy were examined and all except two were solitary cases. Of these, 81% were goldfish, 5% orfe (*Leuciscus idus*), 3% koi (*Cyprinus carpio*), a few tropical freshwater species and one marine porcupine puffer (fam. Diodontidae). In practice, the author mainly sees freshwater coldwater species such as goldfish, koi, carp and orfe in fairly equal numbers. The significantly higher percentage of goldfish confirms that this species is particularly susceptible to buoyancy disorders.

Goldfish were grouped according to body length for this review (Fig 1). Radiographically, there is marked compression of the vertebrae in the area dorsal to the body cavity which results in shortening of the body length and rotund body shape in some varieties of fancy goldfish (Fig 2). The long-bodied varieties (51%) consisted solely of common goldfish and comet-tailed goldfish (Fig 3). The short-bodied varieties (49%) included orandas, fantails, ranchus, black moors and a few other exotic varieties. The distribution of varieties affected may be influenced by the popularity of those kept by hobbyists rather than an increased susceptibility to buoyancy disorders.

FIG 1: Different varieties of fancy goldfish presented with buoyancy disorders

Long-bodied goldfish		Short-bodied goldfish	
38%	Comet-tailed goldfish	17%	Oranda
13%	Common goldfish	15%	Fantail
		13%	Black moor
		4%	Ranchu

Most affected goldfish came from indoor aquaria (77%), primarily because the short-bodied fancy varieties are not suitable for outdoor ponds. The age of affected goldfish ranged from 6 months to 17 years (median 3.5 years). The duration of clinical signs prior to examination ranged from 12 hours to 5.5 years (median 21 days). Where post mortem examinations were performed (35 goldfish), 46% were female and 37% were male: it was not possible to determine the sex in the remaining cases.

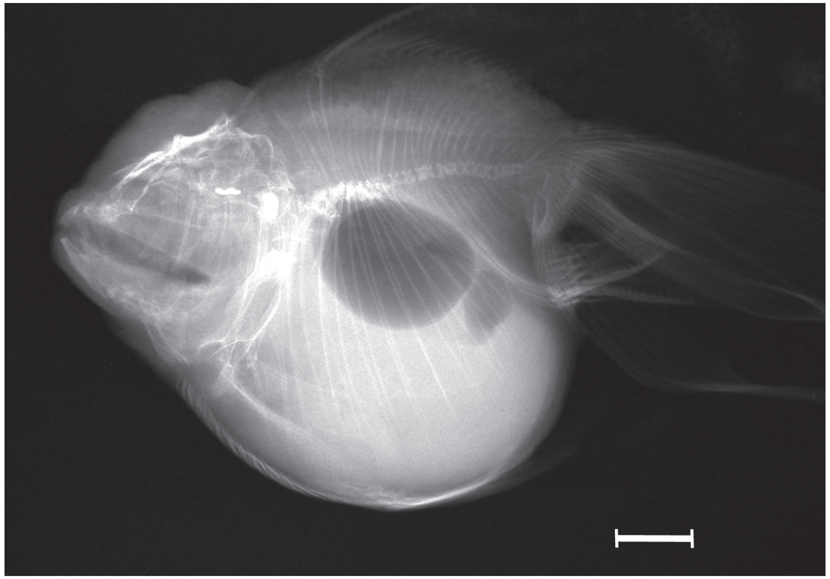

FIG 2: Radiograph of a short-bodied goldfish (oranda) showing marked compression of the vertebrae dorsal to the body cavity. This fish had an enlarged ovary full of eggs. Bar = 1 cm

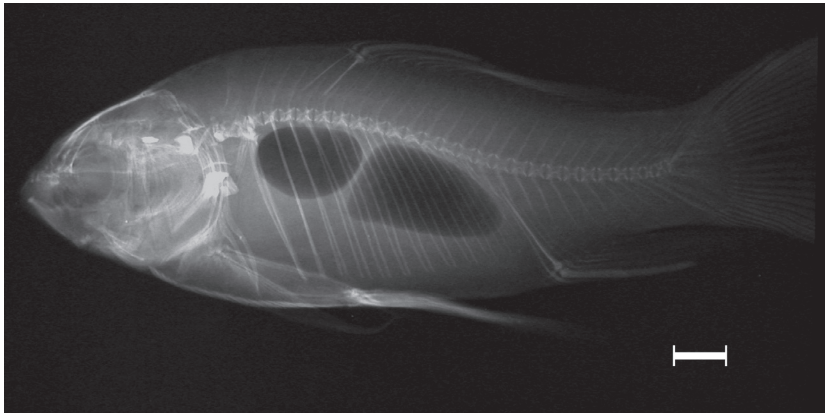

FIG 3: Radiograph of a long-bodied goldfish (comet-tailed) showing the normal shape and position of the two-chambered swim bladder. Bar = 1 cm

Clinically, buoyancy disorders present with abnormal position in the water column and abnormal body posture. Twice as many goldfish cases were on

the bottom (45%) (negative buoyancy) than were floating at the top (21%) (positive buoyancy, Fig 4), and these fish sank to the bottom when not actively swimming. Most fish exhibited varying degrees of listing or rolling to one side (72%), with half of them being completely upside down. Some fish rotated back to their original position when rolled over onto the other side. Only a small number of goldfish had abnormal pitch, most of which were 'head down' in the water (13%). In many cases, there was a combination of abnormal pitch and listing, particularly in the short-bodied varieties. Only a few fish exhibited circling behaviour or abnormal swimming patterns and these had granulomas in the cranial cavity.

FIG 4: A fancy variety of goldfish (oranda) presenting with excessive positive buoyancy and floating upside down at the surface. Radiographically, this fish had an over-inflated swim bladder.

Clinical examination of affected fish was often unrewarding, with few exhibiting any clinical signs other than abnormal posture. In some, there was abdominal swelling and this was often asymmetrical: affected goldfish usually had polycystic kidneys or 'kidney enlargement disease' and oscars had a renal tumour. Some fish exhibited exophthalmos, particularly if they had systemic disease and in one case extensive granulomata were found behind the globe of one eye. Hyphaema and generalised hyperaemia with engorged blood vessels in the fins or skin was sometimes seen. In a few fish that listed permanently to one side, the upper eye was dorsally rotated. In general, clinical signs were of limited value in determining the underlying pathology.

Diagnostic imaging

Radiography proved the most useful non-lethal method of investigating cases and clearly demonstrated the distribution of gas and space-occupying lesions within the body cavity. The procedure requires only brief anaesthesia to remove the fish from water and utilizes standard radiographic equipment and techniques. The radiographic appearance of the swim bladder varies slightly between the long- and short-bodied varieties of goldfish and the posterior chamber is often much smaller or non-existent in the latter. A horizontal beam view is useful where there is partial filling of the swim bladder with fluid. Contrast radiography using barium or other radio-opaque media given by gavage can be used to delineate the intestinal tract. Although ultrasonography has limited use when examining the swim bladder and kidney, it was very useful for identifying diseases of the other abdominal organs and polycystic kidneys.

Several radiographic abnormalities were identified in fish with buoyancy disorders.

Over-inflation of the swim bladder

In goldfish, the most common abnormality was over-inflation of the swim bladder (44%) although in some cases this was difficult to assess because of the variable appearance of the posterior chamber in the different varieties of goldfish (Fig 5). In oscars (*Astronotus ocellatus*), a South American tropical cichlid, renal papillary cystadenomas are common and cause abdominal swelling in the posterior part of the body cavity (Gumpenberger and others 2004, Wildgoose 2004). In two of the five oscars with this renal tumour seen by the author there was excessive positive buoyancy resulting from significant over-inflation of the thin membranous swim bladder (Figs 6 & 7).

Displacement of the swim bladder

In goldfish, the posterior chamber was displaced in 22% of cases. The anterior chamber of the swim bladder has a thick tunica externa and is firmly attached to a bony vertebral process at the anterior pole. The posterior chamber is only attached to the anterior chamber by the narrow ductus communicans and is

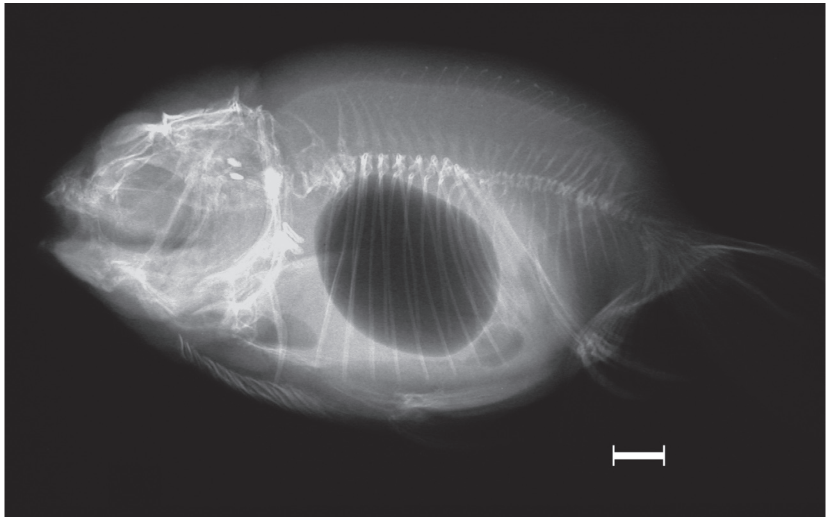

FIG 5: Lateral view of a fancy goldfish (ranchu) with over-inflation of the anterior chamber of the swim bladder. Despite paracentesis and antibiotic treatment this fish deteriorated over four months and was found to have systemic granulomatous disease on post mortem examination. Bar = 1 cm

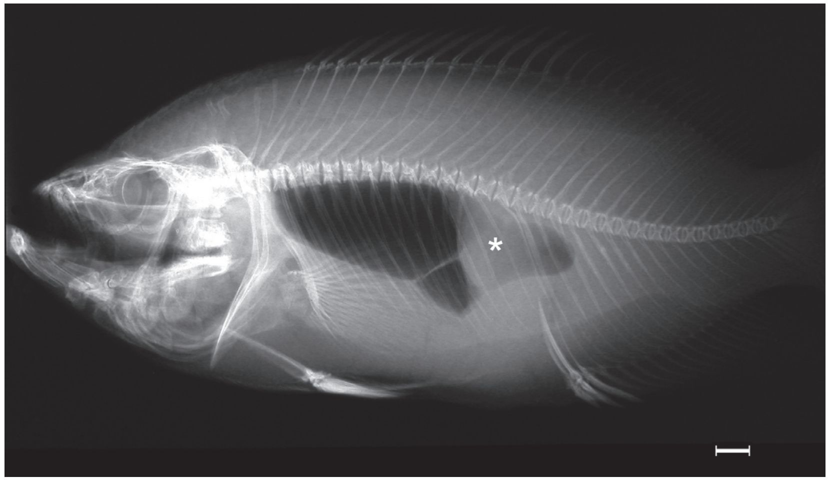

FIG 6: Radiograph of a 6 year old oscar showing mild ventral compression of the posterior part of the swim bladder and increased radiodensity (asterisk) due to a renal tumour. This fish did not exhibit any abnormal buoyancy. Bar = 1 cm

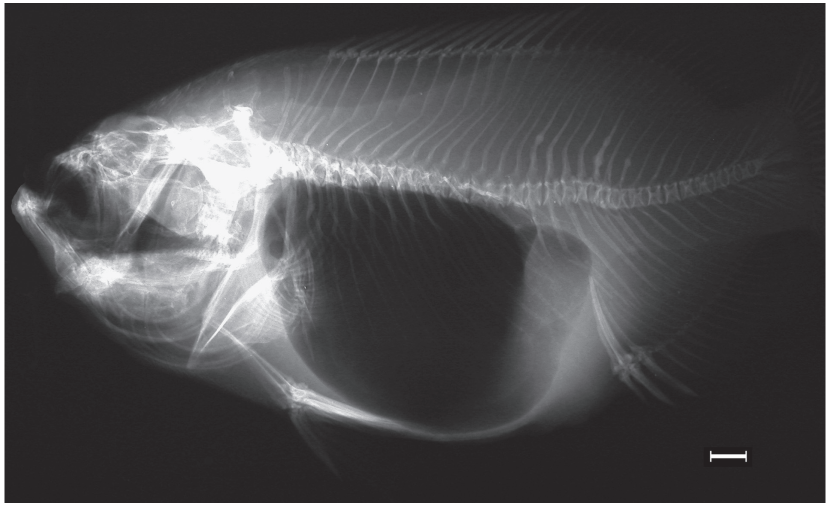

FIG 7: Radiograph of an 8 year old oscar with severe over-inflation of the swim bladder. This fish was excessively buoyant and floated on its side at the surface for five months. The renal tumour appears as an area of increased radiodensity in the posterior body cavity. Bar = 1 cm

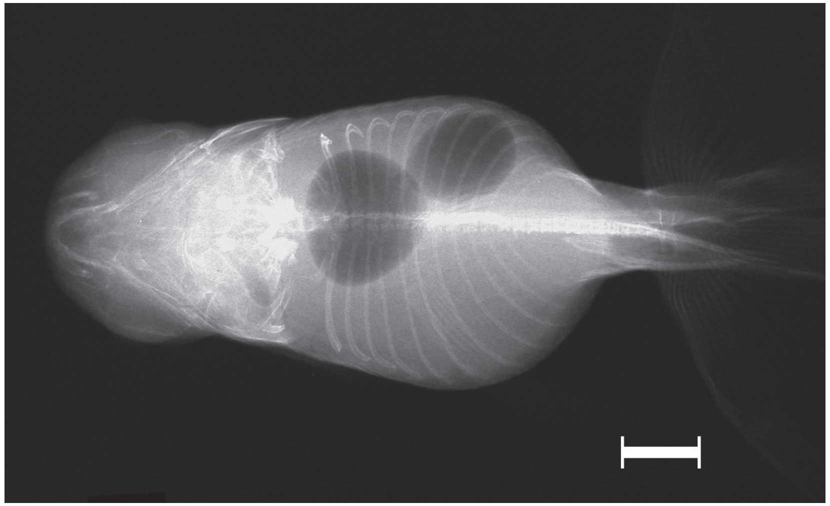

FIG 8: Dorsoventral view radiograph of a fancy goldfish (oranda) showing displacement of the posterior chamber of the swim bladder to the right side due to a polycystic kidney disease. This fish was originally presented after floating at the surface with its right side uppermost for two weeks. Bar = 1 cm

easily displaced laterally from its normal midline position or ventrally into the body cavity by space-occupying lesions (Fig 8). The gap between the two chambers is small, usually about one to two millimetres, but this is widened in goldfish with enlargement of the posterior kidney with polycystic disease, extensive granulomata or neoplasia.

Fluid in the swim bladder

There is rarely any fluid seen in the normal swim bladder, although the epithelial cells produce a surfactant that is thought to have an anti-adhesive and protective function. Researchers studying surfactant deficiency diseases in humans such as premature babies have used goldfish as a model and washed out the swim bladder (Daniels and Skinner 1994). Analysis of this fluid shows that it contains surfactant proteins and phospholipids that bear many similarities to those found in mammalian lungs. The radiographic appearance of fluid in the swim bladder varies depending on the amount present. When full of fluid, the swim bladder is barely visible and has a homogeneous radiodensity similar to that of the surrounding tissues (Fig 11). When partially filled, a faint area of radiolucency is seen in the centre of the affected swim bladder chambers when radiographed in lateral recumbency: the gas lies above the fluid and a fluid line can be detected more readily on a

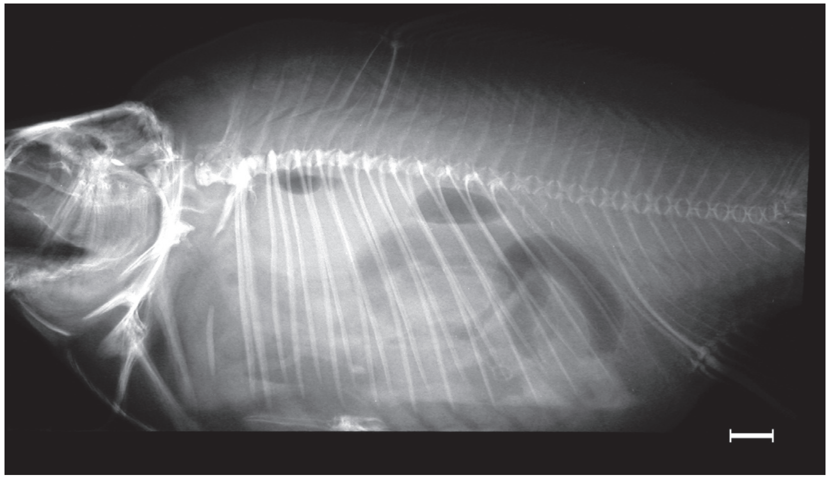

FIG 9: Horizontal beam radiograph of a common goldfish with fluid partially filling both chambers of the swim bladder. Excess gas is also present within the bowel. This fish had exhibited negative buoyancy and a head-down posture for 10 days. Bar = 1 cm

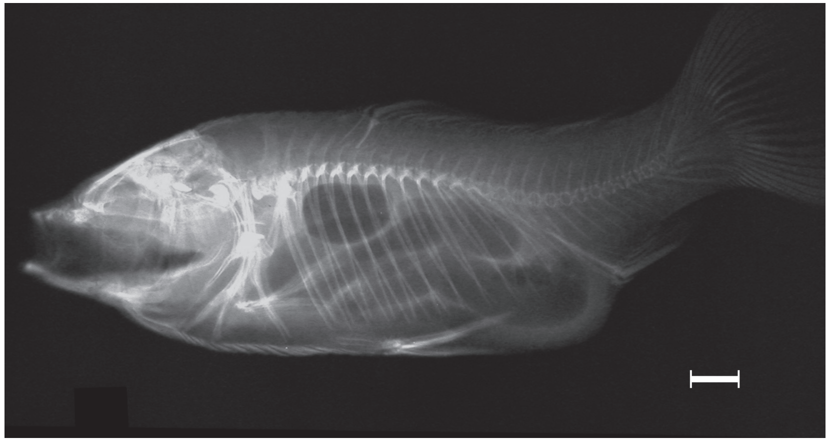

FIG 10: Radiograph of a common goldfish with intestinal tympany causing excessive positive buoyancy. This fish failed to respond to paracentesis of gas and antibiotic therapy or diet change. The fish was euthanased due to lack of recovery after eight months. The anterior bowel was grossly dilated with gas but the swim bladder was normal. No specific cause was identified. There was also a marked degree of spinal lordosis. Bar = 1 cm

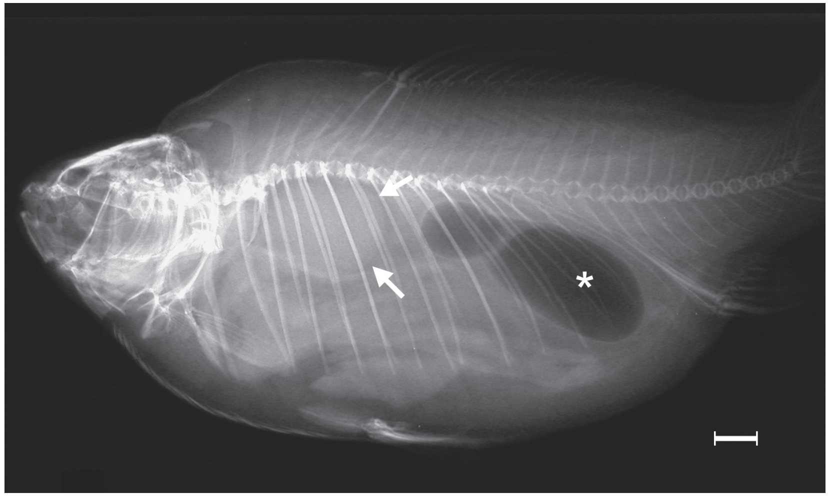

FIG 11: Radiograph of a common goldfish with rupture of the posterior chamber of the swim bladder and free gas in the retroperitoneal space (asterisk). The anterior chamber (arrowed) is full of fluid and has a homogeneous radiodensity. This fish was presented four days after it developed a head-down posture with its tail above the water surface. Bar = 1 cm

horizontal beam image (Fig 9). Abnormal fluid was found in 12% of goldfish in this review and varied from clear straw-coloured fluid to white purulent material. One of the two koi seen had a purulent fluid in the swim bladder with granulomas and contained acid-fast bacteria.

Intestinal tympany

The similar radiodensity of bowel, liver and body fat make it difficult to differentiate the abdominal tissues. Normally, little detail is seen within the bowel but occasionally there may be small amounts of radio-opaque foreign matter such as sand or grit in pond fish or radiolucent gas. Three goldfish had excessive amounts of gas in the bowel and all these were excessively buoyant (Fig 10). In one case, some gas was aspirated through the vent. All were treated with antibiotics but showed no long-term improvement.

Rupture of the swim bladder

The absence of a thick tunica externa in the posterior chamber allows significant volume change and in extreme cases, predisposes it to rupture. Only one goldfish was seen with a ruptured swim bladder and this was complicated by the presence of purulent fluid in the anterior chamber (Fig 11). This case, in common with two orfe with ruptured posterior chambers, occurred in winter, suggesting that low water temperatures may be a contributing factor.

Post mortem examination

Detailed post mortem examinations were performed in 35 goldfish, of which most were submitted for histological examination. Granulomatous disease, probably due to mycobacteria, was present in 23% of cases and all of which were kept in aquaria. Half of these had lesions within the cranial cavity and only a third revealed acid-fast bacteria with Ziehl-Neelsen staining. Fluid was present in 23% of cases and bacterial culture isolated *Aeromonas* and *Pseudomonas* spp. in the fluid, and mycobacteria in one case. It is not known how the bacteria enter the swim bladder but this may be via the patent pneumatic duct or are blood-borne and enter through the vascular rete. Polycystic kidney disease was present in 17% of goldfish. Other identifiable diseases including ovarian disorders, renal disease and neoplasia were found in 22% of goldfish. However, in 17% there was no visible pathology and nothing remarkable found on histological examination. There were very few common factors and even radiography gave mixed results with an even number exhibiting normal, over- and under-inflation of the swim bladder. This may suggest that small but significant lesions were overlooked elsewhere such as in the brain.

In the other species, two of the three orfe had a ruptured swim bladder, one of which had a granulomatous disease caused by a septate fungal infection and the other a non-specific acute inflammation of the swim bladder. The other orfe had a large hepatic tumour and granulomas. The two oscars had renal tumours and over-inflated swim bladders. Of the two koi seen, one had purulent fluid with granulomas in the swim bladder and the other a non-specific necrosis of the posterior kidney. Two of the four tropical species had granulomatous disease and one molly (*Poecilia sphenops*) revealed pathology in the brain suggestive of a lipid storage disease.

Discussion

In goldfish, the swim bladder is a two-chambered organ located dorsally within the body cavity, adjacent to the ventral margin of the spine. The anterior chamber is lined with epithelial cells, supported by several tissue layers and has an outer layer of dense connective tissue (tunica externa) (Morris and Albright 1979). The anterior chamber is cuboidal in shape and has limited capacity to change in volume. At the anterior pole, the tunica externa is firmly attached to the Weberian ossicles and a flattened bony process at the base of the fourth vertebra to assist in sound reception (hearing). The posterior chamber is thin-walled and is thus capable of significant volume change because it does not have a tunica externa. There is a diffuse vascular rete mirabile system that is involved in gas secretion and absorption into the posterior chamber, which assists in buoyancy control. The posterior chamber connects to the left side of the proximal oesophagus by a long patent pneumatic duct and to the anterior chamber by the ductus communicans. The total volume of the swim bladder is about 5-10% of the total body volume. The posterior or body kidney is a compact organ situated dorsally between the two chambers and responsible for excretion of fluid and some nitrogenous wastes.

One of the few scientific papers on swim bladder disorders in goldfish describes buoyancy problems affecting young short-bodied goldfish (Tanaka and others 1998). This was given the name ‘tenpuku’ by Japanese farmers and means ‘capsized’. Affected fish develop the problem after a marked drop in temperature or in winter. Several different postures and positions were identified. Many may be affected at the same time, unlike in the cases

reviewed here. The authors took radiographs and performed autopsies and found a wide range in the size of the posterior chamber of the swim bladder in both affected and unaffected fish. Many anatomical aspects of the swim bladder were studied but the authors were unable to explain the pathogenesis of the abnormal swimming and buoyancy of affected fish.

Goldfish have been subjected to short periods of weightlessness during parabolic flights and taken into space several times for various experiments studying the nature of motion sickness in astronauts (de Jong and others 1996, Ohnishi and others 1998, Takabayashi 2004). In space, goldfish initially exhibit backward somersault swimming behaviour. This gradually diminishes after several days as they adapt to the lack of gravity: the cerebellum may be involved in this adaptation. Similar behaviour is also noted on return to earth. Other experiments investigated the role of the labyrinth, the part of the inner ear that is responsible for balance control. Researchers found that following surgical removal of one or both labyrinths, fish exhibited tilting behaviour with their dorsal surface tilting towards a light source and that the swim bladder has a functional role as a gravity sensor (Takabayashi and others 1993). Although these abnormal swimming behaviours were not seen in goldfish in this review, it suggests that various parts of the brain are involved in balance and buoyancy control.

Treatment

The response of abnormal buoyancy cases to treatment is often poor due to the severity of the underlying disease. Euthanasia is indicated in most instances but in the absence of obvious pathology some owners may request treatment. In a quarter of cases seen, the owners declined euthanasia for personal reasons or because the fish were not exhibiting signs of distress. Many of these deteriorated within a few weeks or died at home and were not available for further investigations. Depending on the clinical signs and radiographic findings some of the following treatments may be of benefit in cases where owners initially request treatment.

Environmental management

Sodium chloride salt added to the water at 2–5 grams/litre as a permanent bath is often physiologically beneficial to freshwater fish. Increasing or decreasing the water temperature by a few degrees, provided it is within the fish’s tolerance range, may alter the fish’s metabolic rate and assist recovery in some cases. Starving for 2–3 days allows the bowel to empty and eliminate any gas-producing contents. There has been anecdotal evidence that feeding a lightly crushed green pea (canned or cooked) once daily is thought to have a mild purgative effect that may dislodge gas in the bowel (Lewbart 2000).

Medical therapy

In the UK, at least one proprietary pet shop medicine claims to treat swim bladder disorders (Aquarium Treatment 13 – Swimbladder Treatment; Interpet). However, the manufacturers have not disclosed the ingredients, making it difficult to assess which cases may benefit from these products. Antibiotics given by immersion, injection or in the food may be effective in some cases where bacterial infections are involved. Carbonic anhydrase inhibitors such as acetazolamide have been used by injection at 6-10 mg/kg to treat gas bubble disease in seahorses and may be beneficial in fish with over-inflated swim bladders by reducing the production of new gas from the vascular rete.

Surgery

Fish with negative buoyancy due to an under-inflated swim bladder have had various flotation devices fitted including cork, polystyrene and Floy® tags with limited success (Lewbart and others 2005). Fish with an over-inflated swim bladder can have some gas removed by paracentesis using a needle and syringe to adjust their buoyancy. These often have a short-term effect and in many cases the swim bladder becomes over-inflated again within a few days. In some cases, repeated paracentesis may eventually resolve the problem. There are reports of partial pneumocystectomy where part of the swim bladder is removed to reduce its size and hence the buoyancy of the fish (Lewbart and others 1995, Britt and others 2002). Coelomic implants placed inside the body cavity have been described on the Internet as a method of adding extra ballast to fish that are excessively buoyant. However, other than paracentesis, most surgical interventions require an advanced surgical approach and success often depends on the underlying cause.

Conclusion

Many cases in this review had no consistent clinical features that related to the pathology found and the abnormal buoyancy may simply be a terminal clinical sign. Many had chronic diseases despite the sudden onset and many had granulomatous disease, probably due to mycobacterial infection. Most goldfish with polycystic kidneys were pond fish, and most fluid-filled swim bladders had bacteria present. All the fish in this review were from private owners and had been kept for several years. These may differ from young fish with similar buoyancy disorders that are culled by farmers and retailers, and which may have other underlying causes such as genetic or congenital defects as suggested in the hobby literature. It is clear that more detailed research is required to improve our understanding of this common disorder.

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This paper is based on a presentation given at the autumn meeting of the Fish Veterinary Society in Glasgow on 17 May 2006. It was submitted for publication on 26 June 2006.