Freshwater fish in the Falklands

Conservation of native zebra trout

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A report by Katherine Ross to the Falkland Islands Government and Falklands Conservation, 2009.

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Summary

- Only two species of freshwater fish, Zebra trout (*Aplochiton zebra*) and Falklands minnows (*Galaxias maculatus*) are native to the Falklands.
- Brown trout (*Salmo trutta*) were introduced to the Falklands in the 1940's and 1950's. They can spend part of their life cycle at sea which has allowed them to spread across the islands causing a catastrophic decline in the distribution of zebra trout. The ways by which brown trout remove zebra trout probably include predation on juvenile fish and competition for food.
- Zebra trout are long lived and therefore adult populations may persist for many years where juveniles no longer survive. Such populations can become extinct suddenly.
- Freshwater fish of the Falklands were last surveyed in 1999.
- This project investigated the distribution of freshwater fish in West and East Falkland by electrofishing, netting and visual surveys and identified conservation priorities for zebra trout.
- Zebra trout populations were found in Lafonia, the south of West Falkland and Port Howard. Brown trout were found across much of Lafonia where their range appears to have expanded since 1999.
- Once brown trout have invaded a catchment they are very difficult to remove. Controlling the spread of brown trout is therefore an urgent priority if zebra trout are to be conserved.
- Freshwater habitats where zebra trout were found were generally in good condition but in some areas perched culverts may prevent juvenile zebra trout from returning to freshwaters (we think larval zebra trout spend their first few months at sea).
- Priorities for zebra trout conservation include:

  Ongoing education and sharing of information between the public, farmers, anglers, the Environmental Planning Department, the Fisheries Department and Falklands Conservation.

  Research and monitoring of zebra trout and brown trout populations to inform the Environmental Planning Department and thus conservation measures.

  Urgent investigation of methods of protecting river systems from brown trout invasion.

  Stabilisation of the eroding dyke between North and South Lake Sulivan to protect the zebra trout populations around Port Philomel.

  Ensuring that zebra trout populations are not endangered by perched culverts under road crossings.
- A variety of education events were carried out and educational material was produced for primary schools.

Contents

1. Introduction

1.1. Overview

This project investigated the distribution of freshwater fish across the Falkland Islands, filled gaps in our current knowledge and identified priorities for the conservation of zebra trout. It was also an opportunity to publicise the problems facing zebra trout and to raise the profile of this species. *Zebra trout are in urgent need of conservation* and we hope that this study stimulates practical action and further research.

The project was largely a follow-up to surveys carried out in 1999 by a team of fish biologists from New Zealand, R. M McDowall, R. M. Allibone and W. L. Chadderton. This group were the first to gather detailed baseline data on the distribution of freshwater fish in the Falkland Islands and their work highlighted the plight of the native zebra trout.

The current project was run jointly by the Environmental Planning Department at the Falkland Islands Government (Helen Otley), Falkland Islands Development Corporation Aquaculture Project (Dan Fowler), Fisheries Department (Paul Brickle), Falklands Conservation (Grant Munro and Pierre Pistorius) and the South Atlantic Invasive Species Programme (Brian Summers and Clare Miller). It was funded by the UK Government's Overseas Territories Environmental Programme (OTEP), the Falkland Islands Government and the South Atlantic Invasive Species Programme, with volunteer workers provided by Falklands Conservation. The Freshwater Fish Project Officer post was contracted to Katherine Ross (frin@topmail.co.uk).

1.2. An introduction to freshwater fish of the Falklands

The freshwaters of the Falkland Islands support two species of native fish, Falklands' minnow (*Galaxias maculatus*) and zebra trout (*Aplochiton zebra*). Zebra trout are referred to locally as Falklands' trout, local trout and brown trout. European brown trout (*Salmo trutta*) were introduced to the Islands between 1944 and 1962 from Chile and the UK. Brown trout that migrate to sea to feed are called sea trout; locally brown trout are also called rainbow trout and introduced trout. Brown trout have become established across the islands as an invasive species which can reproduce and spread without help.

A number of other fish are found in brackish creeks. Mullet (*Eleginops maclovinus*) and smelt / pejerrey (*Odontesthes* spp.) often enter creeks at high tide but are marine fish migrating to river mouths to feed. Southern pouched lamprey, long eel like fish with round sucker like mouths, have also been recorded from the freshwaters of the Falklands but are not common. Freshwater fish and their ecology are excellently described in the book "Falkland Islands Freshwater Fishes, A natural history" by R. M. McDowall, R. M. Allibone and W.L. Chadderton (2005) which is available from Falklands Conservation. This book is essential reading for anyone interested in the freshwater life of the Falklands. Aspects of the ecology of freshwater fish are summarised below.

Juvenile zebra trout Picture Dan Fowler

Zebra trout are common in freshwaters on the west coast of Patagonia and the Falklands (McDowall et al. 2005). They are not commercially fished and we know relatively little about their biology. Zebra trout in the Moody Brook hatchery spawn in the early spring, with the majority of fish spawning on a single night. This is consistent with local reports of fish congregating in ditches close to the sea in September and their eggs being found at that time of year. The eggs are sticky and probably attach to ditch beds or aquatic vegetation. In related species young fish are washed out to sea soon after hatching from eggs and this is likely to be the case for zebra trout. Zebra trout of 40 mm have been found in ditches during electrofishing surveys supporting the theory that young fish return to rivers when they are still small. They do not appear to be powerful swimmers at this stage and it may be that they return to any freshwater rather than their natal river or ditch. A range of sizes of zebra trout up to 29 cm have been found in freshwaters and it seems likely that the fish remain in freshwaters for their adult life. Some zebra trout populations live in isolated ponds and therefore complete their whole life cycle in freshwater. Preliminary aging studies for zebra trout caught in Lafonia with access to the sea, suggest that small zebra trout (4 – 5 cm) are a year old and that after that growth slows down with 9 year old fish perhaps measuring just 18 cm (Tiphanie May *pers. comm.* 2009, via Dan Fowler).

A large Falklands minnow Picture Peter Nightingale

Falklands' minnows are common in cool areas of the southern hemisphere from Australia to Chile. They support a valuable fishery in New Zealand where the young fish are prized as whitebait. Falklands' minnows have therefore been better studied than zebra trout. Minnows spawn on vegetation at the margins of rivers and ditches. Their life-cycle is similar to that of zebra trout, and young minnows go to sea. They return after less than six months as small transparent "whitebait "and spend the rest of their lives in fresh and brackish water. Most minnows live for only one year. Like

zebra trout, minnows can complete their whole life cycle in freshwater if they cannot reach the sea.

Brown trout and sea trout Picture Dan Fowler

The lifecycle of brown trout differs from that of zebra trout and minnows because fish do not go to sea until at least a year after hatching. Fish spawn in the autumn when females use their tails to make nests or redds in clean gravely areas. Eggs and small fish then spend a number of months protected under the gravel. They eventually emerge as fry and can spend the rest of their lives in freshwater. After one to five years however some brown trout may become silver smolts and migrate to sea to feed. These fish return after six months or more as large sea trout or slob trout. Note that sea trout, slob trout and brown trout are the same species of fish and siblings from the same parent fish may remain in freshwater while others go to sea. Sea trout tend to return to their natal rivers, but occasionally individuals stray and this is how they have spread since they were introduced to the islands.

In freshwater zebra trout, minnows and brown trout are generalist predators. They feed on invertebrates that live in freshwater such as water beetles and caddis fly larvae and insects that fall into the water including moths and adult flies. They also prey on fish. At sea young minnows and zebra trout probably feed on small plankton while larger sea trout feed on fish and crustaceans including smelt and lobster krill.

1.3. Why freshwater fish are important in the Falkland Islands

Freshwater fish are ecologically, economically and culturally important to the Falkland Islands. They are part of the islands ecosystem, for example young minnows are preyed on by sea fish and birds including mullet and night herons, in turn minnows prey on fly larvae. Zebra trout and minnows are also a part of the natural biodiversity of the Falkland Islands and fishing trips for zebra trout are remembered fondly across the Islands. However, because of their diminishing numbers zebra trout are now protected by law and deliberately killing them can result in prosecution. Brown trout

are an invasive species but they are also a healthy food source and angling is a cherished recreation that is often accompanied with care for the natural environment. The large sea trout of the Falklands are also famous worldwide and angling tourism brings money to the islands, including areas in camp where revenue can be particularly important.

1.4. Why native fish need conservation

Information from naturalists, farmers and landowners suggests that since brown trout were introduced the abundance and distribution of zebra trout has declined dramatically. The work of McDowall and his team supported this showing that zebra trout were rarely found where brown trout were established. It is likely that brown trout have also impacted on minnow populations but this is not as obvious from presence and absence surveys. The ways by which brown trout remove zebra trout have not been researched in detail and some are likely to be more obvious than others.

We know that brown trout have removed zebra trout through predation because anglers have caught sea trout with juvenile and even adult zebra trout in their stomachs. Brown trout may also have reduced the survival of zebra trout by taking their food or by acting aggressively towards zebra trout and thereby preventing them from reaching their feeding or spawning areas. Ben Perry studied zebra trout in the Falklands for his MSc thesis and found that brown trout, zebra trout and minnows feed on the same invertebrates and might therefore compete for food. Because they can go to sea brown trout can spread to new rivers and are slowly becoming established across the islands with dire consequences for zebra trout.

2. The 2008 – 2009 freshwater fish survey

2.1. Aims and methods

The aim of the survey was to discover if zebra trout were present in areas that had not been surveyed in 1999, principally West Falkland south of Lake Sulivan, and to resurvey areas where zebra trout had been found in 1999 to find out if they had persisted and if brown trout had spread.

The fish survey was also an opportunity to find out more about the biology and ecology of minnows and zebra trout, for example their size range and what they feed on. Freshwater habitats were examined to identify factors which might be important for the conservation of native fish and to help interpret data on fish abundance and distribution.

Sampling trips were made to West Falkland, Lafonia and the Choiseul Sound area. Fifty-two sites were visited and fish were surveyed using a variety of visual, electrofishing and netting techniques as described in appendix 1.

Electrofishing in West Falkland.
Picture Peter Nightingale

Sites in West Falkland were surveyed over three weeks in December 2008 by the Project Leader Katherine Ross, Peter Nightingale, and Carissa Turner and Kevin Payne (who were volunteers with Falklands Conservation). The area south of Fox Bay was surveyed for the first time as a lack of roads had prevented surveying in 1999. North of Fox Bay brown trout dominated catches in 1999. Exceptions were Port Philomel catchments and two sites in Port Howard where zebra trout were found. These sites were resurveyed and some new sites in Shallow Bay, Main Point, Dunbar, Port Howard, Port North and Shallow Harbour were examined.

In 1999 surveys found that brown trout were well established across the north of East Falkland and that zebra trout only occurred in isolated ponds. Zebra trout were, however, found in the rivers and ditches of Lafonia. Zebra trout and brown trout were found together in one site on the Walker Creek side of Choiseul Sound suggesting, perhaps, that brown trout were spreading south. In January 2009 two week-long survey trips were made to East Falkland by Katherine Ross and various colleagues including, Dan Fowler and Antoine Daille (Aquaculture Project, Falkland Islands Development Corporation), Pia Schuchert (Fisheries Department), Fiona Cunningham and Claudia Michler (volunteers with Falklands Conservation), and Bruce Campbell. We re-examined sample sites in Lafonia and carried out additional sampling along the coast of Choiseul and Falkland Sounds to investigate the spread of brown trout and their interaction with zebra trout.

Farmers and landowners provided important information on zebra trout including the locations of possible populations that we did not have time to investigate during this project. This is summarised in Appendix 2.

This survey had a number of important limitations which must be considered when interpreting our results. We wanted to cover as great an area as possible and therefore had a limited time at each site. Consequently the survey positively identifies where fish species were present. The surveys were not fully quantitative (i.e. we did not repeatedly fish an area until we were sure that all the fish present had been caught, or that we knew the percentage of fish that had been caught) and we did not survey entire river systems (catchments). So we cannot say with certainty that species were absent in watercourses where individuals were not caught or seen.

Other factors affecting our results varied between sampling sites. Firstly our electrofishing equipment had an intermittent fault and secondly the electrofishing team changed between locations and often included inexperienced fishers. It was therefore not appropriate to set up new quantitative monitoring sites where the number of fish was rigorously determined so that it could be compared between years or locations. Rather the survey gave us a good and useful overview of fish distributions and whether fish were common or rare in a specific location. It also enabled us to identify catchments that should be monitored in more detail in the future.

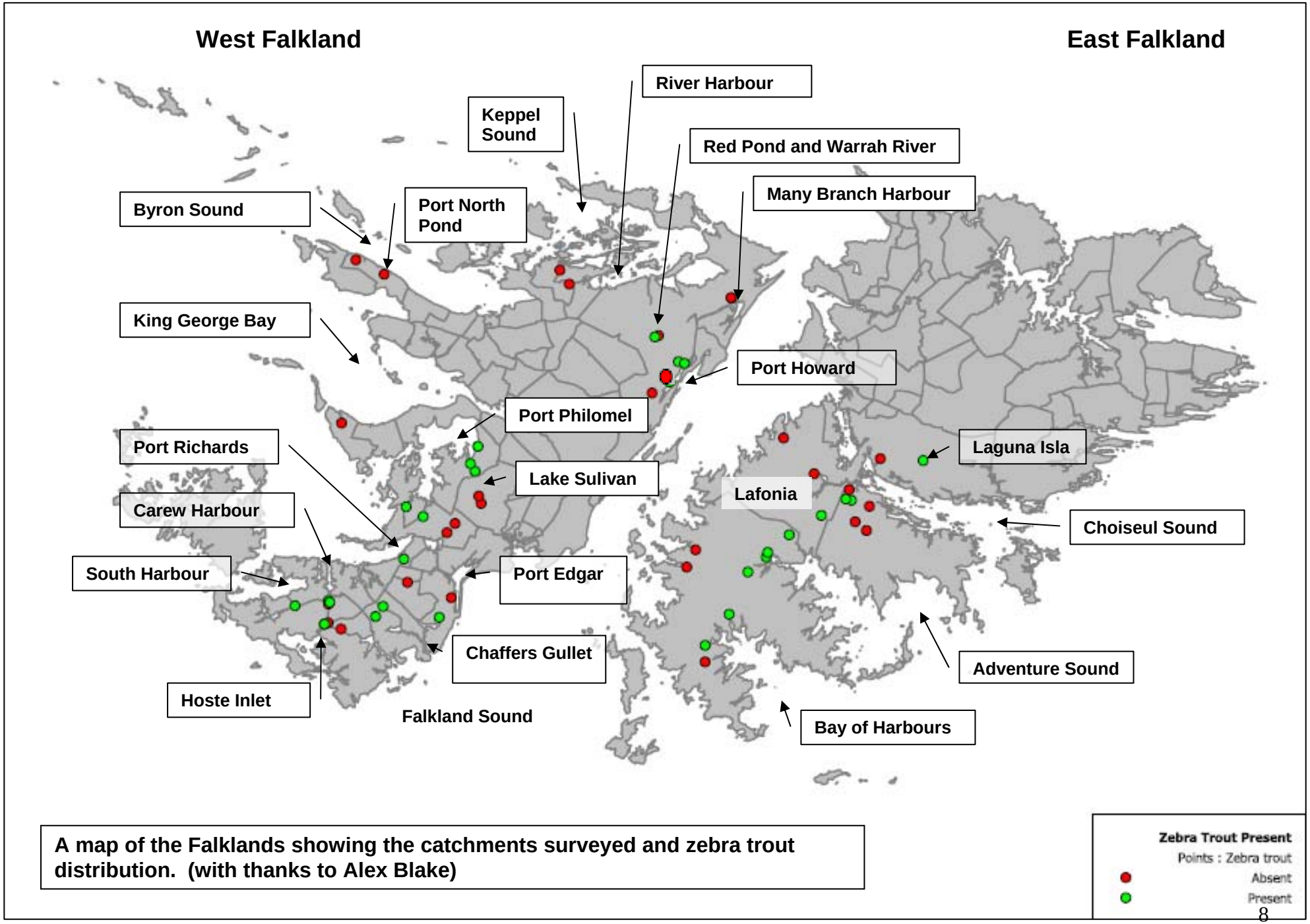
2.2. Samples

Otoliths (ear bones) from a number of small zebra trout were collected and sent to Bob McDowall in New Zealand. He has kindly offered to arrange chemical analysis to determine if the fish went to sea as larvae. Otoliths were also taken from a small number of larger fish so that their age and growth could be investigated. Minnows were collected for a genetics project in New Zealand. Small fin clips were taken from zebra trout so that if funding becomes available, these and further samples could be analysed by geneticists to see if zebra trout return to their natal rivers. The diversity of genetic material can even be interpreted by population biologists to estimate fish population sizes within a river system.

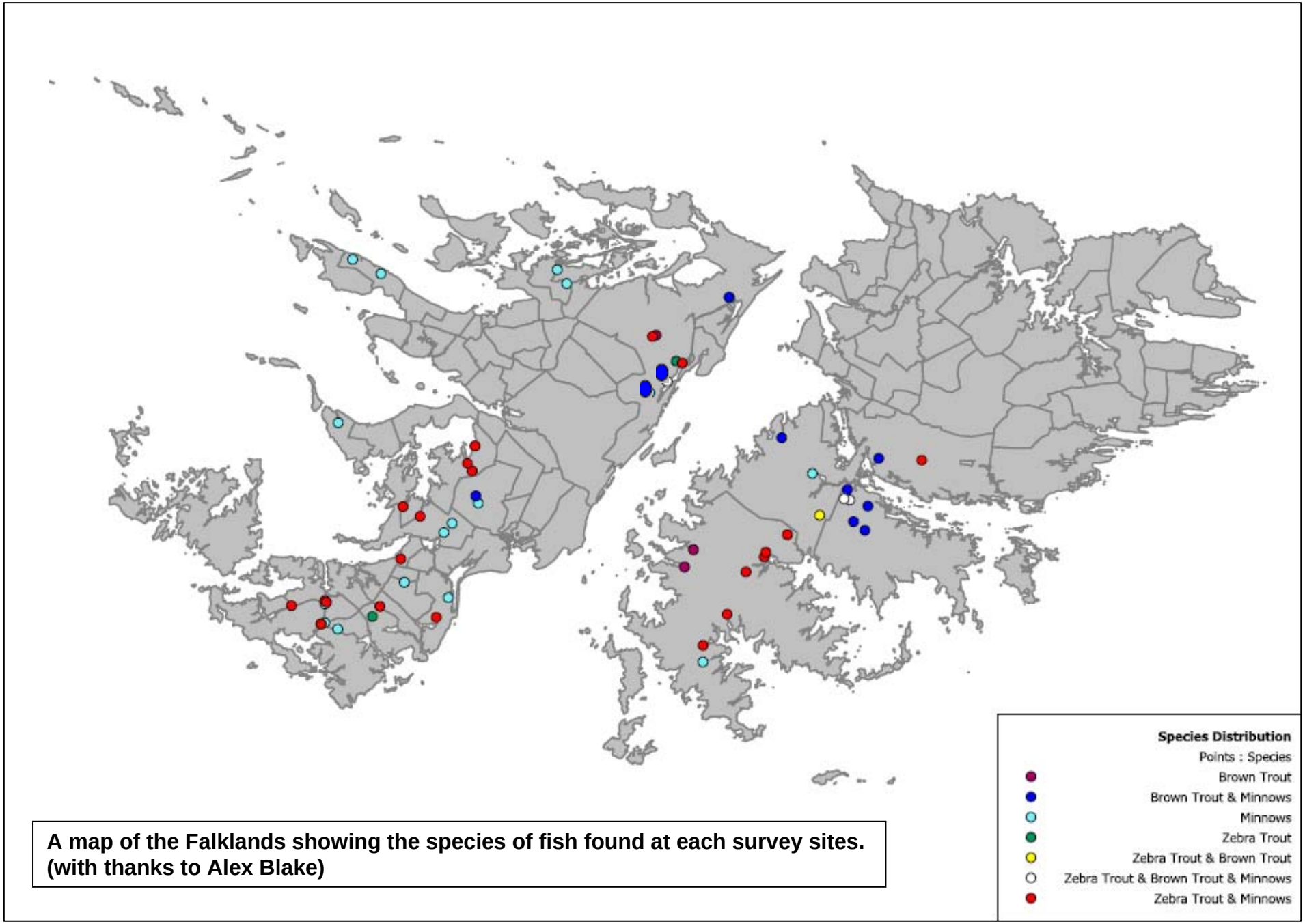
2.3. Results

2.3.1. Freshwater fish distribution and abundance

Our survey timing was fortunate as the weather was dry and water levels were low so fish were often concentrated in main water bodies and easy to see or catch. Zebra trout and minnows were common south of Lake Sulivan and in the south east of Lafonia. Elsewhere minnows and brown trout dominated. Brown trout have spread south in Lafonia since 1999. Fish distributions are summarised in the table overleaf and discussed further on the following pages.



A map of the Falklands showing the catchments surveyed and zebra trout distribution. (with thanks to Alex Blake)



A map of the Falklands showing the species of fish found at each survey sites. (with thanks to Alex Blake)

The fish species we caught or saw in the survey areas are listed below. Ticks indicate that fish were present and for zebra trout colours show whether we caught fish of less than 100 mm (yellow), more than 100 mm (red) or both large and small fish (green). * Indicates that we only caught or saw one fish of that species in the sample area.

The table also indicates where fish may be impacted by culverts under road or track crossings, ** indicates culverts that did not hinder fish passage under normal water flow conditions (although sometimes passage was only possible at high tide). Culverts were not checked thoroughly and others may also be passable at high tide.

Survey types (S, sweep net; V, visual survey; E, electrofishing) are indicated. Note that many watercourses were surveyed in a number of locations. As discussed in section 3.1, particular species or sizes of fish may be present in a watercourse but not detected by our surveys.

Catchment	Watercourse	Zebra trout	Minnows	Brown trout	Culvert	Survey
East Falkland						
Laguna Isla	Laguna Isla	✓*				S
Choiseul Sound	Teal Creek Arroyo		✓	✓		E
Choiseul Sound - Bodie Creek	Unamed stream at Colorado Pass		✓	✓*	Yes	E
Choiseul Sound - Bodie Creek	Unamed stream into Orqueta Arroyo		✓		Yes	E
Choiseul Sound - Bodie Creek	Unamed stream into Ramsgate	✓*		✓	**Yes****	E
Choiseul Sound - Bodie Creek	Bull Pass Stream	✓	✓	✓*	Yes	E
Choiseul Sound - Bodie Creek	Findlay Creek Stream	✓	✓	✓		E
Choiseul Sound - Victoria Harbour	Arrow Harbour Stream		✓	✓		V
Choiseul Sound - Victoria Harbour	Gonzales Arroyo		✓	✓		V
Choiseul Sound - Victoria Harbour	Arrow Harbour Stream		✓	✓		V
Adventure Sound	Spots Arroyo	✓	✓		Yes	E
Adventure Sound	Halfway House Arroyo	✓	✓		**Yes****	E, V
Adventure Sound	Deep Arroyo	✓	✓		**Yes****	E
Bay of Harbours	North West Arm House Stream	✓	✓		Yes	E
Bay of Harbours	Duffins bridge stream	✓*	✓		Yes	V
Bay of Harbours	Stream into Salt House Creek		✓			V
Falkland Sound	Ditches into New Haven		✓	✓	Yes	V
Falkland Sound - Wharton Harbour	Congo ponds area			✓		V
Falkland Sound - Findlay Harbour	Stream by Wreck House			✓		V

Catchment	Water course	Zebra trout	Minnows	Brown trout	Culvert	Survey
West Falkland						
Carew Harbour	Stewarts Brook	✓	✓		Yes	E, V
Hoste Inlet	Deans River	✓	✓		Yes	E, V
South Harbour	Lake Orisa		✓			S
South Harbour	Whisky Creek	✓*	✓		Yes	V
Chaffers Gullet	1st Arroyo	✓				E
Chaffers Gullet	2nd Arroyo	✓	✓*			E
Chaffers Gullet	Gibraltar Stream	✓	✓			E
Port Edgar	Fish Creek		✓		Yes	E
Port Edgar	Campbell Creek Stream		✓		Yes	E
Port Edgar	Lake Sulivan South		✓*	✓		E
Port Edgar	Leicester Stream	✓	✓		Yes	E, V
Port Philomel	Edye Creek	✓	✓		Yes	E
Port Philomel	Fish Creek	✓	✓			E
Port Philomel	Ditch from North Lake Sulivan	✓	✓			E, V
Port Philomel	River Doyle	✓	✓			V
Port Richards	Poncho Valley Stream	✓	✓			E
King George Bay	Rous Creek Stream		✓			E, V
Byron Sound	Waterfall Stream		✓		Yes	E
Byron Sound	Dunbar Creek		✓		Yes	E
Port North Pond	Port North Pond		✓			S
River Harbour	Main Point Creek		✓			E
Keppel Sound	Daddy's Ditch		✓		Yes	V
Warrah River	Red Pond	✓				S
Warrah River	Green Hill Stream			✓		E
Many Branch Harbour	Stream by Mt Rosalie House		✓	✓	**Yes****	V
Port Howard	Double stream		✓	✓		E
Port Howard	Ballan Stream		✓	✓		V
Port Howard	House Stream	✓	✓		Yes	E

West Falkland

The location of zebra trout was often well known locally and following advice we found zebra trout populations in several areas that had not previously been surveyed. Excitingly, (to a fish biologist!) the south of West Falkland was a stronghold for the species, with populations in most of the rivers that we sampled (Deans River, Stewart's Brook, Poncho Valley, First and Second Arroyo, Gibraltar Stream, Fish Creek, Edye Creek, River Doyle and the outflow from North Lake Sulivan) and no brown trout. North of Lake Sulivan isolated zebra trout populations highlighted in 1999 were still present but no new populations were found.

Interestingly zebra trout were still present in House Stream, Port Howard, despite the presence of brown trout in all of the nearby watercourses. The incredible population of zebra trout in Red Pond, Port Howard, has also persisted; we caught 84 fish with one sweep net. As detailed in Bob McDowall's book, zebra trout in Red Pond have an unusual morphology and very slow growth due to a combination of the high fish density and lack of food. An outlet of Red Pond is mapped as flowing to the Warrah via Green Hill Stream. Brown trout were abundant in Green Hill Stream and we were interested to find out if they could enter Red Pond. This eastern outlet of Red Pond was less than 30 cm wide, dry in places and heavily overgrown. It therefore seems unlikely that brown trout regularly enter the pond by this route.

However, brown trout can migrate over flooded vegetation and there is a second outlet which was not investigated so they may reach the pond occasionally. Luckily there were no obvious spawning areas for brown trout in Red Pond, the outlet ditches and lake margins being heavily silted. Thus if brown trout do reach the pond they may not reproduce successfully.

North Lake Sulivan and the other rivers flowing into Port Philomel contained zebra trout, while South Lake Sulivan and the Malo River contained brown trout. The two lakes are separated by a narrow dyke. The importance of preserving this dyke to conserve zebra trout around Port Philomel is discussed in section 4.

As noted in 1999, brown trout and zebra trout were rarely found in the same watercourses and in the new sites we sampled to the north of West Falkland we found brown trout and minnows but no new zebra trout populations. Minnows were caught in most of West Falkland that was surveyed by electrofishing or visual methods (the larger mesh size of the sweep net enables small minnows to escape). In just three sites surveyed by these methods we did not catch any minnows. These sites were in higher reaches of two streams and a lower area where exceptionally heavy weed cover made small fish hard to see so that minnows might have been missed (Green Hill Stream, Port Howard).

Brown trout do not seem to have spread south past Dunnose Head on the west coast and Port Edgar on the east coast since the last survey ten years ago (but note the limitations of our survey discussed in section 3.1). At that time they were recorded around Christmas Harbour, leading to King George Bay and in the Malo River which flows into to Port Edgar. The Little Chartres River at the head of Christmas Harbour and the Malo River are well regarded for their sea trout fishing. We surveyed

Leicester Stream, Campbell Creek Stream and Fish Creek which also flow into Port Edgar and might therefore contain brown trout. We targeted clean gravely areas, which we expected to be favoured by spawning brown trout and juveniles. We caught minnows in all of these streams and saw adult zebra trout in the headwaters of Leicester Stream, but we did not see or catch any brown trout. This suggests that if they are present in these catchments their abundance is low. Because of our interest in the interaction between brown trout and zebra trout we walked 4 km of Leicester stream from its tidal limit to Leicester Falls at the new road. There was a rocky dyke towards the top of the stream which would stop fish movement in medium and low water flows but we expect that brown trout could reach the headwaters (where we found zebra trout) in high water flows. Interestingly we only saw zebra trout towards the upper reaches of the stream.

East Falkland

As in West Falkland, the historic distribution of zebra trout was well known locally and we sampled a number of new sites following advice. The new sites around Choiseul Sound that had traditionally held good numbers of zebra trout were now found to be dominated by brown trout. Brown trout appear to have spread throughout Choiseul Sound since 1999 and were also found along the west coast of Lafonia. Good populations of zebra trout were still present towards the south of Lafonia and minnows were caught in all but one of the areas sampled.

Zebra trout had persisted in North West Arm Stream at the tip of Lafonia since 1999. We also found good numbers of zebra trout in Spots Arroyo, tributaries of Halfway House Arroyo and Deep Arroyo. Zebra trout were not found in Halfway House Arroyo or Deep Arroyo in 1999, perhaps due to differences in water level or sampling sites.

In 1999, surveys around the south of Choiseul Sound only found brown trout in Arrow Harbour Stream. A single adult zebra trout was also found in this stream and zebra trout were caught in ditches off Findlay Creek and Ramsgate which flow into Choiseul Sound. We also found zebra trout in ditches to Findlay Creek and Ramsgate but not in Arrow Harbour Stream. However we now found numerous brown trout in the streams off Findlay Creek and Ramsgate. We also heard that people had caught brown trout with zebra trout in their stomachs in the Ramsgate area. We surveyed Teal Creek and Gonzales Arroyo which used to contain zebra trout (Brian Aldridge and Ian Jaffray *pers comm*.), these watercourses now contained abundant brown trout and we did not see or catch any zebra trout. Interestingly good numbers of adult zebra trout were present in the stream to Findlay Creek despite the presence of adult brown trout. Bull Pass Stream also contained good numbers of adult zebra trout, however juvenile numbers had declined since 1999 (we caught two juveniles where 23 were caught in 1999, but this could be because of differences in time of year or sampling technique between surveys).

Visual surveys were carried out on the west coast of Lafonia at New Haven, the Congo Ponds area at Wharton Harbour and the ditches to Findlay Harbour near Wreck House. All of these watercourses contained large brown trout. No zebra trout were seen although the Congo ponds area historically contained zebra trout.

Across the islands a number of small rivers were sampled which appeared to have good conditions for zebra trout but contained only minnows (e.g. Rous Creek Stream at Shallow Harbour, Main Point Stream, and the ditch into Snug Cove at Salthouse, North Arm).

2.2.2. Fish Biology

Both minnow and zebra trout populations were found in areas without regular access to the sea (Red Pond and the headwaters of 2nd Arroyo) and at river mouths. Zebra trout stomach contents were similar to that reported in other studies by students with the Falkland Islands Development Corporation Aquaculture Group. Contents included fish (likely minnows), caddis fly larvae, water beetles and boatmen, amphipods, water snails and terrestrial beetles. Some stomachs contained vegetable matter but this may have been from the cases of caddis fly larvae which were abundant in many of the catchments sampled, particularly in the south of West Falkland. Most of the zebra trout examined were immature, four larger individuals were males with resting or early maturing testes. A number of larger fish were also sexed by eye, without dissection following advice from Dan Fowler, both males and females were found. Juvenile and adult zebra trout often occurred in different areas, probably so that young fish could avoid predation from adults.

One hundred and twenty seven zebra trout were measured during the survey; they ranged from 46 to 286 mm in length and had weights of between 1 and 243 g. Juvenile zebra trout were caught in a number of locations but were most numerous in the outflow from North Lake Sulivan and Fish Creek into Port Philomel, 1st and 2nd Arroyos on Stoney Ridge land, House Stream at Port Howard and Halfway House Arroyo at North Arm.

Juvenile zebra trout.
Photo Peter Nightingale

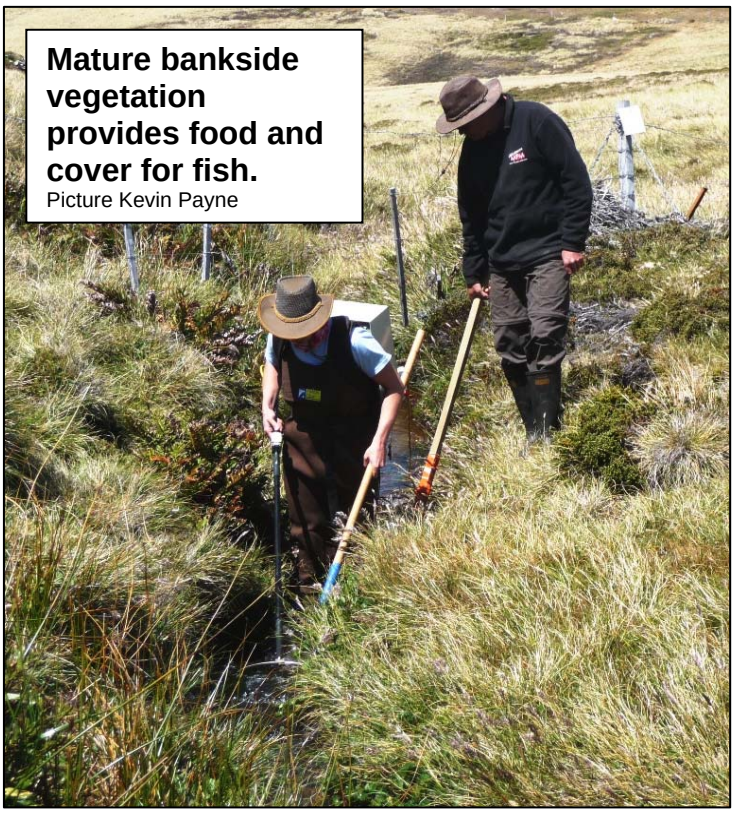
Most of the 333 minnows measured were between 40 and 115 mm long and weighed from less than one gram to 11 g. An exceptionally large female minnow (150 mm, 31 g) was caught in Lake Orisa, South Harbour. Many of the minnows, particularly in West Falkland, were infected with the myxozoan parasite *Myxobolus bartoni*[*1]. The occurrence of this condition was patchy, being prevalent in some areas and totally absent in others others. Small minnows could escape through the mesh of the larger hand net and this should be considered if our data is used in the future. Brown trout were not targeted during this survey but 42 were caught and measured, they were 34 to 279 mm long and weighed up to 258 g. Detailed analysis of fish measurements and habitat use is beyond the scope of this project. However the data we collected has been collated and could be analysed in the future, for example to examine differences in the habitat preferences of adult and juvenile zebra trout.

[*] See Kalavati, C., Brickle, P. and MacKenzie, K., (2000). Two new myxozoan parasites (Myxosporea, Multivalvulida, Bivalvulida) from fishes of the Falkland Islands. *ACTA Parasitolgica,* **45**(4): 285-288.

2.3.3. Habitat

Happily, fresh water habitats were generally in good condition with little pollution or intensive grazing. However we often found man made obstructions in rivers which would prevent or deter fish from migrating to and from the sea.

Good bankside vegetation stabilises river banks and hides fish from predators and strong sunlight. Falling vegetation and insects are also food for fish and invertebrates. Some riverside areas were heavily grazed by sheep and geese but the areas were not large enough to cause concern. Minor pollution included sediment input from roads and small sewage overflows but no pollution of major concern was found at any of the sites sampled.



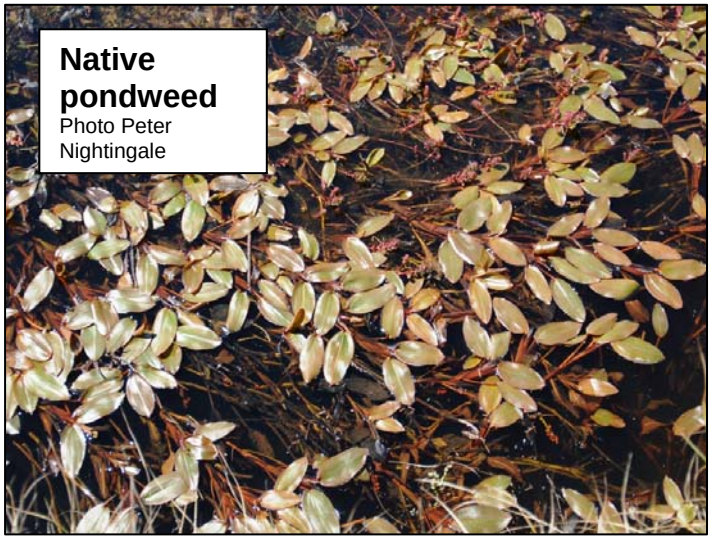
Mature bankside vegetation provides food and cover for fish.
Picture Kevin Payne

We frequently encountered obstacles to fish migration which may impact minnow and zebra trout populations. In one area plastic sacks were trapped against a fence which can block fish movement through smaller ditches. Fish walls were also common, though these were generally open. At many of the sites surveyed water flowed through “perched” road culverts where there was a step up to the culvert on the downstream side. These could have severe impacts on zebra trout and minnow populations because juvenile fish may be trapped below the culverts for long periods (see section 4 for further details).

Weather conditions were dry during both survey periods and so water levels were often low and temperatures ranged from 12 to 19^{o}C. Water pH was only measured in East Falkland and was always close to neutral (7).

Common bankside plants encountered during the surveys included: diddle-dee (*Empetrum rubrum*), white grass *(Cortaderia pilosa*)*,* pig vine (*Gunnera magellanica*), burnet (*Pimpinella saxifraga*), small and tall ferns, and Christmas bush (*Baccharis magellanica*). In West Falkland we also saw occasional sundew (*Drosera uniflora*), faschine (*Chiliotrichum diffusum*), scurvy grass (*Oxalis enneaphylla*), and pale maidens (*Olysnium filifolium*). In Lafonia we saw wild celery (*Apium australe*) and faschine. Rare plants encountered included vanilla daisy (*Leucheria suaveolens*) and Gaudichaud's orchid (*Chloraea gaudichaudii*).

Common aquatic vegetation across the islands included moss, native milfoil (*Myriophyllum quiteuse*), *Lilaeopsis macloviana* and spike rush (Eleochasis melanostachys). In West Falkland we saw native pondweed (Potamogeton linguatus) at a number of locations (it was particularly widespread at the head of South Lake Sulivan) and rare stonewort (*Nitella opaca*) in a pond at the head of Lake Orisa (South Harbour). In Lafonia marsh buttercup (*Ranunculus hydrophilus*) and arrow leaved marsh marigold (*Caltha sagittata*) were common and we saw blinks (*Montia fontane*), tassel weed (*Rappia filifolia*) and Antarctic starwort (*Callitriche antarctica*) in single locations at Orqueta Orroyo, Laguna Isla and Bull's pass stream respectively.



Native pondweed
Photo Peter Nightingale

The birds encountered during the surveys were all common and widespread breeders in the Falkland Islands. This list includes but is not limited to: Long-tailed Meadowlark (*Sturnella loyca falklandica*), Black-throated Finch (*Melanodera melanodera melanodera*), Falklands Pipit (*Anthus correndera grayi*), Two-banded Plover (*Charadrius falklandicus*), Rufous-chested Dotterel (*Charadrius modestus*), Black-chinned Siskin (*Carduelis barbata*), Dark-faced Ground-tyrant (*Muscisaxicola maclovianus maclovianus*), Falklands Thrush (*Turdus falcklandii falcklandii)*, Variable Hawk (*Buteo polyosoma*), Turkey Vultures (*Cathartes aura jota*) , and numerous waterfowl. We did not see any signs of birds predating on freshwater fish during our survey, and were indeed often surprised by the lack of predators given the abundance of juvenile fish and minnows. Mullet were observed feeding in creeks at high tide and we imagine they take minnows and perhaps small zebra trout.

Details of sampling sites, fish and the samples collected have been put in a spreadsheet and copies are available from FIDC and the Environmental Planning

Department. The samples collected and their availability for researchers are detailed in appendix 3.

2.4. Interpreting our results

Excitingly, this project has confirmed the presence of zebra trout in the south of West Falkland, and elsewhere the persistence of populations that were identified in 1999. However the southward spread of brown trout in Lafonia was also apparent and is a grave threat to zebra trout populations there. Zebra trout seem to be long-lived, perhaps living for ten or twenty years. This means that even if the survival of juvenile zebra trout is much reduced by brown trout predation or barriers to migration, remnant adult populations may persist for many years. Eventually, however, as no juvenile fish survive to replace the older ones, the population in a particular area could suddenly become extinct. It seems likely that without intervention brown trout will spread and Falkland zebra trout populations, except those in landlocked ponds, will slowly disappear. Once established in a catchment, brown trout may be impossible to remove without the use of potent chemical poisons. Preventing the spread of brown trout must therefore be a priority. It is also important that we reduce our impact on the remaining zebra trout populations. Much remains to be learned about zebra trout and research is vital if zebra trout are to be properly protected. Important conservation priorities for zebra trout are outlined in the next section and interesting survey results are discussed below.

The continued existence of the House Stream zebra trout population in Port Howard is remarkable because the stream contains clean gravel in which brown trout could spawn and is surrounded by rivers containing large brown trout. The stream is narrow and shallow (less than 1.5 meters wide and 30 cm high when we visited). There were no obvious holding pools for large brown trout in the areas we surveyed (some of the stream is within a mine field preventing a more thorough survey). It may be therefore be that only small brown trout are present in the stream and that these are not able to prey on the zebra trout or push them out of their territories. Zebra trout were also not found in a number of seemingly suitable streams where there were no brown trout. It may be that ocean currents are not suitable in these areas because they would wash larval fish far offshore or prevent small fish from returning to freshwater.

Despite their presence in the Chartres and Malo rivers brown trout do not seem to have proliferated north of Port Edgar or Dunnose Head on West Falkland. It is most likely that this is due to chance, sea trout having yet to stray close to Chaffers Gullet or the entrance to Port Philomel. Their spread may also be slowed by sub-optimal conditions, including silty and compacted spawning gravel and low oxygen levels in ditches during dry summer weather. However, these conditions occur across the islands including areas with brown trout and they will not prevent the eventual spread of this species. The soils of Lafonia are said to be more acidic than elsewhere and acidic freshwater conditions could reduce the survival of brown trout eggs. This is unlikely, except in peaty pools, because waters across Lafonia were close to neutral and brown trout can tolerate conditions up to pH 5. However pH can be easily checked with a handheld pH meter and we suggest that checks are carried out in a selection of rivers south of Fox Bay.

Happily, overgrazing was not a problem at the time of surveying. Should new holding pens be likely to cause overgrazing around rivers with zebra trout, money from the FIG Environmental Studies Budget could be made available for farmers to fence off stretches of important river banks.

This study focused on zebra trout but was an opportunity to collect information on other species. The distribution of minnows does not appear to have been impacted by brown trout but their numbers may have been. This could impact fish and birds which prey on them in freshwater and at sea. Lamprey tend to favour silty areas at river mouths which we did not target during this survey. Future studies might aim to find out more about minnows and lamprey.

Who will champion zebra trout? Zebra trout need urgent assistance. Although brown trout are an invasive species their popularity as a sport fish makes control a contentious issue. As they are a serious threat to the native species and biodiversity of the Falkland Islands it is nonetheless vital that the Falkland Islands Government and conservation bodies initiate practical conservation measures and further studies.

The current bag limit for brown trout is 6 per day with lower limits on some rivers. This supports the conservation of brown trout to the detriment of zebra trout. Fisheries managers and angling clubs may understandably wish to enforce bag limits and fishing seasons to protect their resource. However for areas outside of fisheries we suggest that the rule and publicity about it is reviewed.

3. Education

An aim of this project was to raise awareness about freshwater fish in the Falklands and encourage their conservation. To do this we carried out education events with local schools (Year 5 at Stanley Infant and Junior School, North Arm School, Goose Green School and with children across West Falkland), including trips to watch electrofishing and sweep netting, a visit to the aquaculture facility at Moody Brook and a classroom based presentation on fish life-cycles. Forty six children were involved in total. A poster competition was also held where children were asked to produce posters about zebra trout. Educational material (a PowerPoint presentation and quiz) was also produced and distributed to all of the primary schools and travelling teachers. These were well received and we are very grateful for the support and encouragement of teachers and pupils.

Searching for water bugs with children from North Arm School.

To reach adults, articles were written for the Penguin News, the Falklands Conservation Newsletter and radio interviews were carried out. A Zebra Trout Fact Sheet was also produced for the websites of Falklands Conservation and the Environmental Planning Department. It is hoped that the survey data will also be collated with previous survey results for publication in an appropriate scientific journal.

4. Conservation priorities

Some conservation priorities are detailed below, many were also put forward by the team of New Zealand scientists in 1999 but remain pertinent today. They are based on our survey results, time constraints having prevented wider consultation. It is recommended that the other groups, including farmers, anglers and other parties that receive revenue through trout fishing are also consulted.

Eradicating brown trout to restore zebra trout populations across the islands is not currently a conservation option. In fact, even removing brown trout from a single river system would be difficult and likely unpopular. Instead conservation must concentrate on protecting remaining zebra trout populations as quickly as possible.

a. Education and advice

Conservation measures work best where they are well supported by the public. There are many ways in which people can help to protect zebra trout, for example anglers can carefully release zebra caught inadvertently, farmers can protect zebra trout streams from pollution and overgrazing and engineers may minimise the impact of new roads on rivers that contain zebra trout. An understanding of the life-cycle of zebra trout and why zebra trout are important to the Falklands may help and encourage people to carry out such conservation measures. Similarly information from the public would help, for example if new populations are found, spawning areas are discovered or the spread of brown trout is noted. Anglers often have a good knowledge of local freshwater life and can provide very helpful information and advice.

- **High Priority. Discouraging movement of brown trout**. It is vital that the movement of brown trout is discouraged and that no brown trout are moved to areas where they are not currently found, including islands.

- **Education.** We would suggest that the Environmental Planning Department, perhaps in conjunction with Falklands Conservation, organises annual education events or Penguin News articles on zebra trout and encourages a flow of useful information to and from the public. Farmers in areas with good zebra trout populations should be regularly consulted and farm-led conservation projects might also be supported by funds from the Environmental Studies Budget.

b. Research and monitoring

i. Zebra trout and brown trout biology and ecology

Effective conservation programmes will only be possible if further information is collected on the biology and ecology of zebra trout. For example do larval fish go to sea? Do fish return to their natal rivers? What does a healthy zebra trout population look like? Do fish all spawn at the same time? Do brown trout feed on zebra trout eggs? Have brown trout completely removed zebra trout from catchments or pushed them to marginal habitats in the headwaters and tributaries of streams?

- **Very High Priority. Catchment-scale studies.** Monitoring of whole catchments over a number of years is important to answer many of these questions. Such studies are labour intensive and would make a good PhD project for a self motivated student with a track record of experience in freshwater ecology (because there is not a local freshwater research group for day to day advice).

- **High Priority. Ageing studies.** A number of otoliths have been read but validation of aging, perhaps using fish in the Moody Brook hatchery should be carried out and the otoliths from larger fish should be read to give an idea of the lifespan and growth rates of zebra trout in the Falklands.

- **High Priority. Genetic studies.** If it is confirmed that zebra trout go to sea, genetics studies could give important information on the interaction between zebra trout populations in nearby rivers and around the islands (i.e. are they interbreeding). This would tell us whether it is possible to conserve single river systems or whether whole groups of rivers must be conserved at one time.

- **Brown trout ecology.** Much is known about brown trout but details such as the age at which fish go to sea and when and where fish spawn vary geographically and are not known for the Falklands. Further information on the biology and ecology of brown trout in the Falklands is important for if we are to stop this species from spreading. The timing and location of spawning and spawning success is of particular interest.

ii. Monitoring

Long-term monitoring of zebra trout populations is important because it will enable us to separate the impacts of brown trout, pollution and barriers, from changes due to larger scale environmental factors such as climate change.

- **High Priority. Long-term monitoring schemes.** Ideally a number of large, fixed sites would be marked and fished annually to see how the density and age of fish changed with time. The exact location and timing of sampling would be determined following studies on fish distribution within catchments, but is important that juvenile fish areas are included. From our survey, suitable catchments could include Deep Arroyo, Halfway House Arroyo, ditches to East Bay, 1st or 2nd Arroyo, Gibraltar stream, Deans River and Stewarts Brook.

Other monitoring should investigate particular impacts; this monitoring is shorter term but more detailed.

- **High Priority. The impact of culverts.** Most urgently we need to know if culverts are removing juvenile fish from catchments.

- **High Priority. The impact of brown trout.** Monitoring changes in the number and age of zebra trout in areas with brown trout (around Choiseul Sound) and the spread of brown trout would also give us helpful background information for conservation measures but should not be carried out at the expense of practical conservation actions. Areas into which brown trout seem likely to spread soon include the Walker Creek side of Adventure Sound (e.g. Brazo la Mar) and North West Arm in North Arm.

iii. Protection and control

- **Very High Priority.** **Practical protection measures.** Applied research into the protection of zebra trout and the control of brown trout is urgently required and might also be carried out as part of a PhD project. Methods would probably include placing grids at the mouths of important rivers (perhaps where they have culverts) to keep sea trout out. These would need regular maintenance to prevent flooding. Juvenile zebra trout may return to rivers in a certain bay (e.g. Port Philomel or Adventure Sound) rather than the river in which they were spawned. This could be determined by genetic studies. In the absence of genetic information, it would be prudent to protect a number of rivers in a particular area. Removing spawning adult brown trout by electrofishing and perhaps increasing angling in some may also be possible. To be effective, control measures must be supported by good biological research and monitoring. Brown trout have been introduced across the Southern Hemisphere with commonly devastating impacts on native fish; this type of research is therefore an exciting opportunity for international collaboration.

c. Culverts and fish walls

A new island wide road network has linked farms on East and West Falkland. This has involved culverting rivers and ditches often close to where they enter the sea. The culverts are frequently laid on rock filled gabion baskets to prevent erosion underneath. This creates a number of problems for fish that migrate to and from the sea.

A perched culvert at low tide.

The most obvious problem is that small fish returning to freshwater cannot jump up or through the culverts and are trapped below them for long periods. Trapped fish are vulnerable to predation from fish including mullet, and birds and may not be able to feed. Conversely, when water levels are high, water often flows at such velocity down the culvert that small fish cannot make their way upstream (this is why baffles are often installed to allow salmon through culverts and bridges). Finally, water often seeps below the culverts. The rockfilled basket can then act as a sieve, filtering out and injuring larval fish as they are washed down stream to the sea.

Perched culverts are therefore likely to have dramatic impacts on minnow and zebra trout populations if zebra trout are confirmed to migrate to sea. This was not made clear to road builders and small culverts have understandably been used across the islands because they are an economic way of crossing water courses. Unfortunately the road-building programme is largely complete and replacing the culverts would be expensive.

The table in section 2.3.1. lists nine culverts that may cause a problem for fish migration; two of these were on tracks rather than the road. We would suggest that these are examined under a range of water flows and, where appropriate, tidal conditions to see if they are a problem for fish passage. Fish passage problems can be avoided by bridging ditches or by using large culverts which are well dug into the stream or ditch bed, maintaining the natural gradient and substrate of the watercourse. More technical information and details on fish passage are given in, Engineering in the Water Environment A Good Practice Guide: Construction of River Crossings (Scottish Environmental Protection Agency Document WAT-SG-25, 2008) which is available for download or from the Environmental Planning Department. It was written for salmon and trout but considerations are similar for zebra trout. On the positive side, culverts are often ideally placed for gridding off river mouths to prevent sea trout from entering new areas.

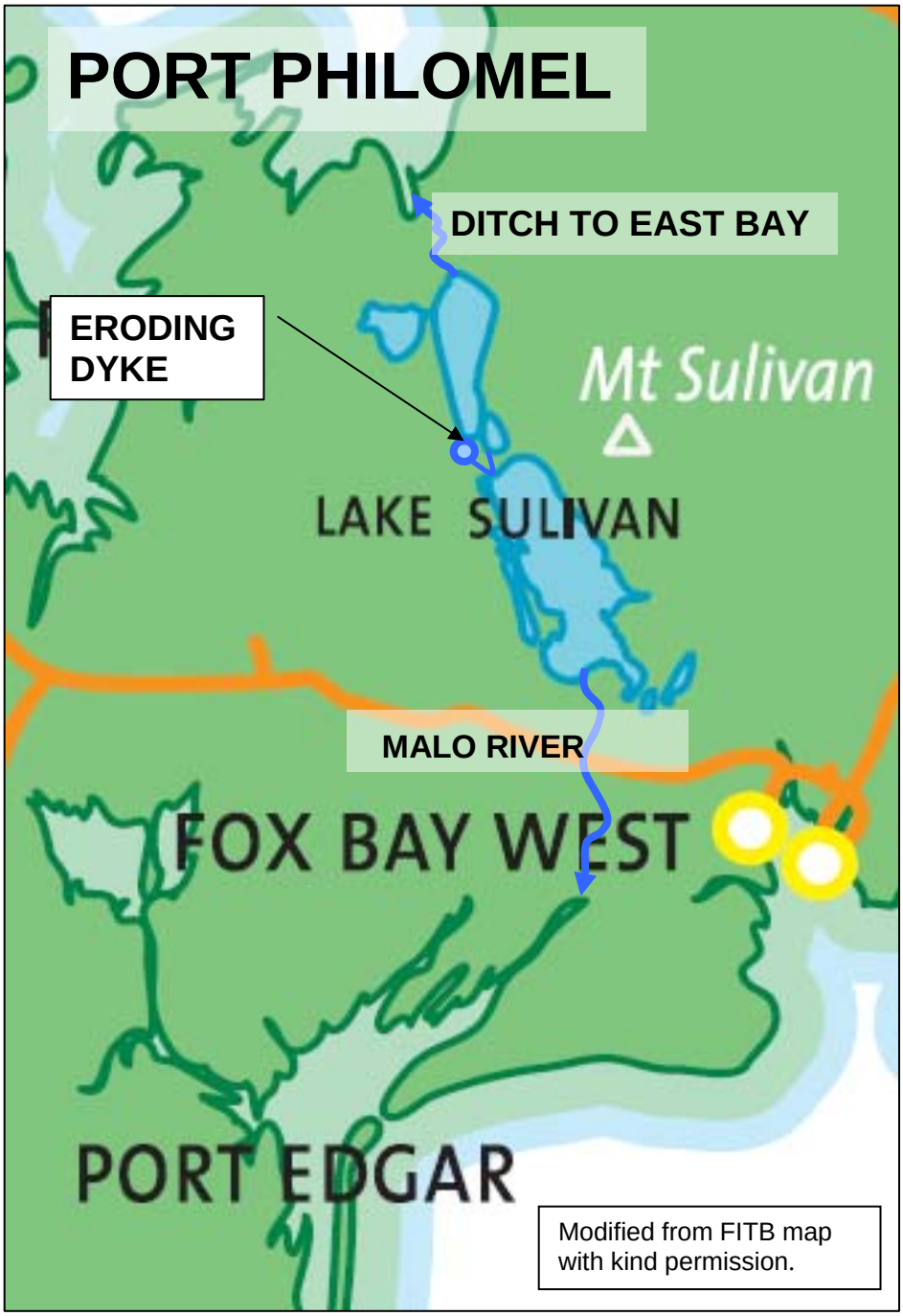
- **High Priority. Work with FIG Road Engineer.** A list of sensitive water courses will be provided to the FIG Road Engineer so that this type of construction can be considered if culverts are replaced during ongoing road maintenance. Should further studies find that zebra trout populations are seriously impacted, replacing the culverts or improving fish passage through them should be considered.

- **Guidance for new roads.** If new roads are planned to cross watercourses with zebra trout or unsurveyed areas of Lafonia or West Falkland, south of Lake Sulivan, care should be taken to protect zebra trout, including protecting their habitat (i.e. minimising in stream work) and ensuring means of safe passage to the sea. Where watercourses are not surveyed, someone from the Falkland Islands Development Corporation, Aquaculture Project may be able to electrofish the area to see if zebra trout are present. Zebra trout could also be temporarily moved away from construction areas by electrofishing if this is necessary. This aquaculture project will probably finish by 2010 and it is important that an electrofishing team remains available on the Falklands.

- **Fish walls.** Fish walls were common across the islands. Where they block rivers with zebra trout it is important that they are properly opened when not in use so that juvenile zebra trout do not become stranded and die.

d. The Sulivan Lakes

The Sulivan Lakes drain to opposite coasts of West Falkland but are separated at their headwaters by less than 20 meters of low-lying land. South Lake Sulivan contains brown trout while North Lake Sulivan supports large numbers of zebra trout and is therefore a stronghold for the species. The importance of protecting North Lake Sulivan from brown trout invasion is discussed below with a number of suggestions for zebra trout conservation.



Schematic diagram of the Sulivan Lakes (South and North Lake Sulivan are collectively referred to as Lake Sulivan) showing how they drain to opposite coasts of West Falkland.

Trout in the Sulivan Lakes

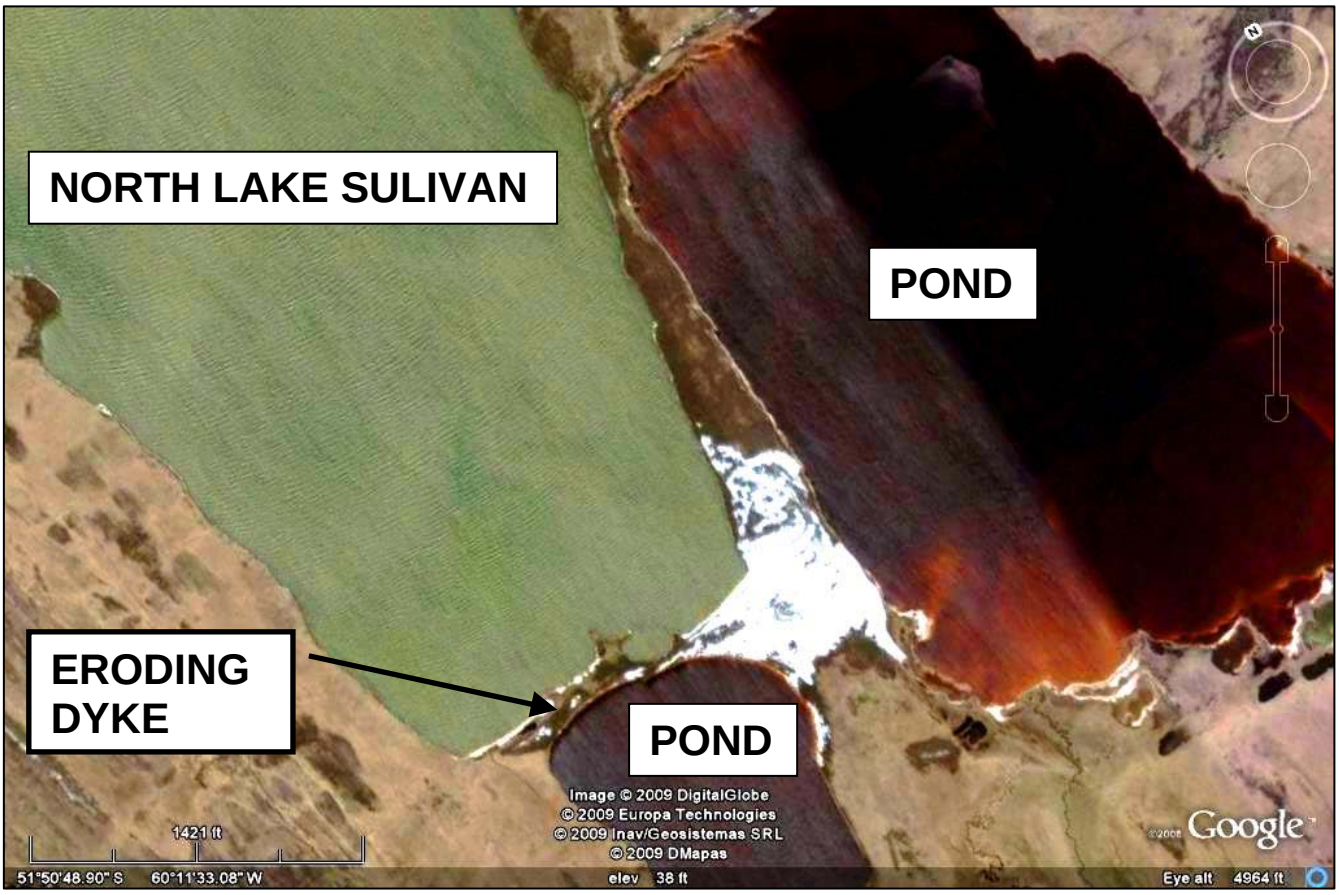
Brown trout were introduced into the Malo River in the 1950s. Today anglers catch migratory brown trout (sea trout) in the estuary of this river which drains South Lake Sulivan into Port Edgar. Brown trout are reported locally to spawn in the ditches around South Lake Sulivan and in 1999 McDowall and his team caught only brown trout and minnows in that lake. In North Lake Sulivan, its tributaries, the ditches by East Bay House, and the nearby River Doyle, however, Bob McDowall found only zebra trout and minnows. Both North Lake Sulivan and the River Doyle drain north through East Bay or Whitsand Bay into Port Philomel.

Almost ten years after McDowall's surveys our results followed the same pattern. We found only brown trout and minnows in the tributaries of South Lake Sulivan and exceptionally high numbers of juvenile zebra trout in the ditch draining North Lake Sulivan, near where it enters the sea. We also found good numbers of zebra trout and no brown trout in other rivers entering Port Philomel, namely, Edye Creek, the River Doyle and Fish Creek. Indeed, the enclosed bay of Port Philomel may be an ideal nursery ground for larval zebra trout if it protects them from being lost to the open ocean.

Rikki Evans and Serena Sinclair recall zebra trout congregating in September in ditches that drain the West Lake Sulivan catchment, a few hundred meters from the sea. Ali Marsh also remembers fishing these ditches in September and that at that time of year, zebra trout eggs were found in the ditches. It seems likely that zebra trout congregate to spawn in the ditches entering Port Philomel in September. These ditches had dry stretches when we visited, but if water levels are high adult zebra trout may migrate to and from deeper water including North Lake Sulivan.

The dyke separating the Sulivan Catchments

At the head of South Lake Sulivan are a series of unnamed ponds connected to the lake by small ditches. We found juvenile and adult brown trout in these tributaries and it is likely that they are also present in the ponds (this could be confirmed by setting fyke nets in the ponds). Two of the ponds are separated from North Lake Sulivan by narrow dykes. Bob McDowall's team and the owners of Lake Sulivan and Rincon Ridge Farms explained how one of these dykes is very narrow and could be breached if the lake floods. This would enable brown trout to enter North Lake Sulivan and then Port Philomel. We therefore examined the dykes during this study.



Arial view of North Lake Sulivan and the ponds which drain into South Lake Sulivan, the eroding sandy dyke is clearly visible.

The dyke separating North Lake Sulivan and the easterly pond is substantial being about 25 m wide and approximately 1 m high, with no signs of rapid erosion. It seems unlikely to be breached in the near future. However, the dyke between the smaller, most westerly pond and North Lake Sulivan is narrow, low and eroded. The whole dyke is 360 m long and is composed of sand with some diddle-dee bushes and whitegrass. The maximum height of this sandy dyke is 1 m and during our visit its narrowest stretch was only 16 m wide. Dyke widths are not available from previous surveys and so we are unsure if or how quickly the dyke is eroding. However, the sand underlying the dyke looks unstable and appears vulnerable to being breached if high water levels occur at the same time as strong winds.

View of the dyke looking west. High water had left debris in line with the net at the right of this picture.

As the rivers entering Port Philomel support significant zebra trout populations, most importantly those inhabiting the North Lake Sulivan catchment, preventing brown trout from entering North Lake Sulivan must be a priority for the conservation of zebra trout in the Falkland Islands.

When deciding how best to protect North Lake Sulivan, it must be considered that brown trout could also enter Port Philomel from the sea and colonise its rivers and lakes. However, the distribution of brown trout in our survey was similar to that found by Bob McDowall ten years previously suggesting that in this area, brown trout are not spreading rapidly. Securing the dyke between the lakes thus remains an important conservation priority for zebra trout.

Conservation priorities for zebra trout around Port Philomel

- **Ongoing monitoring.**

To assist with plans for securing the dyke fixed transects should be set up to repeatedly measure the width and rate of erosion. Because water levels are variable we measured between the maximum vegetated extent of each bank.

- **High Priority. Engineering.**

Farm owners (Rodger and Norma Edwards of Lake Sulivan, Rikki Evans and Serena Sinclair of East Bay, and Leon and Helen Marsh of Rincon Ridge) and people with other relevant expertise (perhaps including the Zebra Trout Steering Group and an engineer) should be consulted by the Environmental Planning Department to determine a reliable and acceptable method of preventing the dyke from being breached. Low cost and low impact methods might include fencing each side of the dyke to keep sheep out (except when they need to move between camps) and thus encourage vegetation to grow and bind the sand, drift fences which trap sand, or careful planting with native vegetation such as blue grass. More invasive and costly measures could include rock armouring or re-engineering the drainage of the top ponds to South Lake Sulivan to lower the water level in the pond behind the dyke. It is very important that that all workers (particularly plant operators) are aware that water or wet soil must not be transferred from one catchment to another (fish eggs could be transferred with sodden earth). I cannot over emphasise this point having

often attended incidents where those working on the ground have not been properly briefed and large numbers of fish have been killed.

Monitoring may be required following works to ensure that the dyke remains water tight.

Methods of stabilising the dyke should be discussed and implemented urgently. Discussions could be mediated by the Environmental Planning Department who might also research possible methods of stabilisation such as methods used to stabilise coastal sand dunes, and look for funding (perhaps from the Environmental Studies Budget). The cost of stabilising the dyke is variable. If a low impact solution is favoured, costs would be low and might be reduced by help from volunteers.

- **High Priority. Protecting the Rivers of Port Philomel from invasion by migratory brown trout (sea trout).**

Methods of protecting rivers from invasion have not yet been investigated. Difficult vehicle access and a lack of permanent residents make protecting the North Lake Sulivan and Doyle River catchments more difficult than others. However, the healthy juvenile numbers in the ditch from North Lake Sulivan make it particularly important. This is even more the case if money is spent on stabilising the dyke. Ideally, methods of protecting the rivers of Port Philomel should be investigated as works are carried out on the dyke.

- **Culverts.**

The ditch running into Edye Creek has a culvert at its mouth with a shelf at its entrance which is dry under medium and low water flows. The culvert should be examined under a range of tides to see if it is regularly passable for small fish - it may be passable when water flows are high or high spring tides occur. Should the culvert be in need of repair or replacement it should be set flush, or preferably embedded in the ditch bottom to enable free migration of zebra trout.

Acknowledgements

This work would not have been possible without the hard work of Falklands Conservation Volunteers Carrissa Turner, Kevin Payne, Claudia Michler and Fiona Cunningham. Also thanks to Pia Schuchert and Peter Nightingale. We were very grateful for the kindness of people in camp and their advice on sampling sites including Peter and Ann Robertson, Jennifer and James McGhie, Mandy and Tex Alazia, Helen and Leon Marsh, Rodger Edwards, Justin Knight, Serena Sinclair and Rikki Evans, Ali and Marlane Marsh, Hugues Delingnieres and Marie-Paul Guillamont, Shelly Nightingale, Myles Lee, Eileen and Ian Jaffray, Bruce Campbell, Paul Ford and Brian Aldridge. Thank you also to Bob McDowall and Richard Allibone for scientific advice and Alex Blake for producing maps.

Appendix 1. Fish Survey Methods

A variety of survey methods were employed depending on the watercourse, vehicle access, fish density and time available for sampling.

Where time or vehicle access was limited or fish densities were low, visual surveys were carried out. Three or four observers walked a stretch of watercourse and recorded the number and type of fish seen, polarising sunglasses helped us to see fish clearly for identification. This type of survey was most successful on calm days when the surface of the water was undisturbed. Zebra trout tend to move more slowly and are bolder than brown trout. Visual surveys were therefore most effective in detecting adult zebra trout.

Electrofishing surveys were carried out where ever possible. These enabled us to identify the species and numbers of fish present in an area. In most cases a net was set at the upstream end of the site to prevent fish from leaving the area. Usually two people fished with a hand net each. The electrofisher used a small dipnet with a mesh size of 1 mm and the second fisher had a larger net with a mesh size of 10 to 13 mm. Because of their abundance, minnows were usually collected only for the first five minutes of electrofishing. In large waterbodies three people were in the water, the additional fisher using a large handnet with a mesh size of 10 to 13 mm. Backpack electrofishing equipment (Electracatch ELBP 2) was used to stun fish with a potential difference of 120 to 150 V. To preserve battery power while minimizing injury to fish a pulsed current with a pulse width of 30 and a frequency of 30 Hz was used. The time and area over which electrofishing was carried out was recorded so that catches per unit effort could be calculated for future studies (but note the variability in our survey results as discussed in section 2).

Fish were collected and weighed to the nearest gram, their fork length was measured, fin clips were taken and then the fish were released unless otoliths were collected. When otoliths were collected fish stomach contents and gonads were also examined. Gonads of stage 3 and above were preserved for reference. Because they might be useful in the future, invertebrate samples were also collected by kick-sampling for five minutes (where the river bottom is kicked and suspended invertebrates are caught in a net downstream). To save time not all invertebrates were picked out of the kick sample for each site but we endeavoured to preserve a representative sample. Most invertebrate samples were stored in 96 % ethanol (so that they could be used for genetic studies) but where soft bodied organisms were common formalin was used. Unusual waterfowl or plants were noted.

A sweep net was used to sample fish in ponds. The net was 25 m long and 1 m high with a mesh size of 20 mm. The number of sweeps carried out was recorded. Towards the end of the project a fyke net was purchased, this was tried in a number of ditches.

At each sampling site a brief site description was recorded and photographs were taken looking up and down stream and across the site, to describe freshwater habitats the landuse and terrain. Habitats and sampling were also recorded in more detail including; number of people fishing, potential obstructions to fish movement, grazing pressure, sea access, water depth and the type of flow, substrate and a brief

description of in-stream and riparian (river bank) vegetation. Water temperature and conductivity was also recorded using an YSI Model 85 handheld meter. Dissolved oxygen levels and pH were measured where possible.

Appendix 2. Anecdotal information on zebra trout

West Falkland

Ali Marsh saw zebra trout eggs in the ditches in East Bay in September (some years ago!). Eggs were along the bottom of the stream. (Eggs spawned in the moody brook hatchery in 2008 were very sticky and therefore I imagine eggs stick to vegetation or the bottom of the streams and ditches in which they are deposited.)

Rikki Evans and Serena Sinclair mentioned that in recent years there are lots of zebra trout in the East Bay ditches in September. Marlane Marsh said they always used to go fishing for zebra trout in the East Bay ditches on the 25th of September.

Marlane Marsh's Grandad, Chris Parry, worked with the doctor and she remembers him saying that when they were on the doctors rounds they would introduce trout (zebra and perhaps brown) in ponds and ditches across the West.

Ali Marsh used to catch zebra trout in the Green Hill and Saddle ditches (South of Mt Robinson, Flowing into the Chartres rivers) before the brown trout arrived. Ali and Marlane think that brown trout have been found in Rous Creek but are not sure.

Leon Marsh and Peter Nightingale mentioned people catching brown trout with zebra trout in their stomachs but I am not sure who the anglers were or where this happened.

Fraser McKay (Teal inlet) and Deanie Luxton at Hill Cove say that there used to be zebra trout in Teal Inlet and beyond but they have not been there since the brown trout arrived.

Roy McGhie said that the Port North pond contains large fish which he has seen breaking the surface when the water levels are very low but he is not sure what they are.

Mike Evans at South Harbour says there are strange fish in the creek by the house, not minnows?

Brian Aldridge recalls that there used to be zebra trout around Hill Cove and Coast Ridge.

Peter Robertson's grandchildren saw lots of juvenile zebra trout in the salt water area of Fegen inlet in the middle of January 2009 (the water was "boiling" with them). (This is interesting because there are no major Zebra Trout streams here although we saw one probable zebra trout in Whisky Creek and just up the coast are zebra trout strongholds).

East Falkland

Ian Jaffray reports that there used to be zebra trout in the ditches around Walker Creek including Miles Creek and Walker Creek, also on the south side in Braz La Mar

also on the Falkland Sound side of Lafonia around Egg Harbour and Congo Ponds. Brian Aldridge also recalls that ten years ago there were lots of zebra trout in the Walker Creek ditches mentioned by Ian, particularly Braz La Mar, he also knew of them in the Low House area (Walker Creek) and also in Teal Creek Arroyo, Bluff Creek area and Laguna Isla.

In Goose Green people recall zebra trout being present in the Cobb's Pass area and have caught large sea trout with adult zebra trout in their stomachs.

Neil McKay remembers catching zebra trout in Hope Stream and Deep Arrojo.

Possible zebra trout sites not investigated in 2008 – 2009

Fraser McKay (Teal inlet) thinks Shingly pond (on top of Shingly Mountain, West Falkland) contains large numbers of zebra trout.

Sally and Dion Poncet have seen juvenile zebra trout in small ditches on Beaver Island.

A possible sighting of zebra trout in the ditches in No Man's Land, East Falkland.

Brain Aldridge and Ian Jaffray recall that Braz la Mar, Walker Creek supported good numbers of zebra trout historically.

Appendix 3. Samples

The table below details the samples collected during this project and their availability for further research.

Sample	Number	Description	Purpose	Availability
Zebra trout fin clips	53	Up to 7 fin clips taken at a range of site. Adipose or tail fin preserved in 96 % ethanol.	For possible genetic analysis to determine population sizes and mixing of fish from different rivers.	Available
Zebra trout otoliths, juvenile fish.	10	Small fish otoliths (ear bones).	For chemical analysis to determine if zebra trout go to sea as larvae.	Sent to Bob McDowall for analysis.
Zebra trout otoliths.	24	Otoliths from fish length 70 to 248 mm. Stored in 96 % ethanol.	To assess the age and growth of zebra trout, and possible chemical analysis.	Available
Zebra trout gonads.	4	Males stage 2 and 3, preserved in formalin.	For reference.	To be kept for reference.
Zebra trout from red pond.	1	Preserved in formalin.	For reference.	Held at fisheries.
Minnow from Lake Orisa.	1	Preserved in formalin. Large female (150 mm)	To check id. For reference.	Held at fisheries.
Zebra trout stomach contents.	6	Preserved in formalin or ethanol.	To look for fish otoliths.	Available.
Brown trout scales	14	Scales kept dry in scale packets.	For age length studies.	Available.
Freshwater invertebrate samples.	24	Representative sample preserved in ethanol or formalin.	For future invertebrate studies.	Available.
Minnows	2	Sets of 30 minnows in 96% ethanol.	For genetic studies.	For Mike Hickford, New Zealand.
Photographs	-	All sample sites photographed.	To show habitat and for future reference.	Available.

Appendix 4

Draft Full Species Action Plan for Zebra Trout *Aplochiton zebra*

1. Current Status

1.1. Zebra trout is a fairly widespread species in the Falkland Islands, inhabiting fresh water, brackish and marine environments (i.e. it is amphidromous). It has a wider distribution in southern South America being found as far north as 45°S and as far south as Tierra del Fuego.

1.2. More detailed species information can be obtained from Fish Base.

1.3. It has declined in the Falkland Islands in recent years, and may still be doing so (see below). A preliminary survey in 1999 of a large number of fresh water systems showed that the main areas where the species persists are Lafonia, around Lake Sulivan (especially Lake North Sulivan) and scattered throughout other areas of East and West Falkland. The survey report (McDowall 1999) gives further details including an indicative distribution map. A recent study found that zebra trout populations identified by McDowall persist and that the south of West Falkland is a stronghold for the species. However brown trout are spreading in Lafonia and zebra trout are severly threatened there (Ross 2009).

2. Current factors causing loss or decline

2.1. The principal factor causing loss and decline of this species is competition from introduced brown trout (*Salmo trutta*). Where the two species co-occur, brown trout will displace zebra trout. There are a number of isolated refugia for zebra trout (land-locked ponds) which will perhaps prevent extinction of this species.

2.2. Zebra trout are caught inadvertently by anglers and netsmen, but the impact on the species status is unlikely to be more than localised.

2.3. The new road network has impacted at least 9 zebra trout catchments with perched culverts blocking free access to and from the sea. This is likely to have a severe impact on local zebra trout populations and may cause local extinction (more details are given in the survey report, Ross 2009).

2.4. Pollution of fresh water streams is an incidental hazard but is not widespread and most streams and ponds are in as a near-natural state as they can be.

3. Current conservation related action

3.1. Zebra trout are specially protected under the Conservation of Wildlife & Nature Ordinance (1999) and cannot be taken deliberately unless under licence.

3.2. Surveys were carried out in 1999 and 2008-2009 to establish presence of fish in fresh water systems (McDowall 1999, Ross 2009).

4. Action Plan objectives and indicative targets

4.1. To maintain zebra trout as a component of the Falkland Island fresh water fish fauna.

4.2. To prevent further loss of zebra trout populations in the Falkland Islands (i.e. to halt the decline in distribution).

5. Proposed actions and lead organisation

5.1. Policy and legislative needs

5.1.1. Consider legislation to prevent the *deliberate* translocation of brown trout [EPD, AGC].

5.2. Site safeguard and management

5.2.1. To consider designation of key fresh water systems as Ramsar sites &/or Nature Reserves to protect important zebra trout populations [EPD, FC].

5.2.2. To manage such Ramsar sites & nature reserves to benefit zebra trout [EPD, FC].

5.3. Species management and protection

5.3.1. To maintain a number of isolated 'refugia' for zebra trout[2] [EPD, FC].

5.3.2. To urgently consider installation of a number of barriers to brown trout invasion at important sites identified as possible refugia - but see foot-note [[1]] below [EPD, FC]. To consider removing brown trout by electrofishing if they are found in zebra trout strongholds.

5.3.3. To prevent deliberate releases of brown trout into catchments and fresh water systems with zebra trout [EPD].

5.3.4. To stabilise the dyke between north and south Lake Sulivan.

5.3.5. To provide new guidelines for construction of river crossings in areas with zebra trout.

5.4. Advisory work with business

5.4.1. To liaise with angling bodies and anglers to implement this action plan, especially actions designed to limit the threat from diadromous (i.e. sea going phase) of brown trout [EPD, FC].

5.5. Research, survey and monitoring

5.5.1. To implement a monitoring scheme to determine the continued presence of zebra trout in key localities and the absence of brown trout [EPD, FC]. Monitoring needs to be annual if brown trout are to be removed from an area before they become established,

5.5.2. To sample opportunistically waters not surveyed before for presence of zebra trout and brown trout and to maintain a database of records of presence for all fresh water fish species, native and introduced [EPD, FC].

5.5.3. To undertake research on growth, age, reproduction and other aspects of the biology of this species in the Falkland Islands [EPD, FC, Fisheries Department?]

[2] Note that this would not protect the component of the population that has a marine phase, and would therefore be protecting only a fraction of the species' genetic and behavioural diversity.

5.6. Education, awareness and understanding

5.6.1. To raise awareness of the significance of zebra trout and threats to the species from brown trout [EPD, FC].

5.6.2. To produce a simple leaflet showing species identification and explaining conservation needs for anglers and others [EPD, FIT, FC]. Zebra trout fact sheet produced written and given to FC with pictures to put on website, should be available on FC and EPD website. Articles put in penguin news and FC newsletter and presentation given to all primary schools.

6. Links with other SAPs and HAPs

6.1. None.

7. Links with other initiatives

7.1. None.

8. Costs and timing

8.1. 5.1, 5.4 No cost.

8.2. 5.2 £10k [**high** priority].

8.3. 5.3 £>10k [**urgent** priority].

8.4. 5.5.1 £10k annually [**urgent**].

8.5. 5.5.2 £5k [**medium** priority].

8.6. 5.5.3 £> 10k [**urgent** priority].

8.7. 5.6 £500 annually [**high** priority].

9. Key references

McDowall, R. M. (1999) Conserving and Managing Falkland Island Freshwater Fishes. *The Falkland Islands Journal* 2001 **7(5)** *[This is reproduced on the Falklands Conservation web site]*.

Ross K (2009) Freshwater fish in the Falklands. Conservation of native zebra trout. *A report for the Falkland Islands Government and Falklands Conservation.*

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