Assessment of the Impacts of Hydro-electric Dams on Eel Stocks in Tasmania and an Evaluation and Assessment of Mitigation Strategies

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2. NON TECHNICAL SUMMARY

2000/186	**Assessment of the impacts of hydro-electric dams on eel stocks in Tasmania and an evaluation and assessment of mitigation strategies.**

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OBJECTIVES:

1. Assess the impacts of hydro-electric dams on upstream eel migration and population structure in Tasmania's lakes and rivers and assess the impact of past elver restocking practises in hydro-impounded catchments on eel populations within those catchments.

2. Assess the direct impacts hydro-electric dams and their associated operations (turbine intakes and water management practises) have on adult 'silver' eel survival rates during their downstream spawning migration.

3. Evaluate various management tools (ladders / bypasses and passage; netting/trapping and translocation) to mitigate impacts and provide recommendations for implementation.

4. To review the management of barriers to eel migration, including overseas experience.

5. SUMMARY:

OUTCOMES ACHIEVED TO DATE

Major outcomes include the positive affirmation of past elver transfer practises in assisting upstream passage. Results gathered support the suggestion that past elver transfer practises have been effective in enhancing upstream populations. The continuation of manual elver transfers will contribute to the future sustainability of upstream eel populations and will play a major role in future eel management plans. Given that selective manual recruitment is an effective means of mitigation for upstream passage, the commercial eel industry will ultimately benefit from the ability to significantly enhance and maintain populations.

The issue of poor downstream migration resulted in a heightened degree of awareness regarding the risk of injury or mortality faced by migrants on their journey downstream. The knowledge of migrating strategies and the current status of the degree of success is critical. Firstly however, there is a requirement for site-specific research investigating the various responsive behavioural patterns of downstream migrating eels. These responses need to be observed against a variety of mitigation options at prioritised sites.

It is not possible to develop a single broad-range solution to aid eel migration for hydro-electric dams in Tasmania. Each dam has its own specific characteristics, which need to be thoroughly assessed before deciding what course of action should be taken to ensure effective eel migration upstream and downstream. For example, upstream mitigation requirements are going to differ significantly for an 80 m dam where only manual transfers are suitable as opposed to a 30 m dam where an elver ladder may apply.

The presence of hydro-electric dams and their effects on eel migration and populations were investigated to further the understanding of measures required to improve the management of native eel stocks. In addition, an investigation on the effectiveness of past elver restocking practises was also undertaken. This study seeks to determine whether or not upstream populations have been successfully sustained through manual restocking. An improved understanding of barriers preventing upstream migration and the effects power stations have on downstream migration is

necessary for future management of eel stocks. This investigation attempts to make preliminary observations regarding the safe movement of sexually mature migrants and to evaluate and recommend necessary means of downstream assistance. There is a substantial base of literature associated with mitigation strategies specific to upstream and downstream eel migration. This investigation seeks to evaluate and recommend such strategies for the future management of the Tasmanian eel fishery and hydro-electric systems.

In Tasmania, elver harvests (netting and trapping) below hydro-electric structures (ie. Meadowbank Dam on the Derwent River and the Trevallyn Tailrace on the Tamar River) were initiated in the mid 1970's by the Inland Fisheries Commission to reduce elver mortalities and, through restocking programs, manually recruit elvers into the upper reaches of these river catchments. While this practise continues today, with a dependency on restocking by the commercial fishing sector, no assessment has been made of the effectiveness of restocking in sustaining eel populations above migration barriers.

Results gathered throughout the project were separated into two major components. Upstream migration and downstream migration. Sampling performed provided age population structure information for the three types of catchment categories sampled in two major river systems in Tasmania;

1) Not dammed and not stocked (river);
2) Stocked and dammed (above dam) and;
3) Dammed and not stocked.

Age structure was compared with results indicating the effectiveness of past elver transfer practises, however, assessment of the impacts of dams on upstream eel stocks proved difficult due to the age of the dams in relation to the eels life span.

Catch Per Unit Effort (CPUE) results, however, highlighted differences in the abundance of populations between dammed and stocked water bodies immediately above the selected power stations. Stocked waters upstream of power stations produced less eels than waters below the power station where natural recruitment is

not impeded by barriers. These results support the theory that hydro-electric dams have a significant effect on upstream eel populations.

The impact of power stations on downstream migration was investigated using a predictive model and existing research to estimate turbine mortality rates during periods of peak migration. Schemes with multiple power stations along a watercourse were found to present significant barriers to sexually mature migrants trying to escape to sea with estimates between 45% and 100% of downstream migrants being killed or injured when entrained in turbines.

Management strategies were reviewed to improve both upstream and downstream migration. It is recommended that manual elver transfers continue, with the formulation of a statewide elver stocking management plan. Results highlight the significance of hydro-electric impacts on downstream migration, particularly turbine entrainment. This information stresses the requirement for further research at the variety of power stations in Tasmania, with a focus on downstream migratory behaviour in relation to site-specific hydrological characteristics.

Key words: Eel, dams, barriers, migration.

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4. BACKGROUND

4.1 BIOLOGY AND LIFE HISTORY OF FRESHWATER EELS

Freshwater eels (Anguillidae) are found in Europe, the east coast of North America and throughout the eastern Pacific and Indian Oceans. To date, fifteen species have been named, although there is some doubt as to the validity of some of the species recognised. They have a complex life history and are usually catadromous fishes found in both tropical and temperate waters. They have an elongate body with minute or embedded scales, possess well developed pectoral fins but no pelvic fins, and dorsal and caudal fins are confluent with the anal fin. All species are important food fishes and are sold fresh, smoked or canned. They are an important aquaculture species where the industry is primarily based on the on-growing of captured elvers and glass eels.

Two species of freshwater eel occur in Tasmania, the shortfinned eel (*Anguilla australis*) and the longfinned eel (*Anguilla reinhardtii*). *A. australis* are found in all waters of Tasmania, whereas *A. reinhardtii* are restricted primarily to waters in the north east of the State. Both species live a catadromous life cycle, that is they spend the majority of their life in freshwater and return to saltwater to spawn (Figure 4.1). *A. australis* forms the basis of the commercial fishery in Tasmania.

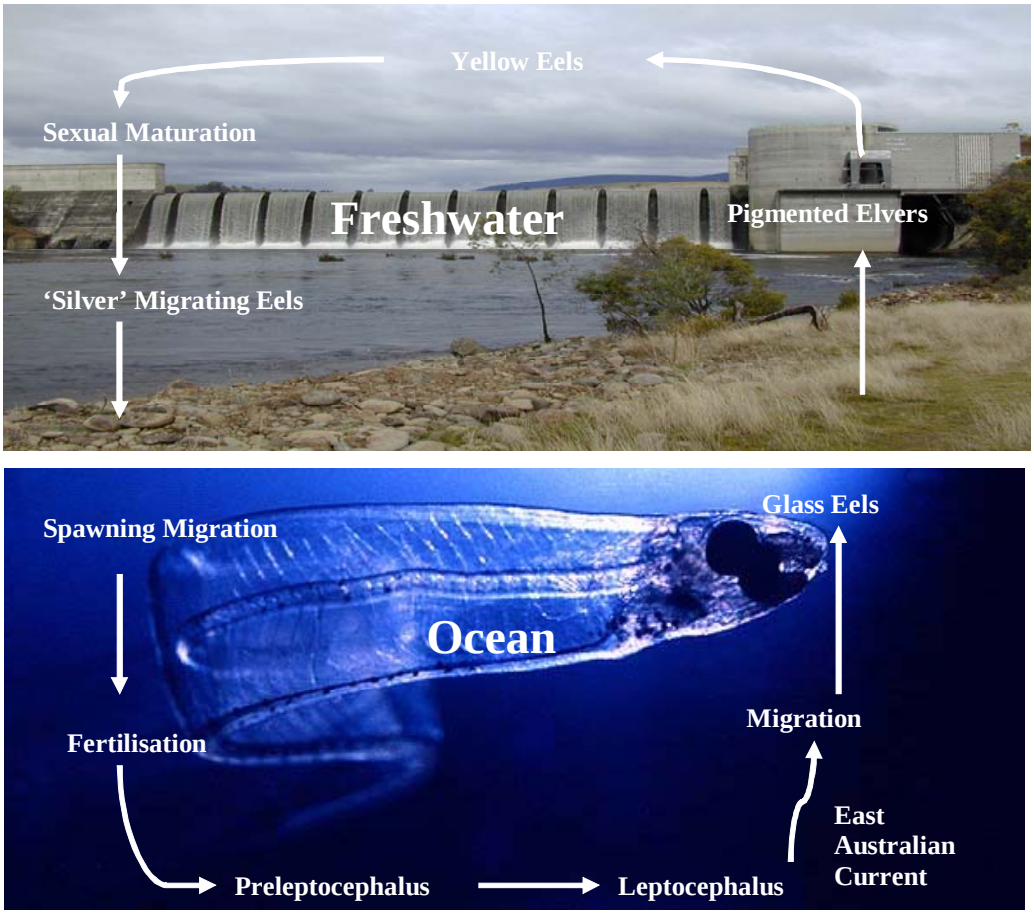

Figure 4.1 Lifecycle of the Shortfinned Eel *(Anguilla australis)*.

The life cycles of *A. australis* and *A. reinhardtii* are similar. Upon attaining sexual maturity catadromous adult eels migrate back to their spawning grounds. The exact location of these spawning grounds is unknown. Schmidt (1925) suggested the spawning area of *A. australis* lies in the Coral Sea, in the vicinity of New Caledonia. Castle (1963) suggests that the spawning ground for *A. australis* and *A. reinhardtii* lies between Fiji and Tahiti, the centre of which is 18ºS and 170ºW (Tesch 1977). Aoyama *et al*. (1999) also suggests this is the area in which *A. australis* spawn, while Jellyman (1987) proposed that the spawning ground for *A. australis* is in the vicinity of 5-15ºS and 150-170ºW, south east of the Solomon Islands. The evidence for the proposed locations of the spawning ground of these species is sparse. The exact timing of spawning is also unknown. Females produce between 5 and 10 million eggs, with both sexes thought to die after spawning. It is believed both species spawn in warm sub-tropical waters at depths near 300m by which time they may be in excess of 16-40 years old. Once hatched the eel larvae (preleptocehpali) drift with ocean and coastal currents, dispersing along the eastern Australian seaboard and into the Tasman

Sea. As the larvae approach the Australian coast they metamorphose from a leaf shaped larva (leptocephali) into a transparent 'glass eel'. These become pigmented juvenile eels or elvers after they enter estuaries and are exposed to freshwater. Migration of glass eels into estuarine systems results in rapid pigmentation and the development of functional teeth (Jellyman 1977, 1979). In Tasmania, invasion of *A. reinhardtii* glass eels into estuarine waters is recorded from mid-Febuary until mid-July at water temperatures of 4.5 – 22^{o}C (Sloane, 1984b). *A. australis* glass eels have been found to invade estuarine waters in Tasmania from mid-March until mid-December at water temperatures of 4 - 22^{o}C (Sloane, 1984b).

Otolith ageing suggests glass eels spend at least one summer at sea with *A. australis* glass eels approximately one to one and-a-half years old while *A. reinhardtii* glass eels are approximately one year old (Jellyman, 1974). The difference in age between the species at migration is most likely due to *A. reinhardtii* having a slightly later spawning season. The restricted estuarine migration period of *A. reinhardtii* and the similar size glass eels throughout the distribution range of the species suggests that it occurs all along the eastern seaboard of Australia at similar times due to a precise larval period. The length of larval life of *A. australis* is probably quite variable, resulting in a more substantial and prolonged influx of glass eels (Sloane, 1984b).

The transformation from glass eel to pigmented eel is referred to as the 'elver' stage. Upstream elver migration occurs after this period and can last several years. Some of these elvers may stay in estuaries while others migrate upstream during their first year in freshwater or as juveniles in subsequent years. Some older 'yellow' eels may even delay migration upstream until sexual maturation commences. It is understood that during the course of their upstream migration, elvers seek cover in substrate (ie. gravel, mud, sand) or opportunistic sources of cover during the day to avoid predation and during the summer months migrate at night. Migration after the glass eel stage varies greatly between individual eels and with time (Naismith & Knights, 1988; White & Knights, 1997).

After a period in freshwater elvers mature into adult eels, commonly referred to as 'yellow' eels. The length of the elver stage varies and is not clearly defined in the literature, although in Tasmania, industry bodies refer to the elver-eel transition

occurring when elvers reach a length of 300 mm, the legal harvesting size, from which point on they are referred to as adult eels. Adult eels remain in the freshwater environment (lakes or rivers) until they begin to reach sexual maturity, when they migrate seaward.

4.1.1 Shortfinned Eel (Anguilla australis)

Description

A. australis typically has an elongated body with continuous dorsal-caudal-anal fins. The dorsal fin originates level with or slightly in front of the anal fin. Adults commonly vary in colour from a uniform dark brown to black on the back and sides, with a lighter and on occasion silvery belly, particularly in mature migratory adults. The species is predatory with dietary preferences including a wide variety of aquatic fauna, such as insects, crustaceans, molluscs and fish. Specimens to 1.1 m and 3.2 kg have been recorded, but are more commonly smaller.

Distribution

A. australis is native to Tasmania, south-east Australia and New Zealand. It is widespread and common throughout most of Tasmania although its distribution is disrupted by major dams in some catchments. It has been recorded in MacQuarie Harbour on the West Coast, but the largest juvenile migratory populations commonly targetted commercially occur in the Derwent and Tamar rivers. The species inhabits most Tasmanian coastal streams including those of King and Flinders Islands, and its range extends as far as 150 km inland in the major river systems. Inland Fisheries Service (IFS) surveys in 1998 captured several eels from the Shannon River approximately 10km downstream of Great Lake (Andrews and Jack, 1999), and a single specimen from the Ouse River below Lake Augusta represents the farthest inland record of the species (Sloane 1984c). Few eels live in higher altitude lakes, but are common in Central Highland lakes at elevations of less than 1000 m. *A. australis* is also common in the Arthur, Pieman and Gordon river systems, indicating a continuous coastal distribution around Tasmania. The only areas where the species appears to be scarce, other than on the western Central Plateau, are in streams and rivers where heavy-metal pollution from previous or existing mining activities are at high levels. These include the upper South Esk and King and Queen rivers on the West Coast (Sloane, 1984d).

Habitat

A. australis occurs in a wide variety of aquatic habitats including rivers and creeks as well as lakes and swamps. Still water is preferred, although eels migrating upstream are found in fast flowing streams and utilise the hydraulic biotope to inhabit areas of reduced current flow where possible.

4.1.2 Longfinned Eel (Anguilla reinhardtii)

Description

A. reinhardtii typically have an elongated body with continuous dorsal-caudal-anal fins. The dorsal fin originates in front of the anal fin. Adults are commonly dark greenish-brown to black with mottled or spotted colouration on the dorsal and pectoral surfaces and a typically lighter ventral colouring. Dietary preferences include a wide variety of aquatic fauna, including insects, crustaceans, molluscs and fish. *A. reinhardtii* has also been known to take large prey such as juvenile waterfowl. The species commonly reaches lengths of 1 m, but has been recorded to 1.5 m and 20 kilograms.

Distribution

A. reinhardtii is native to Tasmania and the eastern seaboard of mainland Australia. Within Tasmania it occurs only in the north-eastern part of the State including Flinders Island. It is usually found in the estuaries, coastal lagoons and lower freshwater reaches of rivers and streams in this region including the Tomahawk, Boobyalla, Ringarooma, Great Musselroe, Ansons, and Douglas Rivers. Adult *A. reinhardtii* have also been recorded in northern Tasmania from the Mersey, North Esk, South Esk and Tamar Rivers, but is rarely seen or caught in these waters. The limited distribution of *A. reinhardtii* in Tasmania is thought to result from a restricted glass eel recruitment which is related to the influence and presence of warm oceanic water off north-eastern Tasmania during late summer (Sloane, 1984d). The presence of *A. reinhardtii* in the lower reaches and estuaries of rivers has been related to avoidance of low water temperatures during winter and forage fish availability (Sloane, 1984d). Although not as commercially targeted as *A. australis* due to smaller populations, small quantities are harvested in north-east Tasmania.

Habitat

A. reinhardtii occurs in a wide variety of aquatic habitats including rivers and creeks as well as swamps and lagoons. This species is not commonly found in lakes however. Still water is preferred, although eels migrating upstream are found in fast flowing streams and utilise the hydraulic biotope to inhabit areas of reduced current flow where possible.

4.1.3 Upstream Elver Migration

Although little information exists on elver habitat and migratory preferences for Tasmanian conditions, New Zealand research and anecdotal evidence in Tasmania suggests *A. australis* in particular, and most probably *A. reinhardtii* elvers seek cover in gravel, mud or sand and under rocks or logs during the day, migrating upstream at night over the summer months. Elvers are able to overcome obstructions such as small barriers and waterfalls encountered during migration by either climbing up any suitable damp surface, or travelling overland during rain periods or following heavy dew. They are believed to be unable to migrate over larger instream structures such as hydro-electric dams. This migration is thought to continue well into the upper reaches of river systems over a period of years before the elvers settle into a sedentary feeding pattern within a defined home range. At this stage they are classed as adult eels and referred to as 'yellow' eels, although there is still much inconsistency within the literature.

During late spring and early summer, upstream migrations of *A. australis* elvers are observable at stream barriers in Tasmania (Sloane, 1984c). The elver run at Trevallyn Power Station in the Tamar River system, commences in early November and continues until mid March. At Meadowbank Dam, approximately 44 km above tidal influence in the Derwent River system, the elver run starts in early-to-mid November and continues until early March. Elver runs of *A. reinhardtii* have been caught amongst *A. australis* elvers, although never in significant numbers.

Tasmania has the most significant juvenile eel migrations within Australian waters in terms of quantity and relative predictability. Hydro-electric dams and other significant instream barriers can obstruct these upstream migrations to varying degrees. As a result the IFS undertake annual harvesting and elver restocking programs to promote

recruitment into Tasmania's upper rivers to support Tasmania's eel fishery. Large aggregations of glass eels / elvers migrating to freshwater are annually trapped at the base of Trevallyn Dam (South Esk River), Trevallyn Power Station (Tamar River) and Meadowbank Dam (Derwent River). Harvested elvers are graded to ensure they are free of any other fish species, and then used to restock lakes and dams above large impoundments to support the eel stocks. A proportion of harvested elvers are also provided for commercial on-growing practises.

There is varying demand for juvenile eels to support the eel industry, and Australian and overseas interests continually seek access to Tasmania's juvenile eel resource. The IFS currently make available a proportion of the annual harvest to these interests. According to Forteath (1998), the Tasmanian eel fishery could potentially produce a minimum of 200 tonne per annum if the resource is sustainably managed. Over the past 10 years the Tasmanian eel fishery has produced on average approximately 42 tonne per annum.

Unpigmented glass eels are generally believed to be sedentary during their first year in estuarine or freshwater, thus elvers resident in streams and rivers for a year or more make up most of the migratory population. The greatest concentration of elvers are recorded from the lower reaches of waterways. In New Zealand upstream elver migration populations are impacted on by mortality and tributary or habitat diversions (Jellyman, 1979). It is likely that similar population impacts would be experienced by Tasmanian elvers. At some dams around the state migrating elvers are known to have high mortality rates through predation or strandings.

Sloane (1984c) undertook age analysis on otoliths and found that *A. australis* elvers in age group 0 (those elvers that have not spent one full year in freshwater), when assigned a birthdate of 1st of October as suggested by Jellyman (1979), were only found at barriers near the upper limit of tidal influence. Further inland, age groups 2, 3, and 4 became more important and eels up to 10 years were found to participate in these summer upstream migrations. This indicates that eels migrate upstream for several successive years. During the migration season, mean length and weight increased with age as the migration progressed (Sloane, 1984c).

It is difficult to isolate the environmental factors that control elver runs in Tasmania. Day length, water temperatures, river flow and behavioural interactions between elvers are suggested as contributing factors in New Zealand (Burnett, 1968; Todd, 1980; Todd, 1981; Town, 1985). In Tasmania, evidence suggests elvers first appear at Trevallyn Power Station on nearly the same day each year, independent of flow outputs, inferring that day length is an important initiating factor (Sloane, 1984c). However, periods of high stream (or power station) flows and reduced water temperatures (>10 ^{o}C) have been shown to inhibit elver migration (Sloane, 1984c). At Trevallyn Power Station, when turbine outputs are high (>2 x 10^6 m^3 day^{-1}), elvers are unable to migrate towards outflow structures in significant numbers (Sloane, 1984c), most likely due to the physical inability of elvers to swim against these flows. When the turbine outputs are low enough for the elvers to swim against, they congregate in large numbers at the base of outflow structures (Sloane, 1984c).

Sustained and burst swimming are used by elvers while holding against ebb tides, vertical movement during flood tides and swimming into freshwater through sluices, fish passes, rapids and up rivers and streams. Determination of swimming performance allows calculation of distances traversable against various water velocities before exhaustion (McCleave, 1980).

Results from experiments by McCleave (1980) showed that swimming endurance (sustained swimming) of *A. anguilla* elvers averaging 7.2 cm total length, decreased logarithmically with increased swimming speed from 3.0 min at 25 cm s^{-1} (3.5 L s^{-1}) to 0.7 min at 36 cm s^{-1} (5.0 L s^{-1}), and 0.27 min at 54 cm s^{-1} (7.5 L s^{-1}). Barbin and Krueger (1994) found that *A. rostrata* elvers averaging 5.6 cm total length spent significantly less time swimming at water velocities of 30 and 35 cm s^{-1} than at 10, 15 and 40 cm s^{-1}. No studies have been undertaken on swim speeds for *A. australis* and *A. reinhardtii* in Tasmania. However, given the morphological similarities of the two species mentioned above compared to the two Tasmanian species, elver swim speeds are assumed to be similar.

4.1.4 Downstream 'Silver' Eel Migration

Once yellow eels reach maturity they migrate downstream, often during floods, to return to their spawning grounds. Adult migratory eels, referred to as silver eels,

undergo several morphological changes (Figure 4.2); the eyes enlarge, the head becomes more streamlined, skin colouration changes to a bright silver colour, sexual organs enlarge, feeding discontinues and the stomach changes to an osmoregulatory organ.

Figure 4.2: 'Silver' and 'Yellow' eels.

Literature concerned with the downstream (seaward) migration of maturing adult eels in Australia is relatively sparse with only Sloane (1984f) focusing specifically on Tasmanian populations. New Zealand studies have been more extensive, but extrapolation from the New Zealand experience to establish mitigatory measures for the Tasmanian fishery should be viewed with caution due to conflicting evidence within the New Zealand literature and dissimilar habitat types and eel preferences between the two regions.

Migrating *A. australis* male and female fish populations in New Zealand have a wide range in age-at-migration, being 6-24 years (mean 14 years) and 10-35 years (mean 19-24 years) in freshwater systems respectively (Todd, 1980). Sloane (1984f) found that female *A. australis* from the Clyde River migrated at ages 18-30, with an average age of 22. Female *A. australis* migrated downstream at mean lengths of 925-962 mm, with a single 495 mm male sampled. Eels captured in December were also found to be larger than those caught in January. Although Sloane (1984f) did not age males

from the Clyde River he did comment that migrating males were generally smaller than females.

There appears to be a distinct difference in the sex ratio of *A. australis* in Australian and New Zealand waters. Sloane (1984f) found only 1 male amongst 190 migratory *A. australis* examined from the Clyde River, while Todd (1980) found that there was a higher proportion of males to females in Lake Ellesmere and the Makara Stream. This high female-to-male ratio could be significant for mitigation strategies dealing with recruitment.

4.1.5 Downstream migratory triggers

The New Zealand literature is more comprehensive than the Tasmania literature regarding eel migratory environmental triggers, especially towards *A. australis*. However, conflicting evidence for *A. australis* between the two regions suggests environmental triggers are substantially different. Further research in Tasmania is necessary.

Movement of migrating New Zealand *A. australis* populations exhibit a lunar periodicity and may also be influenced by various other environmental factors including water temperature, rainfall, increased water level and the passage of a depression (Vollestad, 1986; Todd, 1981, Burnet, 1969). Of these factors, only water temperature was found to be a dominant influencing factor in Tasmania (Sloane, 1984f). However, information gathered from this study indicate that downstream migrating movement in the Lake Trevallyn/South Esk system is influenced not only by temperature but channel and rain associated flow.

New Zealand research suggests lunar periodicity is an important migration trigger (Burnett, 1961; Todd, 1981). However, in the Clyde River, there did not appear to be any relation between migratory *A. australis* numbers and lunar periodicity as 20, 27, 27 and 26% of the total number of eels counted were recorded during the new moon, waxing, full moon, and waning quarters respectively (Sloane, 1984f).

Variation in water temperature was found by Sloane (1984) to be the most significant factor regulating downstream *A. australis* migration in Tasmania. The start of the eel

run corresponded with a period of increasing water temperature. Falls in water temperature may retard the run. Migration appears to be confined to the period of high stream temperatures associated with the summer months. It may be arrested by mean daily water temperatures falling below approximately 12^{o}C. The main peak in migration occurs in January and coincides with the highest mean daily water temperature (20.5^{o}C).

Migrations of the European eel are related to moon phases (*A. anguilla),* (Lowe, 1952; Tesch, 1977). Lowe (1952) and Tesch (1977) also made the suggestion that floods may be a triggering factor, guiding eels in their movement downstream. Similarly, during periods of flooding in New Zealand, downstream movement responses were recorded by Cairns (1941), Burnett (1969), Todd (1981a) and Palmer *et al*. (1987). The literature however, fails to provide adequate statistical relationships between emigrant eel behaviour and environmental parameters (Boubee *et al*. 2001). Boubee *et al.* (2001), states that New Zealand research has not attempted to statistically measure or quantify the environmental variables and conditions that may result in a collective downstream migration event.

4.2 BARRIERS TO MIGRATION: NUMBERS AND DISTRIBUTION

Barriers to fish migration range from culverts and fords to tidal barriers, flood and erosion-control structures, weirs, and hydro-electric dams and their associated turbines (O'Brien, 2000). More than 7000 dams and weirs have been identified along the east coast of mainland Australia, all of which are potential barriers to fish movement and migration (O'Brien, 2000). In Tasmania, there are approximately 57 large dams and weirs within the Hydro network which would act as barriers to fish movements and migrations (Hydro Tas, 2002).

The effect of a particular structure on fish movement, migration, population structure and abundance is dependant on a number of factors including the species, their swimming abilities, the height and design of the structure and the frequency and timing of floods and/or tides that may inundate the structure and hence permit fish passage. Some structures may be passable by fish that are able to climb (eg. eels), yet completely restrict other species, or all species if the barrier is too large. Any impacts will be further compounded by factors such as reduced water quality, water

temperature differentials (thermal barrier), de-snagging and altered flow regimes (O'Brien, 2000).

Downstream migratory silver eels generally have few options of continued downstream movement when faced by a dam. They may either: (1) pass over a dam during a spill event, (2) pass through the turbines or (3) pass through riparian releases. All these options present problems to migrating eels. Passing over a spillway is not always an option for migrating eels, because some dams do not have conventional spillways (such as Hydro Tasmania's Gordon Dam). Other dams, particularly those on medium and large storages, have operating regimes designed to reduce spills by passing excess water at full-gate through the power station. Also, in Australia, and especially Tasmania, with its hydro-electric capacity, the eel's downstream migration during summer generally coincides with low river levels in run-of-river power schemes that are not conducive to spill events.

The impediment posed by barriers to eel migration worldwide is a large scale problem. Hydro-electric infrastructure and the impacts of barriers, modified habitats and power generating operations (turbines, flow regimes) threaten conservational, biological and commercial eel fishery values. Although the adverse effects on eel survival, distribution and abundance are widely reported in the literature for *A. anguilla* (Aprahamian, 1988; Naismith and Nights, 1993), there is a lack of scientific information specific to the impacts of barriers on populations of the Australian freshwater eel, and on critical eel habitat. In Europe, studies have shown that abundance and population structure of the European eel, *A. anguilla*, in a given catchment are primarily dependent on the annual recruitment of elvers to the estuary, the number subsequently migrating to freshwater and the presence of barriers to migration (Naismith and Knights 1993).

4.3 TURBINE MORTALITY

Hydro-electric power is viewed by some as an environmentally friendly method of energy production. However, one of the biggest problems associated with hydro power is the potential injury or mortality of downstream migrating fish including eels. Several causes of injury or mortality can result from turbine entrainment including; hydraulic velocity shearing on weirs, turbulence generated at the base of the fall,

sudden variations in pressure and physical shock or mutiliation when hit against sills or baffles (Travade *et al*. 1992), (Figure 4.3).

Figure 4.3. Mutilated migrants entrained in a Francis turbine. Photo: Jacques Boubee.

Literature on anguillid passage through hydro-electric generating turbines is scarce and often contradicting. It does however indicate that the mortality rate during turbine passage varies (McCleave, 2001). Past studies have suggested that mortality is highest for small turbines running under high head conditions. In many scenarios, due to the large size of adult eels, turbine induced mortality has been estimated at rates greater than 25% (EPRI, 1999). Monten (1985), reported that 73 cm eels passing through Kaplan turbines suffered an injury rate of 40-100%. Eel mortality was stated as 15-50% in a Kaplan turbine (McCleave, 2001). The mortality rate of downstream migrating eels depends on a range of site-specific factors. The mortality and injury of the migrating eel is not only related to the speed, design and the size of the turbine runners (EPRI, 2001), but is also related to the operating conditions such as generating capacity and flow (Monten 1985, Hadderingh and Bakker 1998).

Another important issue related to turbine entrainment is the potential long-term effects or indirect mortality suffered by downstream migrating eels that survive entrainment, particularly if a migrating eel has to pass through a number of power stations before gaining access to the sea (eg. Derwent River system). Immediately after the fall, eels suffer trauma and disorientation causing them to be more vulnerable to predation and other natural dangers (Travade *et al*. 1992). The risk of mortality at

the second hydro powered facility downstream may also be significantly increased after being injured at the first (McCleave, 2001). Because of the distance migrating eels have to travel to spawn, injuries incurred along the way (due to passage through generating and water management infrastructure) have time to manifest and become more lethal (McCleave 2001).

The three most common turbine designs utilised around the world are the Francis, Kaplan and Pelton turbines. All these types consist of rotating blades that are immersed in water. However, all three vary in design and are made of different components resulting in varying degrees of fish mortality.

The Francis Turbine (Figure 4.4) is a robust design operating in a relatively small turbine space. Turbines typically consist of 10-20 fixed angle blades (McCleave, 2001), and operate at high revolutions (engine speed) per minute (www.energotech.gr/hydro2.htm). The Francis turbine looks like a spinning wheel (similar to a waterwheel), this wheel is referred to a as a 'runner'. The quantity of water driving the runner is controlled by a circle of guide vanes, which project water onto the runner on all sides causing it to spin (www.greenhouse.gov.au/renewable/technologies/index.html).

Figure 4.4. Francis Turbine

Tasmania has 34 Francis turbines installed on major water catchments throughout the state (Hydro Tas, 2002). It is well documented and understood that Francis turbines are responsible for a high degree of downstream migrating eel mortality, more so than the Kaplan turbines. Travade and Larinier (1992) state that the mortality rate of eels in Francis and Kaplan turbines vary, depending on specific turbine and site characteristics. On average, the mortality rate is less in Kaplan turbines than Francis turbines (Travade and Larinier, 1992).

Kaplan turbines (Figure 4.5) typically consist of 4-8 adjustable blades meaning that the eels encounter variations in the spacings through which they have to penetrate (McCleave, 2001). These adjustable blades can be altered to suit the water flow and are a suitable design for high flows. They are designed to operate in situations involving a small head of water and due to the variable pitch component, the turbine is able to operate efficiently over a range of heads. Therefore, the turbine is able to operate efficiently throughout the seasonal variation of water levels in a dam (www.greenhouse.gov.au/renewable/technologies/index.html). There are only 4 Kaplan turbines present in Tasmania (Hydro Tas, 2002).

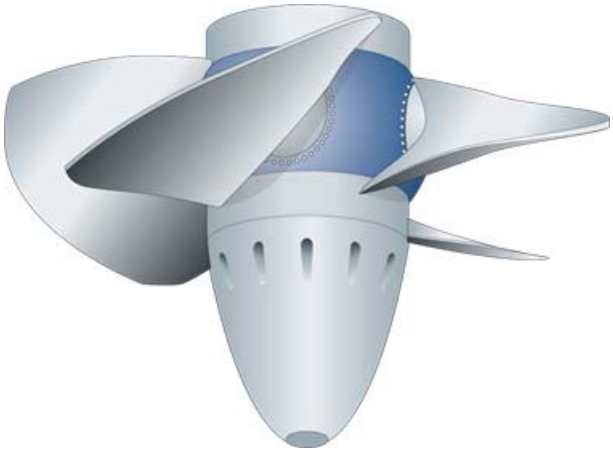

Figure 4.5. Kaplan Turbine

Pelton turbines (Figure 4.6) are implemented in systems containing a ‘large head’ and small flow. The wheel consists of ‘buckets’ fixed around the rim, which are hit by a water jet generated from nozzles fed from the dam water (www.greenhouse.gov.au/renewable/technolgies/index.html). The Pelton is a

relatively easy and robust turbine design with low investment and is well equipped to handle flow variation (www.energotech.gr/hydro2.html). There are currently 20 Pelton turbines in operation in Tasmania (Hydro Tasmania, 2002). Literature classifies the Pelton turbine as resulting in 100% mortality due to the nature of the design (Travade and Larinier, 1992).

Figure 4.6. Pelton Turbine

4.4 TASMANIA'S COMMERCIAL EEL FISHERY

The commercial fishery for freshwater eels (shortfinned eel *(Anguilla australis)* and longfinned eel *(Anguilla reinhardtii)*) in Tasmania commenced in the mid-1960's, following (or in some instances coinciding with) the construction of many of the State's hydro-electric power schemes. Hydro-electric dams are situated on nine major river catchments within Tasmania, with a total of 51 dams within the hydro network.

A. australis forms the basis of a commercial fishery in Tasmania. The fishery is managed on a limited entry basis currently comprised of 12 commercial fishing licences with up to 30 fishers seasonally employed in the industry. Annual harvest is approximately 35 tonnes. Over the last ten years, the average harvest of eel has been around 42 tonne per annum with *A. australis* comprising 98% of the catch and *A. reinhardtii* the remaining 2%. Harvested eels are mostly exported frozen to Europe, however live product is exported to Asia and some value added product (mainly smoking) is produced for the local domestic market. Licences are restricted to specific water catchments with the main capture methods including fyke nets and baited eel traps as well as some limited downstream trapping of migrating adult eels.

5. PROJECT RATIONALE / OBJECTIVES

The presence of hydro-electric power stations and their impacts on eel migration and populations were investigated to further the understanding of measures required to improve the management of native eel resources. Combined with investigating the effectiveness of past elver restocking practises, this study seeks to determine whether or not selected upstream populations have been sustained through restocking. An improved understanding of barriers preventing upstream migration and the effects power stations have on downstream migration is necessary for effective future management of eel stocks. This investigation attempts to make preliminary observations of downstream movement of sexually mature migrants and to evaluate and recommend management tools to facilitate safe passage. There is widespread literature associated with available mitigation strategies specific to upstream and downstream eel migration. Specific to Tasmania's hydro-electric operations, this investigation seeks to evaluate and recommend such strategies for future management.

In Tasmania, elver harvests (netting and trapping) below hydro dam barriers (Meadowbank Dam, Derwent River) and hydro power stations (Trevallyn, Tamar River) were initiated in the mid 1970's by the Inland Fisheries Commission. The aim of the harvests was to reduce elver mortalities and through restocking programs, manually recruit elvers into the upper reaches of these river catchments. While this practise continues today, with a dependency on restocking by the commercial fishing sector, no assessment has been made of the effectiveness of restocking in sustaining eel populations upstream of barriers. No other elver harvesting or transfer programs are carried out in Tasmanian waters despite the existence of many significant barriers to eel recruitment.

Stock enhancement strategies can be a cost-effective means of restoring or maintaining fisheries, and have proven essential in catchments with barriers to migration (Knights and White 1998). Regulation of natural river systems has obstructed eel migration in many catchments in Tasmania, but with the implementation of appropriate management tools such as fish passes / ladders and

translocation through trapping / netting programs, restoration of stocks can be achieved. Such strategies have not only proven successful in increasing commercial fishery yields, but also contribute to enhancing spawning stocks.

Hydro electric operations (dams and power generating turbines) reduce the chance of successful emigration of silver eels, especially for larger female eels, and depending on flow, turbine type and number, may represent a major source of mortality to pre-spawning adults (Ritter *et al.* 1997). The magnitude of dam-related mortality has not been measured.

Mortality depends on the proportion of adult eels that:
(1) pass over the top of the dam when spilling;
(2) pass around the side of the dam via fish passages / spill ways and riparian valves, and;
(3) survive the passage through the turbines.

Spawning stocks successfully migrating to oceanic waters are critical to future recruitment. The design of downstream passage ways, and the use of non-generating periods to reduce mortality have been trialed and implemented in New Zealand, the United States of America and Europe, but have yet to be adopted or investigated in Australia.

Primary Objectives of the study

- Assess the impacts of hydro-electric dams on upstream eel migration and population structure in Tasmania's lakes and rivers and assess the impact of past elver restocking practises in hydro-impounded catchments on eel populations within those catchments.

- Assess the direct impacts hydro-electric dams and their associated operations (turbine intakes and water management practises) have on adult 'silver' eel survival rates during their downstream spawning migration.

- Evaluate various management tools (ladders / bypasses and passage; netting/trapping and translocation) to mitigate impacts and provide recommendations for implementation.

- To review the management of barriers to eel migration, including overseas experience.

Project Strategy

- Determine the age structure of eel populations in three catchment categories – undammed, dammed, and dammed-and-restocked by taking representative population samples from a number of sites in each catchment category.

- Determine age structure through the examination of otoliths by the IFS, the Central Aging Facility in Victoria and the National Institute of Water and Atmospheric Research Ltd (NIWA) in New Zealand and compare the results of agencies.

- Determine relative abundance and population structure (length, weight and age) within and between catchment categories.

- Augment the biological data gathered during the course of the sampling with records of (i) past and present elver aggregations, harvests and translocations; (ii) commercial catch composition and catch-effort data; and (iii) restocking histories.

- Collate turbine characteristics, 'silver' eel catch data and environmental parameters to predict periods of downstream movement and obtain estimates of eel mortality through turbines.

- Collate, classify and prioritise the number of and type of hydro barriers (including construction data, height and slope; number and type of turbines) specific to the selected catchments.

- Provide a cost benefit analyses of various fish passage (ladders; bypasses) and translocation / restocking (netting / trapping) options for migrating juvenile and ‘silver’ eels.

- Review and evaluate mitigation strategies against catchment characteristics (including Hydro infrastructure and operations) and formulate prioritised recommendations for implementation by industry, the HEC and fisheries managers alike.

6. MATERIALS AND METHODS

6.1 UPSTREAM ELVER MIGRATION AND EEL POPULATIONS

6.1.1 Site Description

Two of the largest river catchments of Tasmania were selected for sampling. Both river systems are known to attract large quantities of juvenile eels and contain a number of various hydro-electric power stations along their respective water courses. The Derwent River system, sampled during the 2000/2001 season is situated in the southern end of Tasmania and the Great Lake – South Esk system in the north of the State was sampled in the 2001/2002 season (Figure 6.1). Refer to Appendix 3 for an overview of the two river systems.

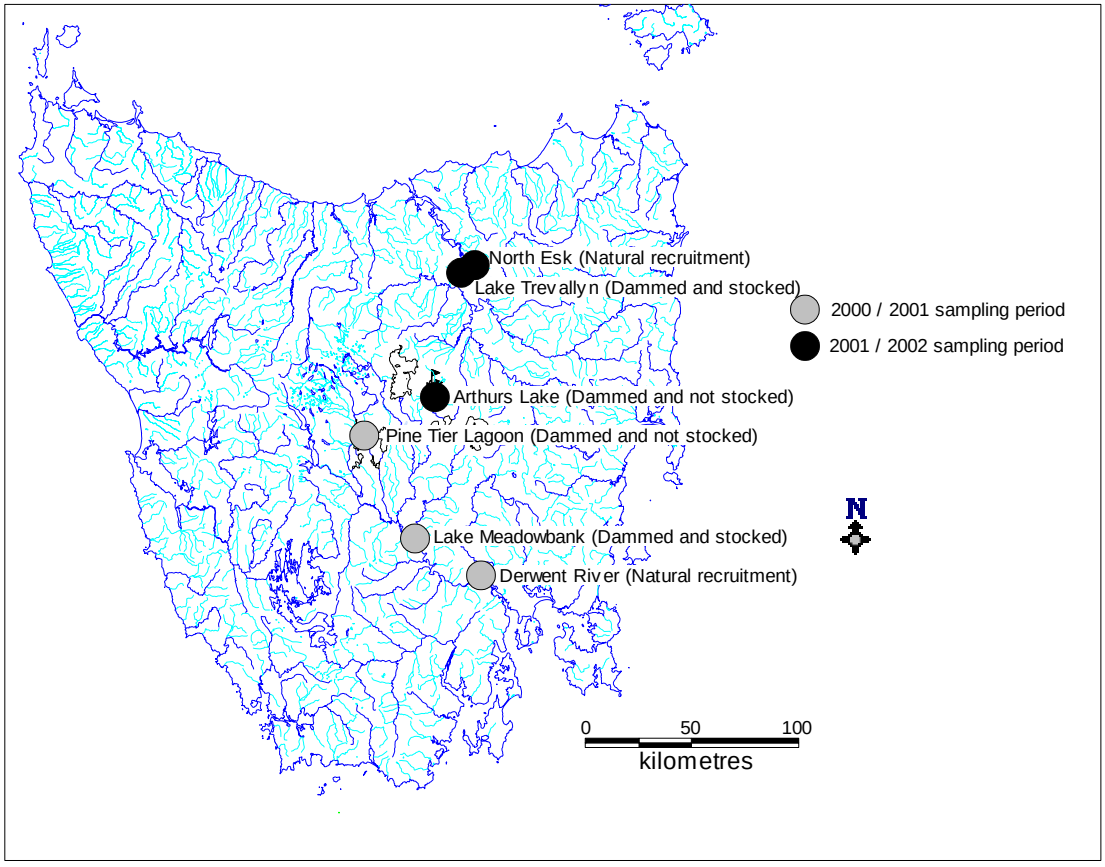

Figure 6.1. Catchments sampled between 2000 and 2002.

The first major hydro impoundment juvenile eels face when migrating the Derwent River is the Meadowbank Power Station utilising water stored in Lake Meadowbank. There is currently no commercial eel fishing occurring in Lake Meadowbank. However, similar to waters further upstream, Meadowbank provides adequate eel habitat for a sustainable population and has been subjected to annual manual elver

transfers. To satisfy each catchment category proposed, sites were randomly selected in the Derwent River below the Meadowbank dam in areas that were designated as 'fishable' using conventional fishing techniques (Figure 6.2). Equal effort was placed in Lake Meadowbank above the station (Figure 6.3). To satisfy the dammed and not stocked criteria, Pine Tier Lagoon was sampled (upstream above another dam) for a significant period with total fishing effort. (Figure 6.4). Total fishing effort describes the practise of setting all fyke nets in the one water body as opposed to placing half above a dam wall and half below as done in the other catchment categories.

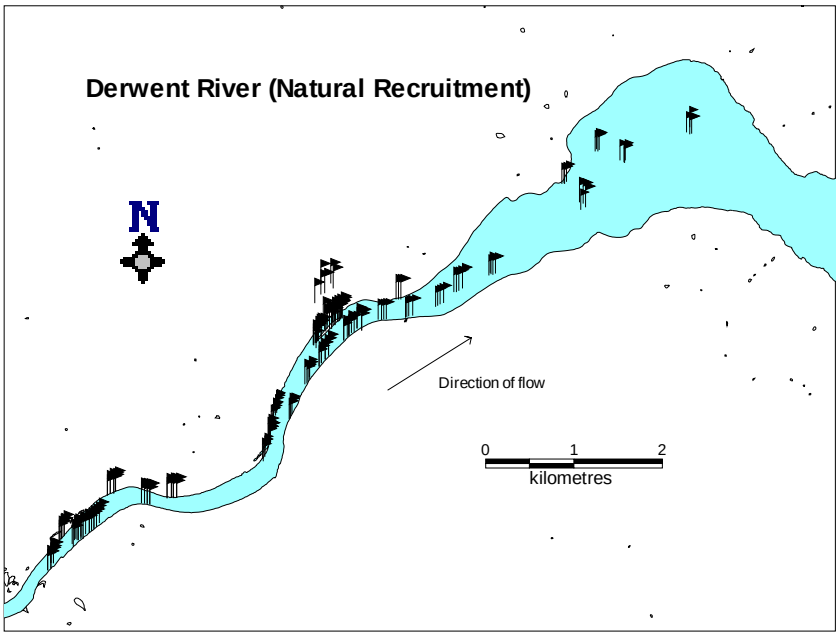

Figure 6.2. Derwent River sampling sites.

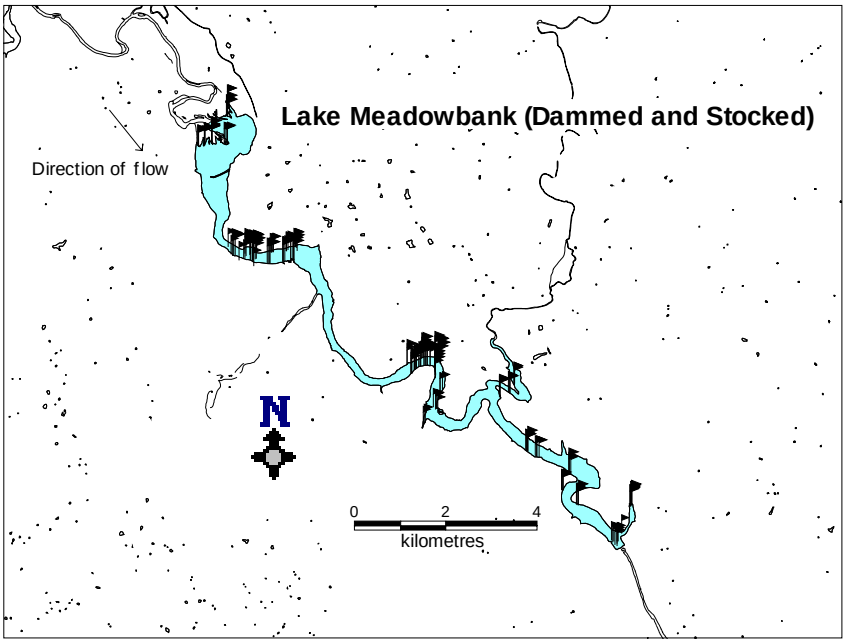

Figure 6.3. Lake Meadowbank sampling sites.

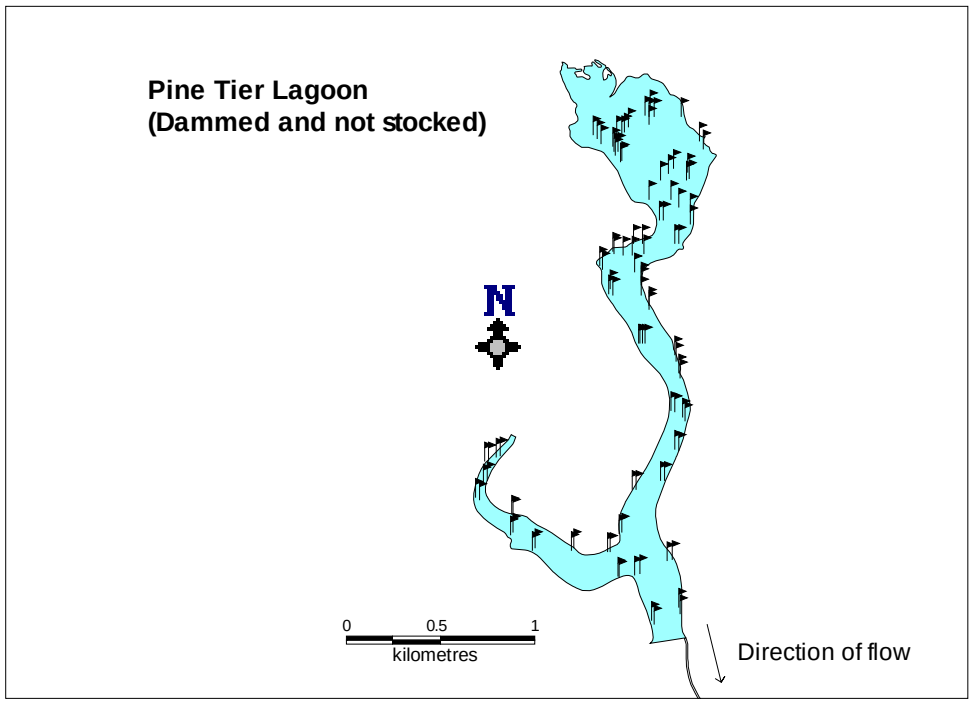

Figure 6.4. Pine Tier Lagoon sampling sites.

Similarly to the Derwent River system, the study focused on the first major hydro impoundment faced by juvenile eels when sampling in the South Esk – Great Lake Catchment. The first impoundment was focused on because of the relatively close proximity of water that is naturally recruited with freshwater eels annually before coming into contact with a major barrier. Equal fishing effort was randomly allocated in Lake Trevallyn above the Trevallyn Power Station and below in the North Esk River (Figures 6.5 and 6.6).

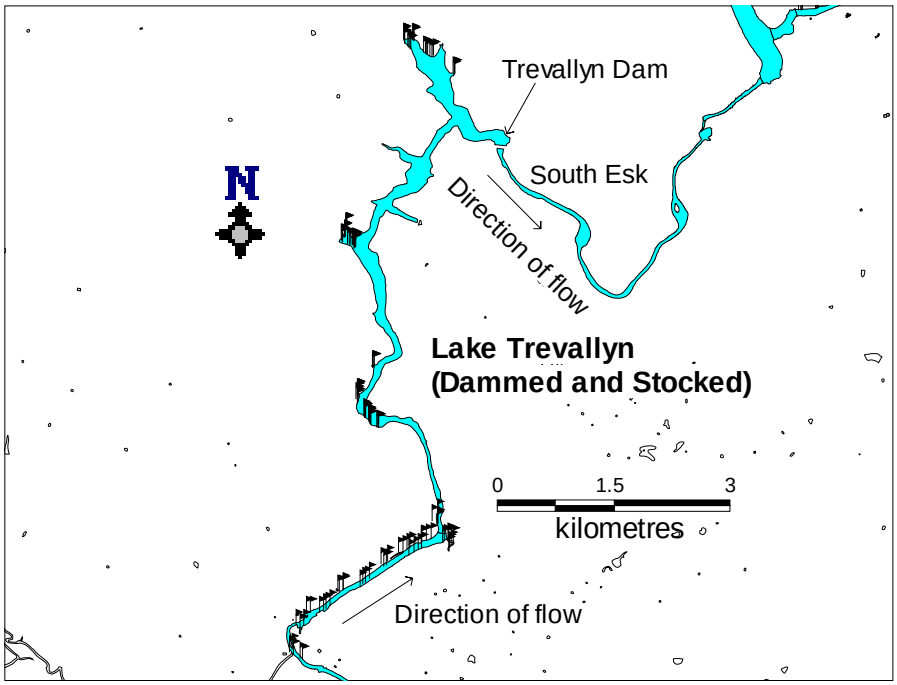

Figure 6.5. Lake Trevallyn sampling sites.

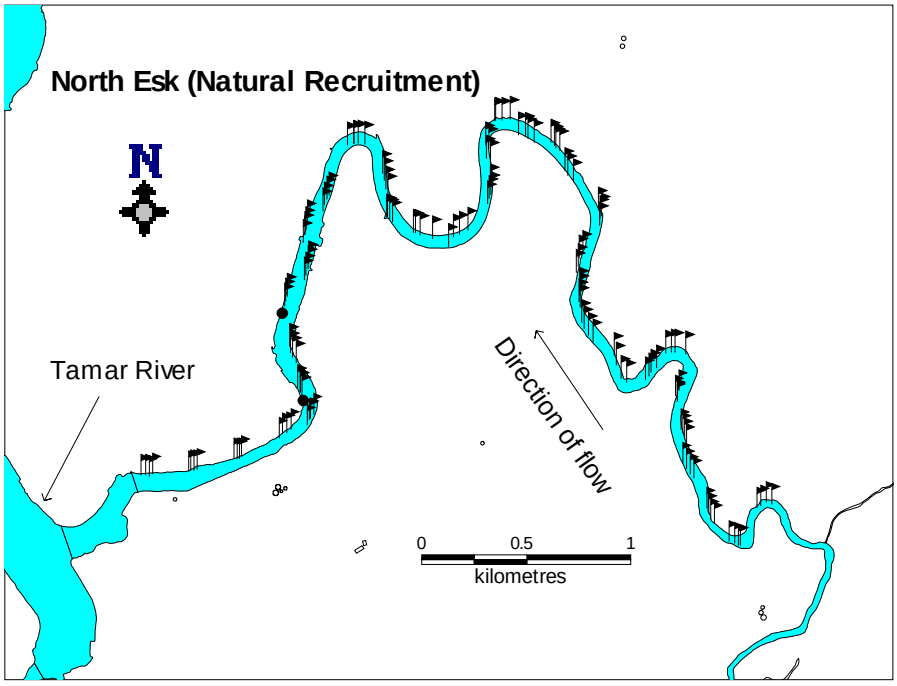

Figure 6.6. North Esk sampling sites.

Rather than fishing in the South Esk directly below the Trevallyn Power Station, the North Esk River was the preferred option as this water body satisfies the natural recruitment catchment category. Habitat in the South Esk below the Trevallyn Power Station proved impractical for fishing, with large rises and falls in water levels due to

the dam often spilling. To satisfy the dammed and not stocked criteria, Arthurs Lake was randomly sampled in appropriate habitat using total fishing effort (Figure 6.7).

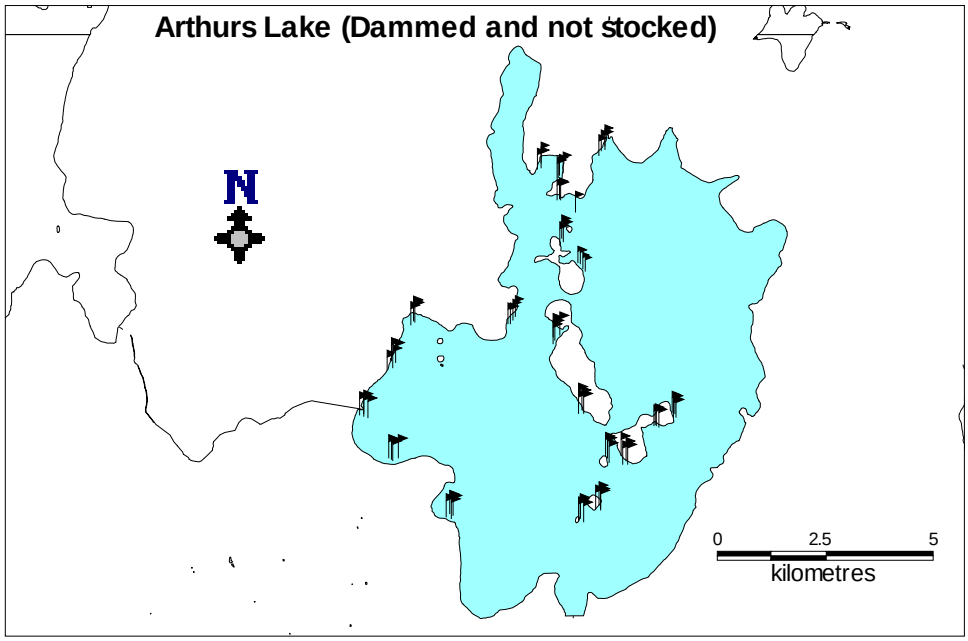

Figure 6.7. Arthurs Lake sampling sites.

Two additional sites were selected for sampling above and below the Meadowbank power station. The Ouse River, which flows into the Derwent River directly upstream of Lake Meadowbank and the Plenty River, which flows into the Derwent system downstream of the Meadowbank Power Station were sampled (Figure 6.8). These sites were selected to obtain samples from riverine habitats above and below the associated power stations in order to sample two similar freshwater habitats as opposed to the major focus of an estuarine environment versus a lake habitat.

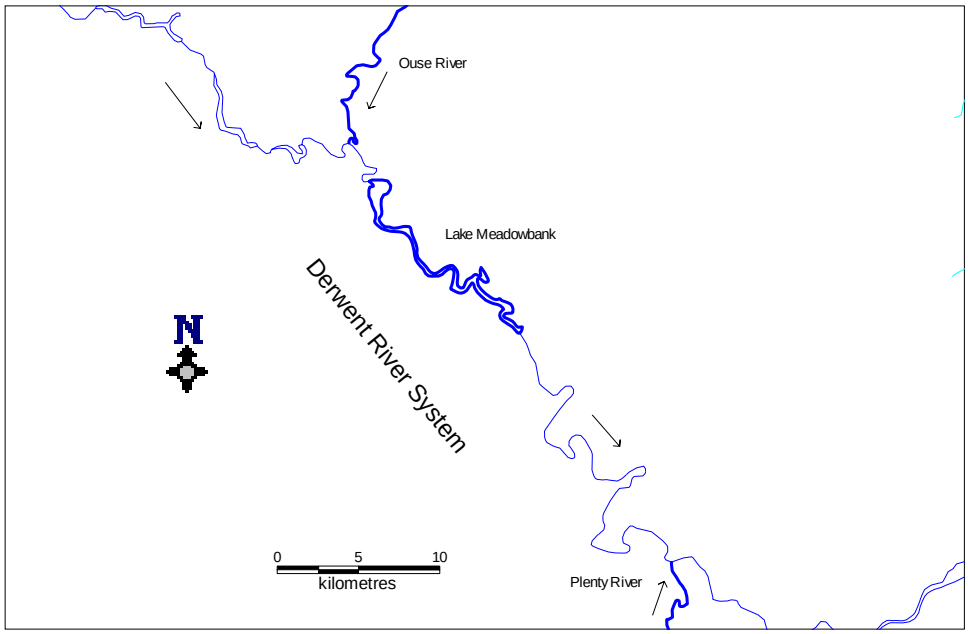

Figure 6.8. Riverine habitats above and below the Meadowbank Power Station.

6.1.2 Data Collection

Sampling and data collection was undertaken from November to early March in 2000/2001 and 2001/2002 at the respective sites (Figure 6.1). The November to March period is the most productive to harvest eels, due to the increased water temperature that occurs over these months. Shortfinned eels (*Anguilla australis*) are most active during this time of year in terms of feeding and migratory behaviour. All waters were sampled with the use of fine mesh fyke nets (2 mm stretched mesh) (Figure 6.9) to obtain a representative sample of the complete size range of the population at various sites visited. Fyke nets are regarded as one of the most efficient harvesting methods for freshwater eels. For commercial operations however, coarse mesh fyke nets are predominantly utilised for the purpose of specifically targeting marketable sized eels.

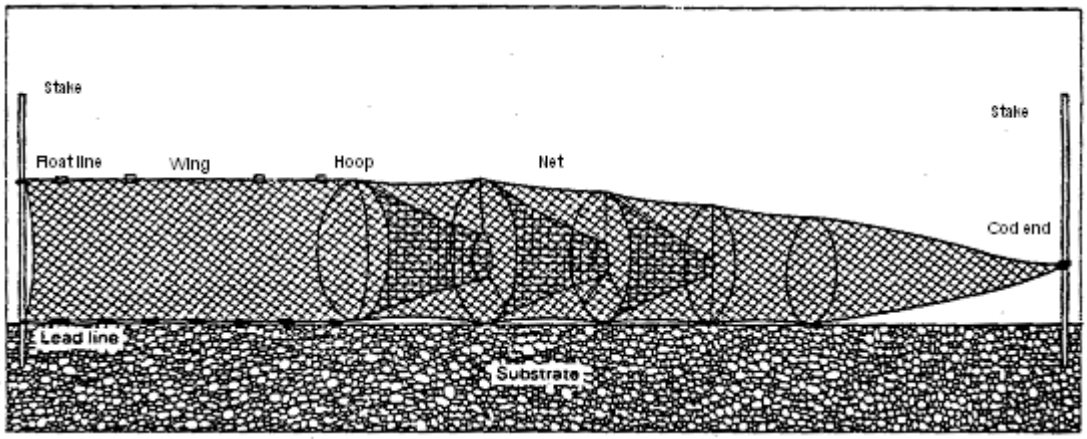

Figure 6.9. Standard Fyke net.

Half of the nets used consisted of 5 m wings and the other half were shorter with 3 m wings. For the river systems sampled, a total of 50 fine mesh fyke nets were set in clusters of five using a random stratified sampling technique. When fishing effort was focused on waters above and below hydro-electric power stations (dammed and stocked, not stocked and not dammed), nets were split evenly and randomly set in clusters of five and fished for the same duration each fishing week. Nets remained in the water for a period of four nights at each site with daily checks. Setting, checking and hauling nets in the Derwent River and the North Esk required timing, dependent on the tide. It was very important to perform these tasks during low tide. Clusters were randomly shifted from site to site between fishing weeks. Nets were numbered and plotted on a Geographical Positioning System (GPS) upon the deployment of each new site. All nets were deployed in Pine Tier Lagoon and Arthurs Lake in their respective sampling seasons and set for a period of two weeks. Catch data and environmental conditions (water temperature, wind, lake level and tide) were all recorded in the field and subsequently entered into relevant data sets.

Regulations during the 2000/2001 season limited fishing effectiveness as all cod ends were raised above water for the entirety of each fishing night. This was instigated to ensure the survival of any air-breathing animals that may become trapped. Exclusion screens were installed in all nets at the beginning of the 2001/2002 sampling period due to the implementation of new conditions. As a result, the presence of screen selectivity was tested to determine whether or not the introduction of exclusion screens significantly affected the size of eels entering the nets.

Eels captured in the nets were anaesthetised by placing them into plastic bins containing iso-eugenol solution (AQUI-S Aquatic Anaesthetic) at a concentration of 30 ml per 1000 L. AQUI-S is the only anaesthetic to be registered in Australia and New Zealand with a nil withholding period, allowing it to be used for the harvesting of fish for human consumption. The dosage used during the project is slightly in excess of the dosage required (25 ml) for heavy sedation and acts by suppressing gill ventilation, causing death by asphyxiation. All eels were labelled and frozen for later processing.

6.1.3 Selectivity analysis

Sampling was performed during 2001/2002 using only fine mesh fyke nets. Selectivity analysis was performed between fine mesh and course mesh fyke nets during the 2000/2001 season to determine if there was bias in the size of eels in the catch of the two nets. It was critical that the eel population samples represented the actual population structure as closely as possible. Eels can choose to enter a net or not (unlike active fishing methods, such as seine nets, where choice is not an issue). There may be a size-based bias if there is a size-related avoidance of the fine-meshed fyke nets. This may occur for example, if smaller eels are not inhibited by entering dark places whilst larger eels may avoid them.

Similarly, the selectivity of the catches of short-finned eels (*Anguilla australis*) by 110 mm stretched mesh exclusion screens was also tested for. During the course of the study (season 2001/2002) screens were attached to the net as new State regulations were implemented to deter bycatch. If there was to be any size-related avoidance of these exclusion screens once again the catch data may have been biased.

Field Methods

Selectivity trials were performed in association with the investigations field sampling and accordingly separated from the results.

Mesh selectivity: Nets were deployed in clusters of five fine-mesh (2mm stretch) and one large-mesh (30mm stretch) fyke net.

Screen selectivity: Nets were deployed in clusters of five fine-mesh (2 mm stretched mesh) nets. Three of the nets were fixed with a screen of a particular size: 100 mm, 110 mm and 140 mm stretched mesh. However, because it was agreed to enforce 110 mm screens on all fyke nets fished following this trial, the analysis was focused on any size selectivity that occurred as a result of the implementation of this particular screen size.

Methods of analysis.

Mesh selectivity: The data were analysed for each location [Derwent-below-Meadowbank Dam ('Derwent') and Derwent-above-Meadowbank Dam ('Meadowbank')] separately. Two methods of analysis were used: a χ^2 contingency table analysis and a direct selectivity analysis. The selectivity analysis, described by King (1995, pp. 114-116), was found not to work, for reasons explained in the discussion.

Screen selectivity: Catch data was compared in fine mesh fyke nets containing no screen with fine-mesh fyke nets containing 110 mm screens. Data from each location were included in the analysis. A χ^2 contingency table analysis was used to determine whether there was any statistical significant difference in the size of eels captured between the two variations.

6.1.4 Age Determination

Otolith Preparation

During eel processing, otoliths were extracted and retained. Various otolith preparation methods were trialed and evaluated for age determination. The 'crack and burn' technique was chosen as the most suitable method of otolith preparation. An evaluation of eel otolith preparation literature revealed that the 'crack and burn' technique is commonly practised internationally and has been validated in New Zealand (Chisnall and Kalish, 1993). A modified version of this technique (Graynoth, 1999) was investigated and used to prepare one otolith from all eels captured throughout the total sampling period. Graynoth (1999) focused on improving techniques used to prepare eel otoliths and the development of criteria to separate supernumerary checks from winter annuli, improving the accuracy of age estimates.

Sheets of black paper displaying white gridlines were used as a background for otolith preparation with rows of double-sided adhesive tape applied across the page. Each otolith half was placed concave face-up parallel with the horizontal line and aligned over the top of the vertical line so the cross hair lies directly beneath the centre of the nucleus. Once a sample is laid out and labelled, transparent adhesive tape was then applied over the otoliths and gently compressed to hold the otoliths securely in position. Each otolith was then carefully sliced through the nucleus transverse to length with a fine scalpel blade. This was done using a gentle sawing action to prevent fracture of the otolith (Graynoth, 1999). The cut otoliths were burnt in a hot gas flame 400-450°C for 10-15 seconds on a scalpel blade (Graynoth, 1999). The duration that the otolith was exposed to the gas flame varied according to the size of the otolith with larger otoliths requiring more burning time. The burnt sections were mounted in epoxy-resin with the cut half pushed flush against the slide. Otoliths were mounted in numerical order beside the attached label.

Increment Interpretation

The burnt otoliths were examined through a compound microscope under reflected light. Otoliths were generally observed at X40 magnification and X100 magnification alternatively (Figure 6.10). Each otolith was interpreted twice for the first sample from the 2000/2001 season. To gain an estimate of the precision of age estimates, all otoliths were read by two researchers and the results compared.

Inter-reader variability was then observed for the 2000/2001 sample, evaluating the need to go through a similar process for samples collected during the 2001/2002 season. The results were found to provide enough justification to limit all increment interpretation to one reader for the otoliths collected in the 2001/2002 season.

There were varying degrees of quality in otolith preparation. Preparations that were not satisfactory, were not assigned an age and the 2nd otolith of the individual was then prepared. If both otolith preparations from the one eel were not satisfactory, then that particular eel was not assigned an age and not included in the results.

The presence of false structure (lines or rings that did not represent an annual growth increment) were evident to varying degrees. Relevant literature has proven that otoliths can be difficult to age due to the presence of these supernumerary (false winter) checks (Deelder, 1976; Moriarty and Steinmetz, 1979). This is especially difficult for older eels that have been subjected to irregular growth rates combined with over or under-burning and an otolith face that cannot be read on the same plane (Graynoth, 1999). The 'crack and burn' technique produces approximately 3-4% of otoliths that are unreadable or unclear (Chisnall, 1989; Chisnall and Hayes, 1991; Chisnall and Hicks, 1993). Due to the large sample size captured during the two-year study, 16% of all otoliths prepared were unreadable or too ambiguous. Increment interpretations were established for years spent in freshwater excluding structure prior to the freshwater check, which represents growth that occurred during time spent in marine waters.

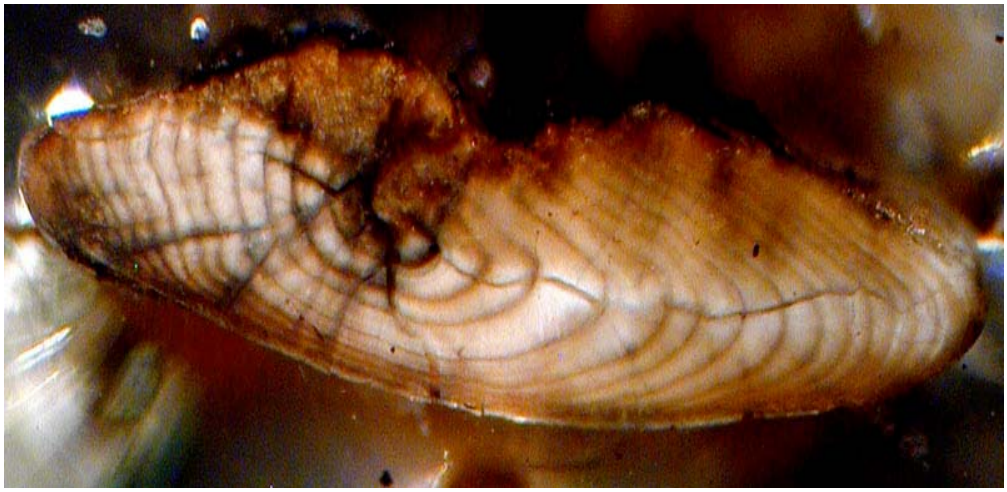

Figure 6.10. Burnt Otolith from a 14 year old, 677 mm shortfinned eel caught in Lake Trevallyn.

Age Validation

The short 2-year time frame of the study did not permit experimental studies on age accuracy and validation. However, previous studies in New Zealand have validated the otolith burning technique (Chisnall and Kalish, 1993). Chisnall and Kalish (1993) investigated validation of annual growth rings laid down each winter by New Zealand shorfinned eels (*Anguilla australis*) and longfinned eels (*Anguilla dieffenbachii*). Using essentially the same method of otolith preparation in this study, the validation of increment interpretation is based on the previous research mentioned.

The validation study involved capturing a sample of shortfinned eels (*Anguilla australis*) and longfinned eels (*Anguilla dieffenbachii*), tagging and then releasing them. Within a period of 3 years approximately 50% of the tagged eels were recaptured. It was stated that translucent zones counted after single flourescent rings corresponded to the number of years the eels had been free after being tagged. At the time of tagging otoliths were marked with oxytetracycline hydrochloride (OTC) and the occurrence of this OTC fluorecence within the translucent zone confirms that these zones were formed during winter in both species of eel. The crack and burn technique, which was utilised in this study was also validated and accepted as a tool for age determination for both species of New Zealand eel (Chisnall and Kalish, 1993).

The shortfinned eel (*Anguilla australis)* occurs in south Australia and New Zealand. A sample of approximately 50 otoliths were taken from both sampling periods and sent to New Zealand for preparation and increment interpretation. New Zealand estimates were compared to estimates generated by IFS staff. The chosen method of validation is again supported with secondary readings from the same organisation that completed the OTC validation work in 1993.

6.1.5 Data Analysis

Preliminary data analysis focused on otolith age estimations. Otoliths that provided age estimations with a satisfactory level of confidence were used to determine the mean age and age frequencies for the various sites fished. Where required, a two sample t-test was used to determine whether mean ages between locations were significantly different. Individual age class frequencies were tabulated and plotted. Age structure data was also plotted against past restock numbers in previous years relative to the mean age (years in freshwater) of elvers captured at the corresponding elver congregations at the two power stations. Samples of elvers were collected and aged for this reason including samples from past years to determine whether or not variation occurred between average ages. By subtracting the mean age (years in freshwater) of elvers from the total number of years since the year of restock, those eels captured throughout the sampling periods of the investigation are assumed to be of the same restock cohort.

Relative abundance of shortfinned eel (*Anguilla australis)* was quantified using Catch Per Unit Effort (CPUE), for the various sites and categories sampled. CPUE was measured by calculating the number of eels caught per net, per night. Due to the log-linear nature of the data, the geometric mean was then taken of the natural-logarithm of CPUE (ln(CPUE)) for each month fished. When CPUE is log-normally distributed, the arithmetic mean does not accurately describe the data (Sokal *et al*, 1997).

The geometric mean is calculated as the *n*th root of the product of the scores (y_i)*:*

$$GM_{\bar{y}} = \sqrt[n]{\prod y_i}$$

This is equivalent to calculating the arithmetic mean of the logarithm of each number, and then taking the exponent:

$$GM_{\bar{y}} = \exp\left[\frac{1}{n}\left(\sum \ln\left(y_n\right)\right)\right]$$

Differences in relative abundance between sites were statistically tested using one way Analysis of Variance (ANOVA).

6.2 IMPACTS OF HYDRO-ELECTRIC OPERATIONS ON 'SILVER' EEL MIGRATION

It was anticipated that the proportion of pre-spawning migrants impacted upon by hydro-electric operations would be determined from the number and condition of downstream-migrating silver eels captured: (i) immediately upstream of hydro dams; (ii) immediately below the dam; and (iii) immediately downstream of the turbine intake below the power generating station. However, during the course of the study, these methods could not be undertaken due to unforeseen circumstances. eg. Hazardous and unsafe working conditions including extremely high flows. Of the adult eels captured during sampling with fine mesh fyke nets, only a small proportion were true migrating eels. This may have been attributed to the unusual seasonal conditions that Tasmania had experienced over the study period (low rainfall and the resultant poor river flows).

It became apparent that it was not feasible to trap all eels passing though turbines below power generating stations, due to the sheer volumes of water that are released (even during periods of low power generation) and Occupational Health and Safety (OH&S) issues when operating in tailraces. Various options were investigated with

respect to the trapping of eels that pass through the Meadowbank and Trevallyn power stations. In particular, the Trevallyn Tailrace water discharge levels and the viability of attaching a large scale net was assessed. Pressure placed on anchor points and the associated force applied to the net were perceived to potentially be too great creating an unsafe workplace.

6.2.1 Data Collection

The sample size of migrating eels during the months of October, November and December 2002 was increased by purchasing random/representative samples from commercial eel fishers, which were not available to the IFS during the first sampling period. Rainfall and channel flow data was gathered and plotted against 'silver' eel catch data collected from commercial eel fishers. This data enabled the formulation of a model predicting periods of downstream movement of 'silver' migrating eels as a function of water flow. Relationships derived from the model were then used as inputs to simulate downstream movement of eels through major dam environments in Tasmania. Mortality varies as a function of power generation, water flow (riparian releases) and dam spills. Information gathered on downstream movement coupled with turbine mortality results enabled mortality predictions for different operating scenarios.

6.2.2 Data Analysis

By using turbine characteristics in addition to migrating eel data, eel mortality rates from the relevant Hydro-electric stations have been estimated. A study carried out in France (Larinier and Dartiguelongue, 1989), has resulted in a predictive formulae estimating the mortality rate of juvenile salmonids and eels through Kaplan turbines and juvenile salmonids through Francis turbines, based on the properties of the turbine and fish length.

For eels passing through a Kaplan turbine:

$$P = 100 * (SIN((3.14/180)*(28.6+48.7*((TL*NAP)/(3.14*D)))))^{\wedge 2}$$

Where P is the percentage mortality rate, TL is the length of eel, NAP is the number of blades and D is turbine diameter.

Predictive formulae utilised in the study is therefore limited to Kaplan turbine design and is applied to power stations within the two river systems containing them. However, certain assumptions may be applied for power stations containing Francis turbines such as the Trevallyn power station. Past research reveals that Francis turbines are responsible for higher mortality rates than Kaplan turbines due to the nature of the design (Travade and Larinier, 1992). By using mortality results obtained at power stations with Kaplan turbines, a benchmark is provided for the assumption that the mortality rate is higher in power stations that contain Francis turbines.

7. RESULTS

7.1 UPSTREAM ELVER MIGRATION AND POPULATIONS

7.1.1 The Derwent Catchment

Mesh Selectivity

Field personnel noted that some fine-mesh fyke nets sustained damage such as holes and tears. Some of the damaged areas had rings of mucus/slime around them, indicating the egress of an eel through the damaged area. These holes tended to be at the base of the entrance, suggesting that this was where eels attempted to escape. Damaged fyke nets did not contain large eels, and so this was accounted for in the analysis by excluding data from damaged nets.

Figure 7.1 represents the variation in catch rates for the two different mesh sizes. The coarse mesh fyke nets in the Derwent River produced more large eels compared to the fine mesh fyke nets. For the situation in Lake Meadowbank, there is no clear difference in catch rates of larger eels between mesh sizes.

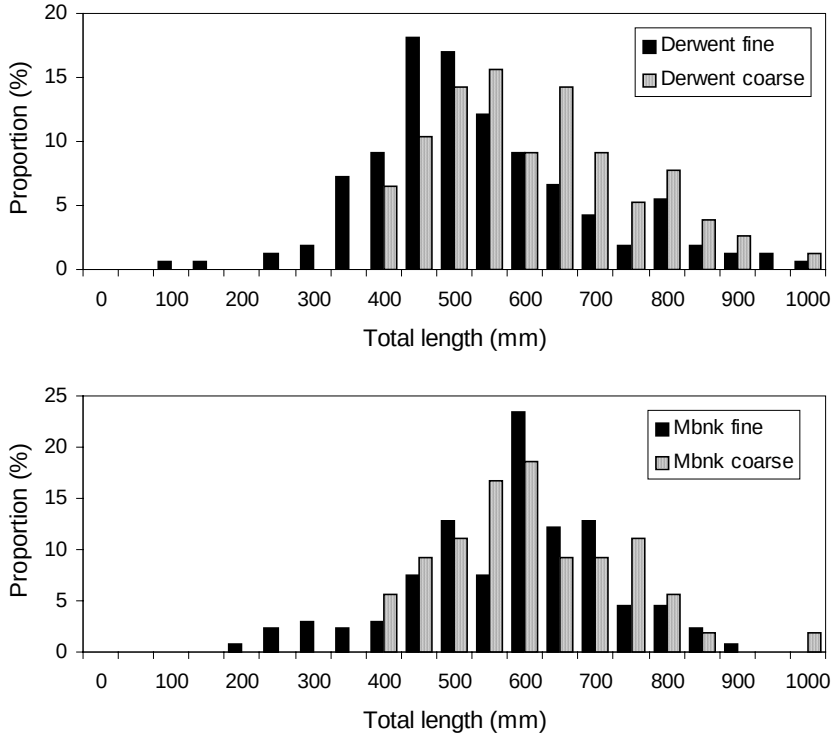

Figure 7.1. Size composition of short-finned eels (*Anguilla australis*) captured in fine- and coarse-mesh fyke nets in the Derwent River below Meadowbank Dam and in Lake Meadowbank.

Contingency table analysis was used to test for statistical difference in size composition of eels captured by the fine and coarse-mesh nets. Catches from Meadowbank and Derwent locations were analysed separately. Eels <400 mm total length were excluded from the analysis as the focus of the analysis is whether large eels are less selected for in the fine-mesh nets (not whether small eels are not sampled by the coarse-mesh nets, which is known). When the expected number of eels in a cell was <5, actual counts were pooled until all expected values were ≥5 (Table 7.1).

Table 7.1. Observed frequencies of short-finned eel (*Anguilla australis)* caught by fyke nets in the Derwent River and Meadowbank Dam.

Derwent			***Meadowbank***		
Fine-mesh (% of catch)	Coarse-mesh (% of catch)	Total (No's)	Fine-mesh (% of catch)	Coarse-mesh (% of catch)	Total (No's)
75	25	**20**	57	43	**7**
79	21	**38**	66	34	**15**
72	28	**39**	74	26	**23**
62.5	37.5	**32**	53	47	**19**
68	32	**22**	76	24	**41**
50	50	**22**	76	24	**21**
50	50	**14**	77	23	**22**
43	57	**7**	50	50	**12**
60	40	**15**	67	33	**9**
50	50	**6**	67	33	**6**
62.5	37.5	**8**			
146	**77**	**223**	**121**	**54**	**175**

There was no statistical significance in eel size composition between fine-and coarse-mesh nets at either the Derwent or Meadowbank: (Derwent: $\chi^2 = 11.00$, df = 10, P = 0.53; Meadowbank: $\chi^2 = 7.27$, df = 9, P = 0.61.

Screen Selectivity.

Contingency table analysis was used to test for statistical difference in size composition of eels captured by nets without an exclusion screen and nets with 110 mm (stretched mesh) screens attached. The data was pooled for all locations from the 2000/2001 sampling period and any eels <400 mm total length were excluded from the analysis as the analysis was to determine whether or not large eels are excluded in the nets containing a 110 mm exclusion screen.

Figure 7.2 represents the variation in eel catch in nets with and without a 110 mm screen attached. From preliminary observations, eels throughout the size range captured were caught in both types of net.

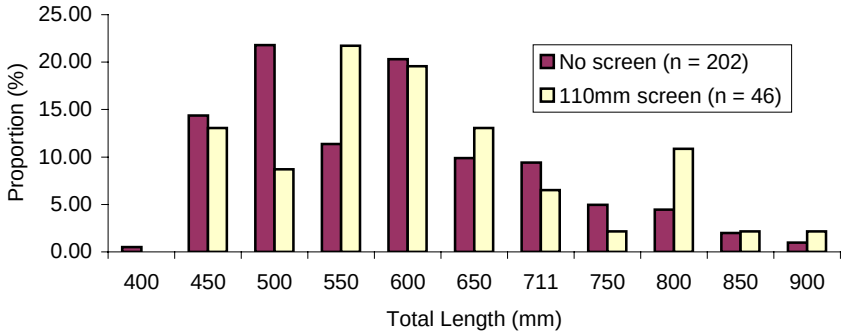

Figure 7.2. Size composition of shortfinned eels (*Anguilla australis)* captured in fine mesh fyke nets containing no screens and containing 110 mm screens.

There was no statistical significance in eel size composition between nets without screens and 110mm (stretched mesh) screen nets for the pooled data: (χ^2 = 11.14, df = 10, P = 0.34).

Data Analysis

The results focus on data from sites above and below hydro-electric dams in an attempt to determine differences in population structure, due to the impacts of hydro-electric power stations. The results were also compared to past elver restocking events in order to assess their effect on upstream populations.

The estimated mean age of eels captured in the Derwent River during the 2000/2001 sampling period is significantly greater than those from Lake Meadowbank (t_{599} = 5.494, P<0.05) (Figure 7.3). Sampling undertaken during the 2001/2002 period for both sites resulted in a significant drop in mean age; Derwent River (t_{586} = 17.588, P<0.05); Lake Meadowbank (t_{327} = 5.120, P<0.05). The Derwent River in 2001/2002 produced a mean age significantly less than that of Lake Meadowbank (t_{301} = -4.676, P<0.05). These results contradict those of the 2000/2001 sample.

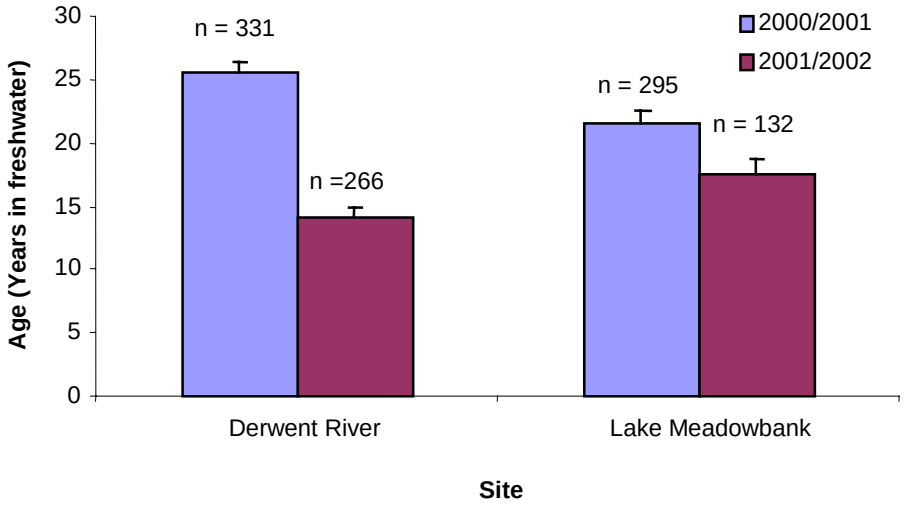

Figure 7.3. Inter-annual mean age of *A. australis* between sites above and below the Meadowbank Dam. Mean ages are plotted with 95% confidence limits.

Results show little variability between age frequency data above and below the Meadowbank dam. Both populations had catches representing eels from a wide range of year classes giving a relatively 'normal' age frequency distribution for the two zones (Figure 7.4; Figure 7.5). Lake Meadowbank age frequency results (Figure 7.5) show that 92.5% of eels caught were younger than the age of the dam while 7.5% were older than the age of the dam at time of sampling.

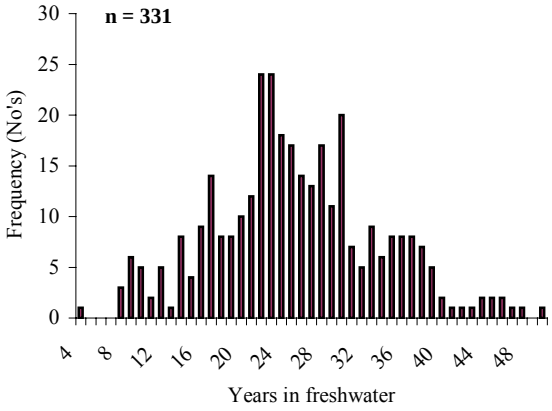

Figure 7.4. Derwent River *A. australis* age frequency distribution (2000/2001).

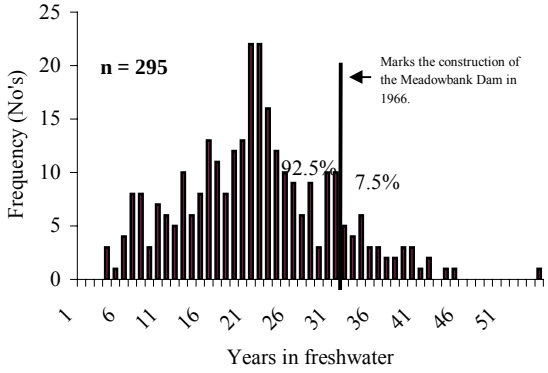

Figure 7.5. Lake Meadowbank *A. australis* age frequency distribution (2000/2001).

Variability was observed between the age frequency distributions for sites above and below the Meadowbank dam in the 2001/2002 sampling period (Figure 7.6; Figure 7.7). Consistent with sampling from the first year, the sample size collected from the Derwent River (Figure 7.6) was significantly greater than Lake Meadowbank (Figure 7.7). Secondary samples collected from the Derwent River however, contained larger numbers of juvenile eels including many that have spent no more than a year in freshwater. Explanations for annual variations in age structure within the Derwent River are given later in the discussion. Lake Meadowbank age frequency distribution from the 2001/2002 season shows a similar pattern to that of 2000/2001.

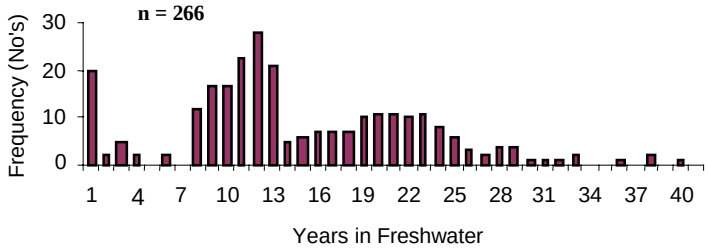

Figure 7.6. Derwent River *A. australis* age frequency distribution (2001/2002).

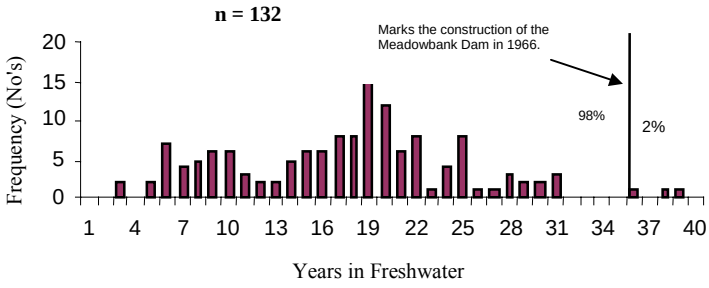

Figure 7.7. Lake Meadowbank *A. australis* age frequency distribution (2001/2002).

The separation of age structure showing frequencies of eels that have spent no greater than 10 years in freshwater are shown in Figure 7.8 and Figure 7.9. The Derwent River (Figure 7.8) produced high numbers of juvenile eels that had spent no more than 1 year in the Derwent River system, as opposed to Lake Meadowbank (Figure 7.9) with the youngest having spent approximately 3 years in freshwater.

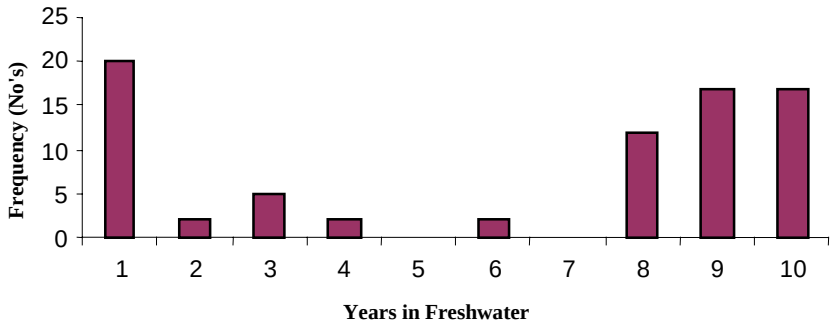

Figure 7.8. Derwent River age structure of *A. australis* <10 yrs old (2001/2002).

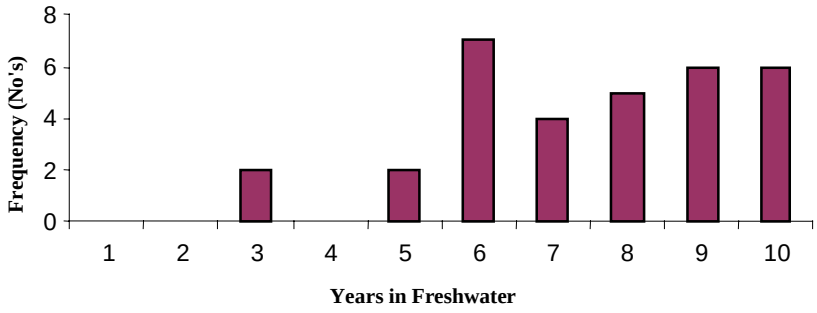

Figure 7.9. Lake Meadowbank age structure of *A. australis* <10 yrs old (2001/2002).

Age structure formulated from data collected in Lake Meadowbank is also presented relative to historic elver restocking records (Figure 7.10). Figure 7.10 examines the relationship between past restocking practises in relation to quantities of those age classes captured throughout the sampling period. The average age of elvers captured in the Meadowbank trap is 4 years in freshwater. Therefore, an eel captured during sampling that has been classed as spending 10 years in freshwater, is assumed to have been trapped below the dam and transferred upstream during the 1994/1995 elver migration 6 years ago (estimated at time of sampling). Eels captured during sampling represented by the darkened columns in Figure 7.10 are not accounted for using historic elver records (no records were kept prior to 1980/1981). There are no clear relationships between restock records and age frequency data.

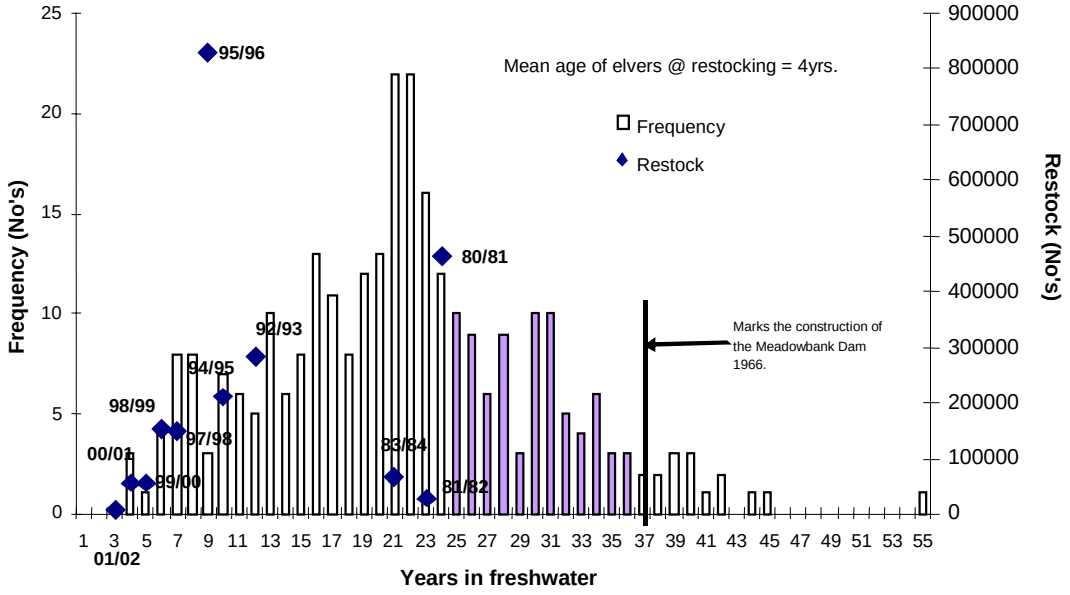

Figure 7.10. Lake Meadowbank *A.australis* age frequency distribution (2000/2001) vs historic elver restock events. Note: the area darkened represent those eels not accounted for with past restock records.

Population differences are highlighted in CPUE data (Figure 7.11). The Derwent River shows a higher CPUE compared to Lake Meadowbank. However, differences in relative abundance were not statistically significantly different ($F_{1,32} = 1.779$, $P>0.05$) between the Derwent River and Lake Meadowbank for 2000/2001. Sampling undertaken during December resulted in the largest difference in relative abundance between the two sites. As sampling continued through January and February, CPUE in the Derwent River steadily declined whilst Meadowbank CPUE remained relatively constant. Fishing was not undertaken in the Derwent River in November at the beginning of the sampling season.

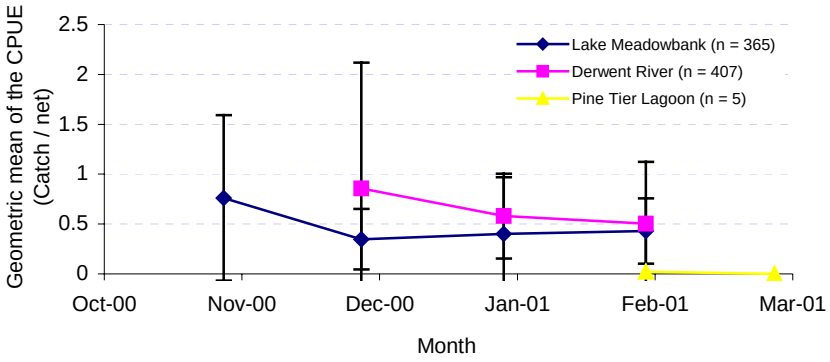

Figure 7.11. Derwent River / Lake Meadowbank *A. australis* CPUE (2000/2001). Geometric means are plotted with 95% confidence limits.

Figure 7.11 also highlights an extremely low relative abundance of eels in Pine Tier Lagoon where only 5 individuals were captured during the two weeks of sampling. CPUE results are given for the 2001/2002 sampling period in Figure 7.12. Sampling times throughout the second season in the Derwent Catchment were inconsistent as sampling during this time was concentrated on the Tamar Catchment. For the periods that sampling was performed in the Derwent Catchment, clear variations in relative abundance are observed between the Derwent River and Lake Meadowbank. The difference in relative abundance for 2001/2002, are significantly different ($F_{1,28}$ = 6.87, $P<0.05$).

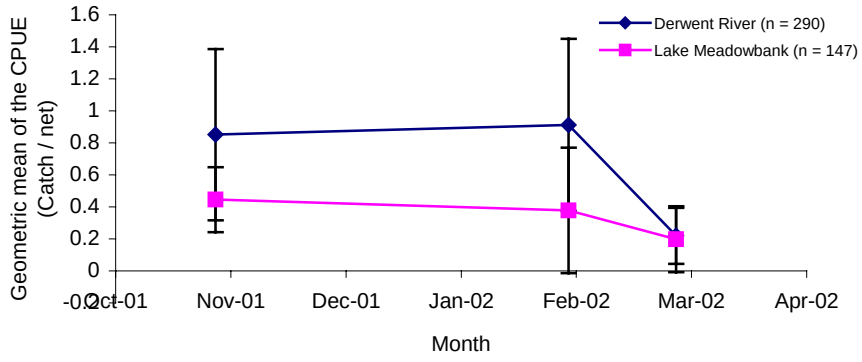

Figure 7.12. Derwent River / Lake Meadowbank *A. australis* CPUE (2001/2002). Geometric means are plotted with 95% confidence limits. No sampling undertaken in Dec / Jan due to sampling in northern sites.

Average age results for other sites sampled during the 2000-2001 season show little variability between sites with the exception of the Meadowbank trap that actively attracts juvenile eels (Figure 7.13). The Meadowbank trap catch had a large number

of eels that have spent a small number of years in freshwater, compared to those eels sampled using conventional fishing methods (Figure 7.14). Pine Tier Lagoon produced five eels with little confidence placed in mean age estimation.

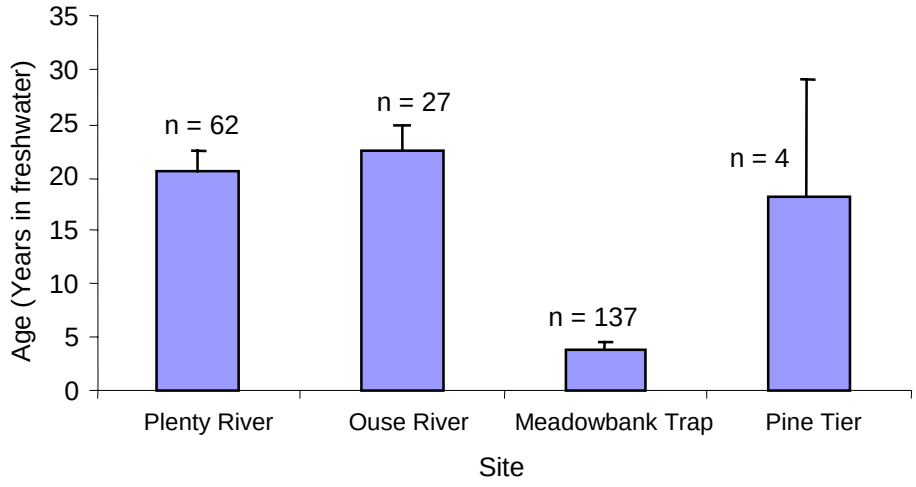

Figure 7.13. *A. australis* mean ages for sampling sites in 2000/2001. Mean ages are plotted with 95% confidence limits.

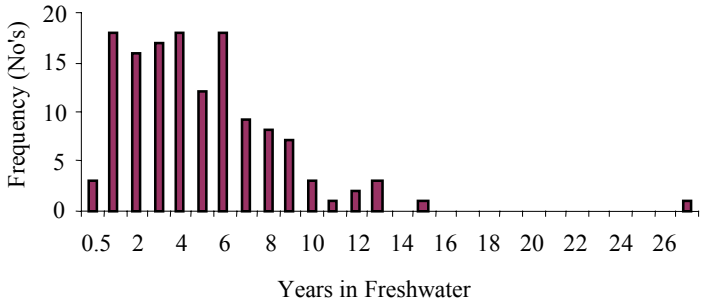

Figure 7.14. Meadowbank trap *A. australis* age frequency distribution (2000/2001).

Samples obtained from the Ouse and Plenty rivers are significantly smaller resulting from lower levels of fishing effort. Age frequency results however, signify clear variations in age structure between the two riverine habitats above and below the Meadowbank Dam (Figure 7.15; Figure 7.16). The Plenty River (Figure 7.15) represents a wider age distribution compared to the Ouse River (Figure 7.16) where no eels under 12 years old were sampled. It should also be noted the difference in sample size resulting from equal fishing effort between the two rivers, is indicative of variations in abundance with greater numbers captured in the Plenty River.

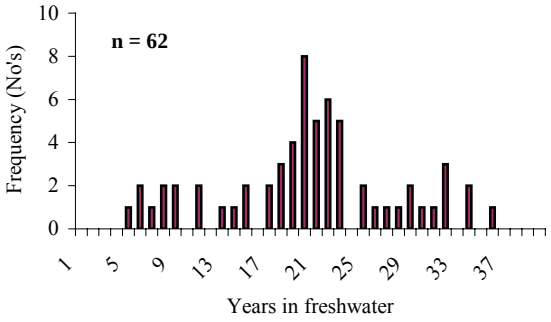

Figure 7.15. Plenty River *A. australis* age frequency distribution (2000/2001).

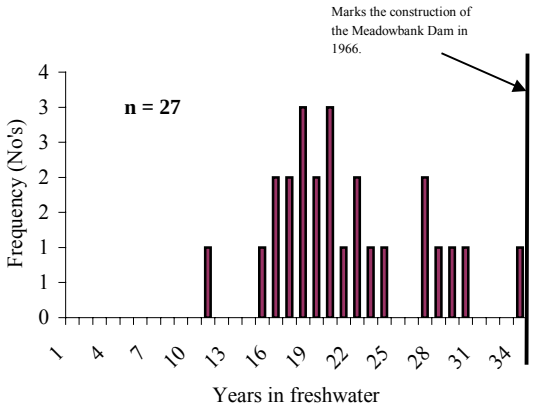

Figure 7.16. Ouse River *A. australis* age frequency distribution (2000/2001).

7.1.2 The South Esk – Great Lake Catchment

Figure 7.17 shows the average age of eels captured at sites within the Tamar Catchment during the 2001/2002 season. The North Esk on average consisted of older eels than Lake Trevallyn and was estimated to be significantly different ($t_{195} = 3.476$, $P<0.05$). The average age of the elver samples obtained from the Trevallyn Tailrace is estimated to be no greater than 1 year in freshwater. Arthurs Lake (not represented) produced only 1 eel, which was estimated to have lived in freshwater for approximately 50 years.

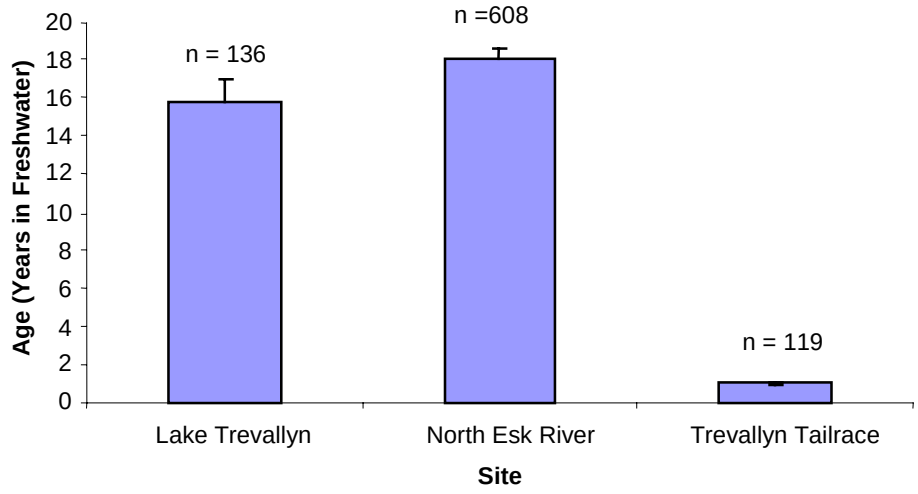

Figure 7.17. Mean ages for samples taken in 2001/2002 plotted with 95% Confidence Limits.

Age frequency distribution results are illustrated in Figure 7.18 and Figure 7.19. Catches in the North Esk (Figure 7.18) were very high relative to Lake Trevallyn (Figure 7.19) representing eels of all age classes. The smaller sample sizes represented in Lake Trevallyn produced a scattered age frequency distribution with inconsistent catch rates of varying age classes. The majority of eels collected out of Lake Trevallyn were estimated to be younger than the age of the dam.

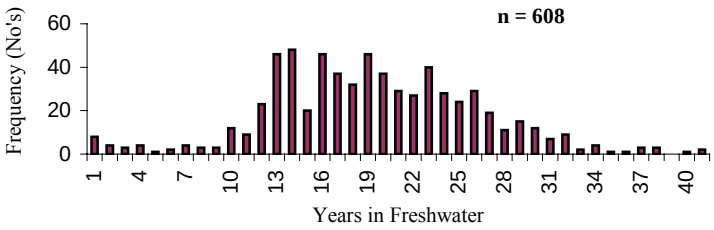

Figure 7.18. North Esk *A. australis* age frequency distribution (2001/2002).

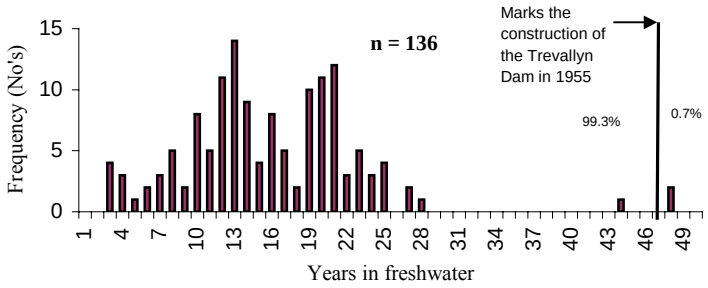

Figure 7.19. Trevallyn *A. australis* age frequency distribution (2001/2002).

Age structure was observed in greater detail by separating all eels 10 years and younger from the data set (Figure 7.20; Figure 7.21). Eels captured of these ages are assumed to be of the feeding eel class and represent the true populations inhabiting sites sampled. High confidence is also placed in age estimations of younger eels due to the increased clarity and improved presentation of otolith preparations.

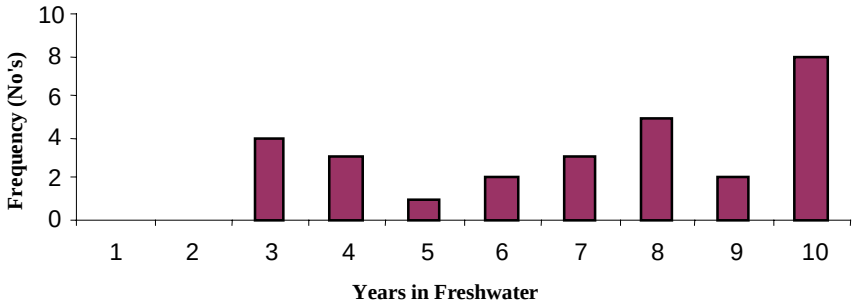

Figure 7.20. Lake Trevallyn age structure of *A. australis* <10 yrs old (2001/2002).

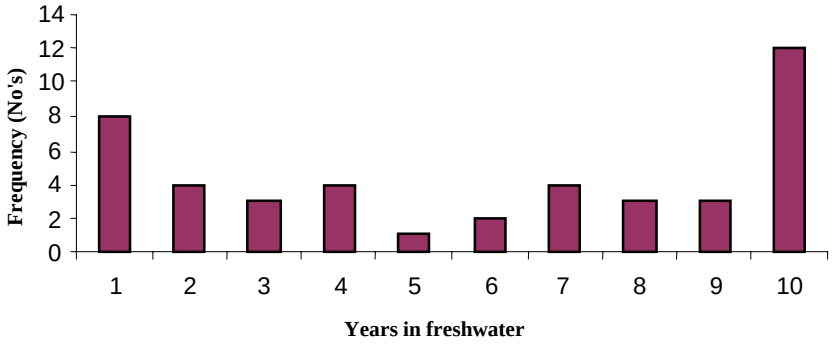

Figure 7.21. North Esk age structure of *A. australis* <10 yrs old (2001/2002).

Lake Trevallyn did not contain any eels that had spent less than three years in freshwater. The North Esk consists of eels from each individual year class from 1-10 years in relatively substantial numbers.

Figure 7.22 presents the age frequency data relative to past restock events in Lake Trevallyn. Past restock records, as mentioned earlier, are not available prior to the 1980/1981 elver harvesting season. Similar to the restock diagram presented for Lake Meadowbank, there is no apparent relationship between restock records and

corresponding age frequencies of eels (assuming they are from the same cohort). There is, however, an absence of eels between the age of 29 and 43 where there is clearly no record of elver transfer into Lake Trevallyn.

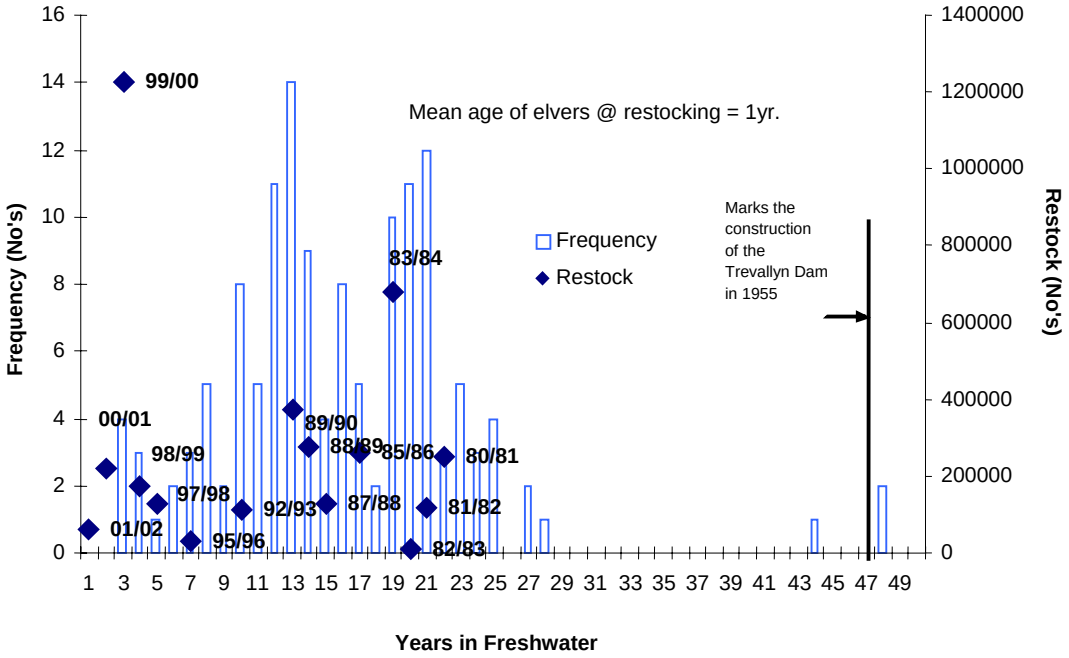

Figure 7.22. Lake Trevallyn *A. australis* age frequency (2001/2002) Vs historic elver restock events.

CPUE results (Figure 7.23) illustrate the differences in relative abundance above and below the Trevallyn Dam. Results show a much clearer difference in seasonal CPUE above and below the Trevallyn dam as opposed to Meadowbank results. Throughout the 2001/2002 sampling season, the North Esk consistently produced a high CPUE relative to Lake Trevallyn, with the years variation in relative abundance variations being significantly different ($F_{1,42}$ = 53.790, P<0.05) Arthurs Lake with only one eel caught for the 2 weeks of sampling marks a low CPUE.

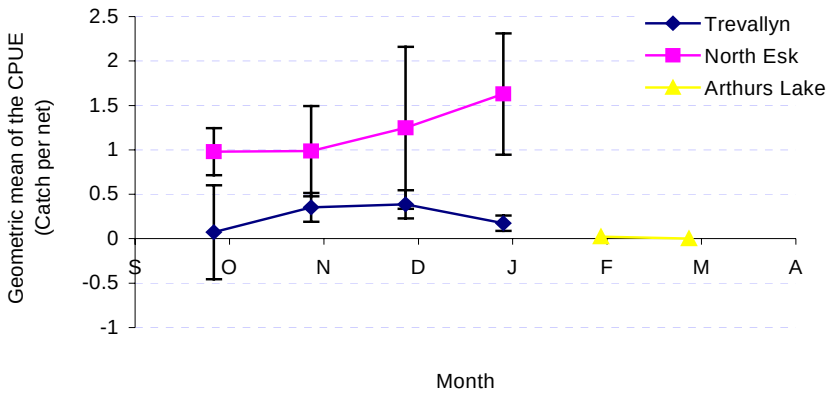

Figure 7.23. Trevallyn / North Esk *A. australis* CPUE (2001/2002).
Geometric means are plotted with 95% Confidence Limits.

7.2. DOWNSTREAM 'SILVER' EEL MIGRATION

Downstream movement predictions

Potential relationships between migrant catch data and environmental variables considered influential in triggering downstream movement: rainfall and channel flow were analysed (Figure 7.24; Figure 7.25). Migrant catch data has been collected from commercial eel fisher returns. The eels were harvested in front of the intake tower of the Trevallyn Power Station and are subsequently all 'silver' migrating eels. The resulting plots of flow vs eel catch shows an inconsistent pattern (Figure 7.24). Clear correlations are observed in some years (eg. 1994/1995 and 1999/2000) between peak catches and periods of high water flow. Other years however, show low water flow during times of peak catches (eg. 2000/2001) For the majority of years observed, the silver eel catch consistently increases during the month of February providing no real relationship between catch and channel flow. Results indicate a more defined relationship between monthly average rainfall data and migrant eel catch (Figure 7.25), with peak eel catches consistently associated with relatively high rainfall periods.

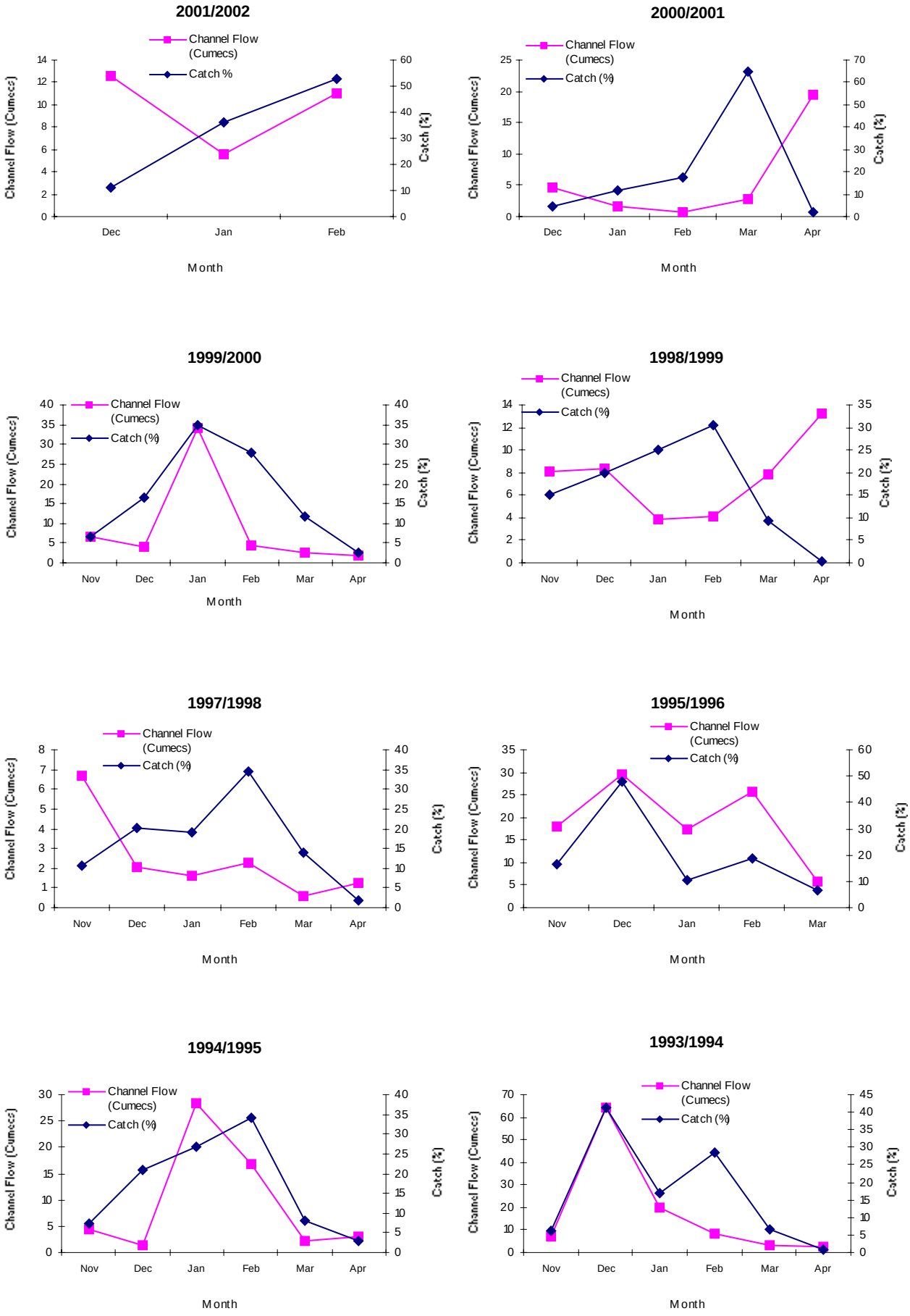

Figure 4.24: Channel Flow Vs 'Silver" Eel Catch

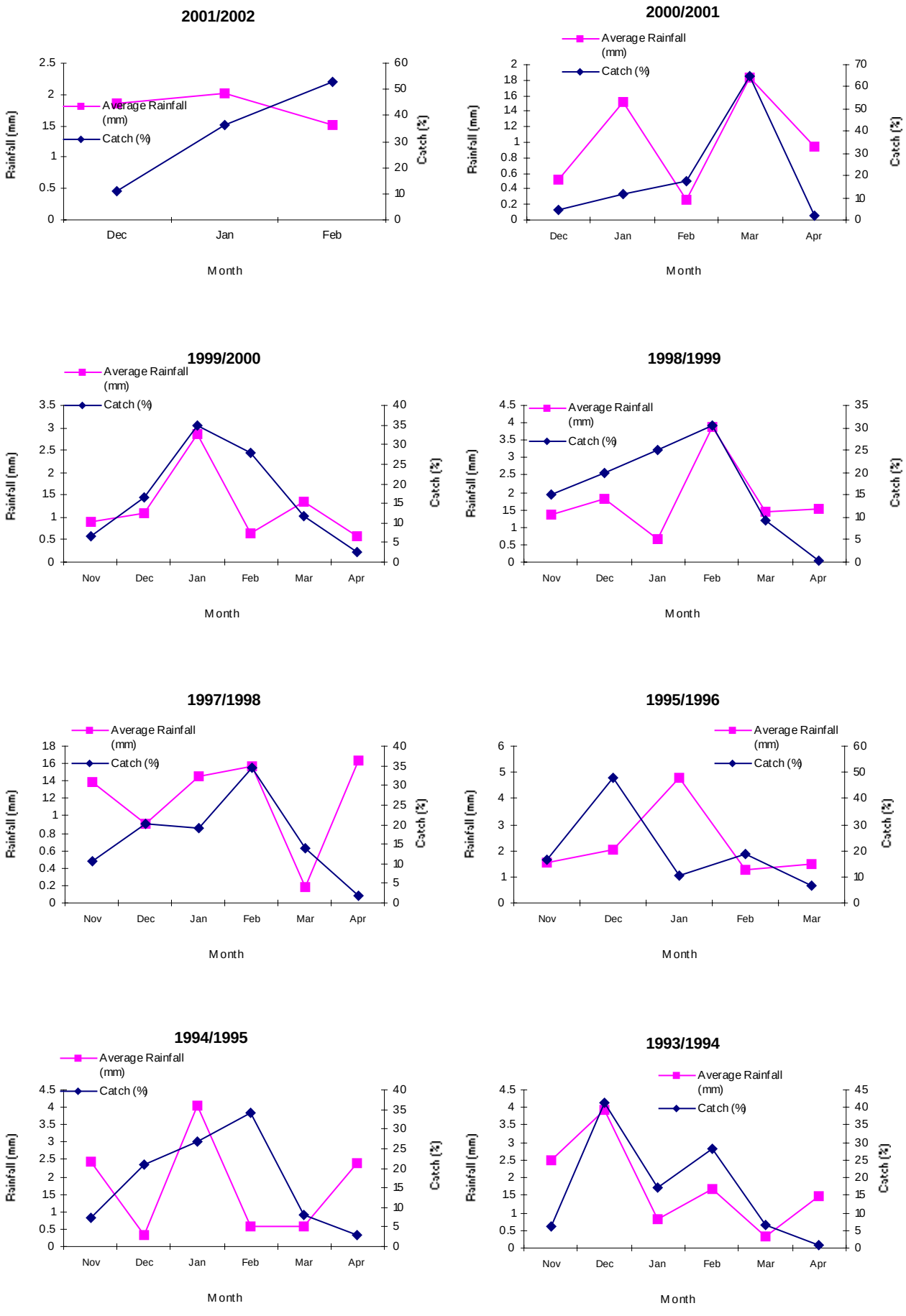

Figure 4.25: Rainfall Vs 'Silver" Eel Catch

Commercial catch data indicate that silver eels start their migration during the months of October / November and generally run into March and April. This data is somewhat limiting in that the commercial eel fisher who has over 20 years experience in targeting migrating eels only fishes during these months. Very little effort is made to harvest migrating eels outside of these months due to small quantities harvested (i.e. not commercially viable).

The sample of sexually mature migrating eels that was obtained had an average length of 800 mm with the range being 600-1000 mm. All migrators were female with an average age of 25 years in freshwater.

Turbine Mortality

Parameters considered influential to mortality rates were standard for Kaplan turbines resulting in equal estimations for the Repulse, Cluny and Meadowbank power stations. Parameters taken into consideration include the diameter of turbine (4.5 m), the number of blades (5) and the mean eel length (0.8 m). The estimated mortality of Kaplan turbines is 45%. For the purposes of the study, the mortality rate at a Francis turbine is generalised at 50%. The mortality rate at a Pelton turbine is assumed to be 100% after reviewing relevant literature (Monten, 1985; Travade and Larinier, 1992). Figure 7.27 and Figure 7.28 illustrate these mortality estimations in relation to turbine locations within the two catchments investigated.

For eels that become entrained in Kaplan turbines along the Derwent River, it was estimated that 45% are killed. Francis turbines are responsible for higher mortality rates averaging approximately 20% higher than Kaplan turbines (Travade and Larinier, 1992). Calculations show a linear relationship between Total Length and Mortality rate (Figure 7.26). The larger the eel, the higher the probability of death or injury.

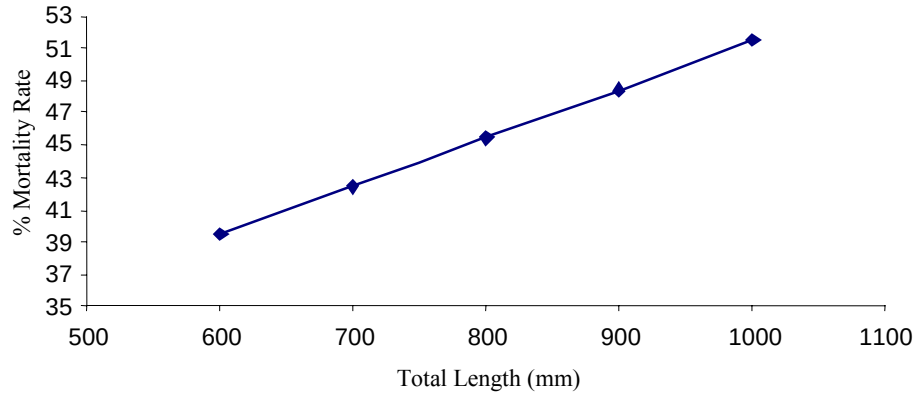

Figure 7.26. Mortality rate through the Meadowbank Kaplan turbine vs total length of *Anguilla australis*. (Equation Source: Travade and Larinier, 1992)

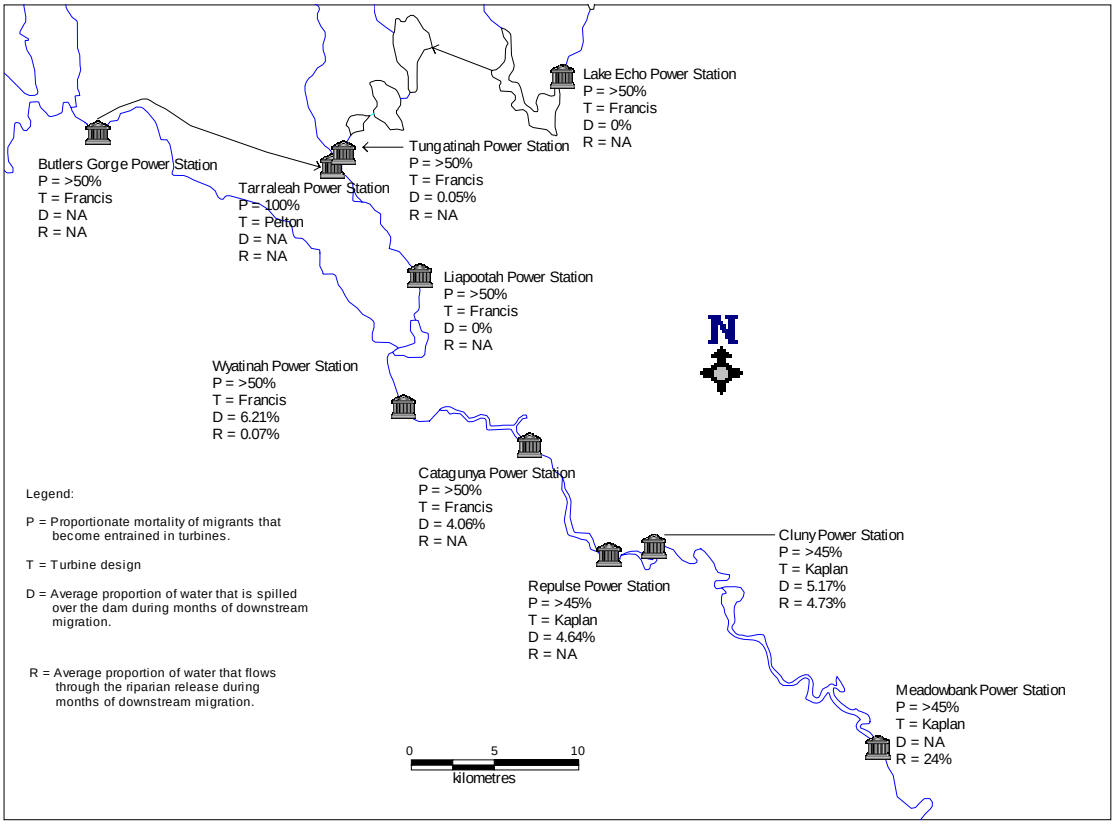

Figure 7.27. Turbine induced mortality rates within the Derwent River System.

Information gathered has enabled the formulation of conservative mortality estimations that may occur at various power stations around Tasmania and the probability of 'silver' eels successfully emigrating out to sea from the variety of

populations within the two catchments sampled. Using these conservative estimates, the numbers of eels that can potentially escape to sea can be estimated depending on the area of habitation and the number of barriers between it and the sea.

For example:

Example 1

Any populations upstream from the Tarraleah Power Station will not survive downstream migration due to the presence of Pelton turbines.

Example 2

A population of 1000 'Silver' eels inhabiting Lake Echo attempt to migrate downstream and must pass through multiple power stations to reach the spawning grounds (Table 7.2)

Table 7.2: 'Silver' eel turbine mortality rates downstream of Lake Echo.

Power Station	% Mortality	Survivors
Echo	50	500
Tungatinah	50	250
Liapootah	50	125
Wayatinah	50	62
Catagunya	50	31
Repulse	45	17
Cluny	45	9
Meadowbank	45	5

Therefore, according to Table 7.2, a total of 5 downstream migrating eels from the original population in Lake Echo are expected to reach waters below the Meadowbank Dam alive.

Example 3

A population of 1000 'Silver' eels inhabiting Cluny Lagoon attempt to migrate downstream.

Table 7.3: 'Silver' eel turbine mortality rates downstream of Cluny Lagoon.

Power Station	% Mortality	Survivors (No's)
Cluny	45	550
Meadowbank	45	302

Therefore, according to Table 7.3, a total of 302 downstream migrating eels from the original population in Cluny Lagoon are expected to reach waters below the Meadowbank Dam alive.

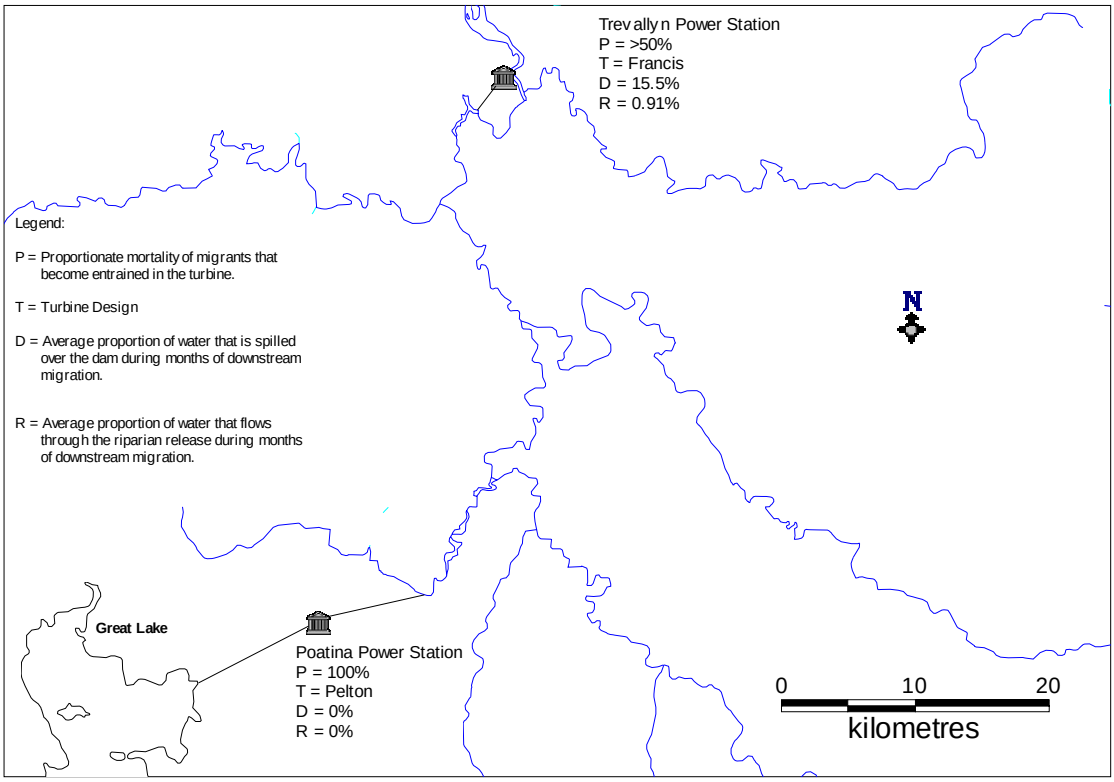

Figure 7.28. Turbine induced mortality rates within the Great Lake – South Esk system.

Example 4

Any eel inhabiting the Great Lake will have to pass through the Pelton turbines within the Poatina Power Station, where it is believed that 100% mortality occurs.

Example 5

A population of 1000 eels inhabiting Lake Trevallyn and waters upstream of the lake attempt to migrate downstream. A total of 500 eels survive entrainment through the

Trevallyn Power Station turbine (50% mortality) assuming the dam wasn't spilling at time of migration.

8. DISCUSSION

8.1 UPSTREAM ELVER MIGRATION

Selectivity studies undertaken throughout the investigation indicate that a representative sample of the population was consistently obtained using fine mesh fyke nets with the inclusion of 110 mm exclusion screens. The paired-trawl approach to determining the size-selectivity characteristics of a net is based on a comparison of the size composition of the catch in the retention area (eg. the cod end) of the two nets being compared. If the wings of the two nets have different effects on the target species, then a comparison of the cod end capture will be a comparison of the selectivity characteristics of both the cod end and the wings. When the difference in catchability/selectivity of the two nets is based on eel behaviour, especially when size-dependent, then it is impossible to measure the size-selectivity of the nets (Millar *et al.* 1999). Results obtained from this investigation are based on the assumption that equipment used did not present any size selectivity when capturing eels and a representative sample of each population was adequately obtained. Contingency table analysis supports this assumption.

Data gathered is somewhat limited. Results show some degree of variability between key sites sampled above and below selected dams but gives little valuable information with regard to applying definitive levels of hydro-electric impacts on eel migration and populations. Before the analysis of data collected in the field, a number of expectations were established.

For the situation of natural recruitment (not dammed, not stocked), it is expected that the age structure of the population would have a normal distribution. (Figure 8.1).

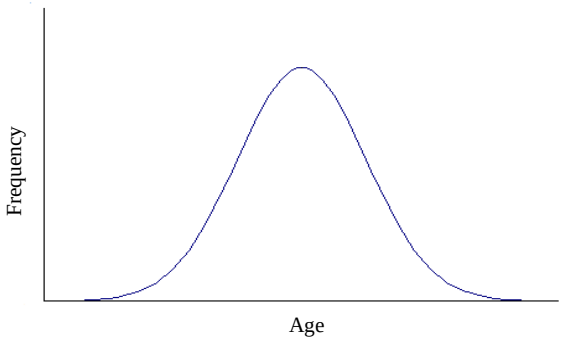

Figure 8.1. Natural recruitment

For waters that have been dammed and not stocked, it is expected that the age structure would show eels only older than the age of the dam, presenting a skewed distribution towards older stock, assuming the water has maintained a closed population since the construction of the dam wall (Figure 8.2).

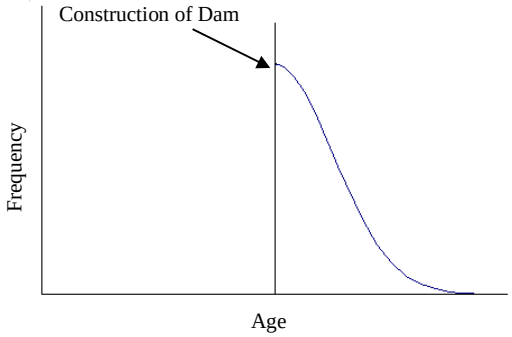

Figure 8.2. Dammed and not stocked

For waters that have been dammed and stocked, the age frequency distribution would ultimately depend on the levels of stocking in past years, therefore a variable distribution would be anticipated for eels younger than the age of the dam (Figure 8.3).

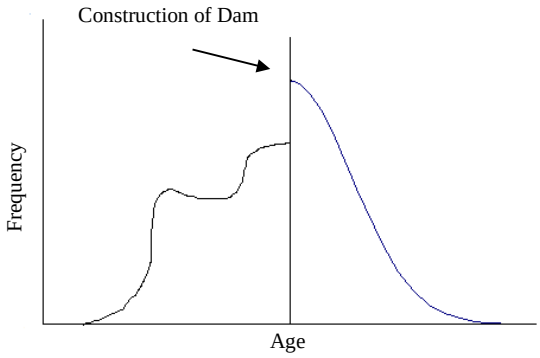

Figure 8.3. Dammed and stocked

Two of the objectives of this investigation were to assess the impact of hydro dams on eel populations in Tasmanian rivers and lakes, and to evaluate the effectiveness of the elver restocking program that has occurred for more than 20 years. It was originally proposed that information gathered from results would determine the effectiveness of elver restocking. If the quantity of elvers transferred is a small proportion of what would have migrated upstream in the period prior to dam construction, or if a large proportion of them died after transfer, then the contribution to the upstream population would have been minor. In this case there would be few eels in the population younger than the age of the dam. If the transferred elvers made a significant contribution to the upstream population then a large proportion of the population would be younger than the age of the dam.

However, there are implications involved with this otherwise relatively simple experiment. Both major dams investigated are very old relative to the average age of a feeding eel (Figure 7.5; Figure 7.7). Meadowbank dam was 36 years old and Trevallyn dam was 47 years old at the time of sampling. With the average age of the feeding eel much younger (10-30 years in freshwater) than the age of the dams, regardless of the impacts of hydro-electric power stations, the majority of captured eels anywhere in the State will be younger than the age of these two dams.

The data indicates that past restocking practises have had an effect in maintaining populations above hydro-electric dams. There is also however, information indicating significant differences in population structures in the sampled waters giving reason to believe that populations have the potential to improve and enhance through improved stocking regimes or strategic mitigation practises.

Age frequency results in the Derwent catchment show little variability in the 2000/2001 sampling period (Figure 7.4; Figure 7.5) between Lake Meadowbank and the river downstream. The Derwent River (Figure 7.4) is recruited naturally and as expected, the age structure consists of a range representing all age classes. The population consists of juvenile eels migrating upstream in addition to feeding eels inhabiting the area before returning to sea. Lake Meadowbank (Figure 7.5) illustrates a normal distribution throughout the age range similar to the Derwent River. It is difficult to try and separate age structures before and after the Meadowbank dam was constructed because of the age of the dam. However, Figure 7.5 indicates a healthy population of young eels to old eels, thereby supporting the effectiveness of past manual elver transfers for restocking. Meadowbank / Derwent age frequency results for the 2001/2002 sampling period (Figure 7.6; Figure 7.7) indicate more obvious differences in the age structure between the two sites. The natural recruitment that enters the Derwent River results in a higher frequency of very young eels (Figure 7.6) compared to Lake Meadowbank (Figure 7.7). An explanation for this may be associated with the modified fishing techniques implemented after the introduction of the exclusion screen policy. This allowed the nets to fish more effectively at low tide increasing the chances of glass eel / elver capture during the night and therefore reducing the resultant average age.

Figure 7.10 highlights a range of year classes that have not been manually transferred according to restock records. An explanation for this may be the fact that the mean age of elvers trapped at the base of the Meadowbank dam has been estimated to be 4 years old. This sample of elvers contained ages ranging from 0.5 to 15 years in freshwater. This suggests that there may be a significant proportion of elvers stocked into Lake Meadowbank, which have spent well over 4 years in freshwater but the generalisation of the data have designated them into a restock year that is not particularly accurate. By taking the mean of the data, the end result is those ages highlighted, which were not accounted for in the restock records (Figure 7.10). Also, anecdotal evidence suggests that restocking has been operating well beyond recorded events. The IFS does not hold records of elver stockings that may have occurred in waters prior to 1979-80. IFS staff employed in the 1970's verified that unofficial restocking was carried out by Hydro Tasmanian employees and was a regular annual occurrence prior to the 1980's (Vic Causby, pers. com.). Both charts (Figures 7.10

and 7.22) fail to present any relationship between restock levels and age frequency but they do show a correlation between restock years and year classes, indicative of the effectiveness of past restocking practises.

Although population structure differences appear marginal between Lake Meadowbank and the Derwent River, there is a marked difference in sample size between the two sites and CPUE results support the difference in relative abundance (Figure 7.12). Although past elver restocking has made a significant contribution, the Meadowbank Dam has clearly effected populations immediately upstream even with the support of elver transfers. CPUE results for 2000/2001 (Figure 7.11) show seasonal variations in relative abundance between the two sites but statistical analysis confirms that variations are not significant. It is thought that the CPUE estimated for the Derwent River is underestimated. The Derwent River suffers tidal fluctuations affecting the efficiency of the fyke nets. Cod-ends were required to be out of water at the highest of tides, adding to the decreased efficiency of the nets. Population estimates from the Derwent River in 2001/2002 clearly illustrate a greater population density suppported by an Analysis of Variance stating that the relative abundance between the two sites are significantly different (Figure 7.12). A strong indication that the Meadowbank dam has directly resulted in a decline in eel abundance.

Results obtained from sampling in the Plenty and Ouse rivers support findings from Lake Meadowbank and the Derwent River in that the sample size, as expected, was greater in the Plenty below the dam compared to the Ouse above. Both rivers contained feeding eels with an average age of around 20 years in freshwater (Figure 7.13). The age composition for the Plenty River (Figure 7.15) represents a structure that is more normally distributed to that of the Ouse (Figure 7.16). The small sample size collected in the Ouse River may be due to a number of factors, one possibly being the failure of natural recruitment due to the presence of the Meadowbank Dam. The Ouse River was once targeted as a successful and highly productive migratory ‘silver’ eel fishery, this ceased in the 1960’s due to the fact that it was no longer a commercially viable operation. Results illustrated in Figure 7.15 and Figure 7.16 highlight the clear differences in sample size between the two sites produced with equal fishing effort. Essentially, where sampling was undertaken in the Plenty River, there are minimal barriers to recruitment supporting the assumption that

Meadowbank dam is a significant barrier to natural recruitment as this is the major barrier effecting recruitment to upstream populations in the Ouse River (there are small weirs throughout the Ouse River, however they are not regarded as being detrimental to eel recruitment).

Pine Tier Lagoon, a controlled sample site, was classed as a body of water that had been dammed and not stocked for the purpose of making direct comparisons with results obtained from other catchment categories (ie. natural recruitment / dammed and stocked). It was expected that no eels would be captured in Pine Tier Lagoon as no 'known' stocking had taken place since the time of dam construction. Five eels were captured in the lagoon and all were relatively young eels. The population within Pine Tier is clearly very small. On close observation of the hydro-electric scheme constructed within the Derwent River System, it was discovered that eels could have migrated from Bronte Lagoon (evidence of previous restocking in 1997) and gained access into Pine Tier Lagoon via the series of canals and penstocks connecting the two water bodies.

Greater variability was observed between the age composition of the two catchment categories in the North Esk and Lake Trevallyn. Figure 7.18 and Figure 7.19 reiterate the obvious differences in population structure above and below a major dam in a different river system. The capture of more young eels (1-2 years in freshwater) was again higher in the North Esk (Figure 7.18) compared to Lake Trevallyn (Figure 7.19) with the youngest eels captured in Trevallyn having spent 3 years in freshwater. Differences in juvenile eel capture between the two sites are highlighted in Figure 7.20 and Figure 7.21. The presence of higher numbers of young eels inhabiting areas below the dam indicate a healthy population that is recruited naturally. Although the North Esk produced more juvenile eels than Lake Trevallyn, it also contained higher numbers of older eels. The distinct and consistent differences in relative abundance in the sites sampled from the South Esk Basin may be explained by the Trevallyn Dam. The Trevallyn Dam like Meadowbank relies on the manual transfer of elvers and does not contain high numbers of eels from any year class when compared to the North Esk. This data adds to the evidence that hydro-electric power stations impose negative impacts on eel populations around the state of Tasmania.

Age frequency information and its association with restock records for Lake Trevallyn (Figure 7.19) provides no correlation between the two. However, the subsequent plot indicates that the majority of eels captured in Lake Trevallyn are associated with those that were transferred in the past. It is clear that where there is no record of past elver transfer (ie. 1955/1956 through till 1979/1980), sampling failed to record any significant number of eels (albeit only a small number of eels were sampled from within these cohorts, these may have been stocked as older eels amongst elvers) at the time of sampling. This supports the suggestion that elver restock has made a significant contribution to the upstream population of eels.

CPUE results from both sampling periods (2000/2001 and 2001/2002) (Figure 7.11; Figure 7.12; Figure 7.23) clearly highlight significant differences in relative abundance for sites above hydro-electric power stations compared to sites below. It is these impacts that this investigation has attempted to identify amidst confounding factors such as variability of eel life history and habitat parameters. Hydro-electric dams appear to have a direct impact on the relative abundance of upstream populations more so than age structure, which is being reasonably maintained through past manual transfers. Data gathered during the course of the investigation supports the fact that past restocking practises have sustained upstream populations.

8.2 DOWNSTREAM 'SILVER' EEL MIGRATION

Any populations of eels inhabiting waters in the Upper Derwent catchment cannot freely migrate downstream. To do so they must pass through the Tarraleah Power Station, consisting of 6 Pelton turbines. Due to the nature of the Pelton design, it is virtually impossible for eels to survive passage through the turbine. It is believed that eels cannot pass though the nozzle's small diameter and its interior components uninjured (Monten, 1985). In the unlikely circumstance a smaller migrating eel passes through a nozzle, it would then have to encounter the turbine blades at high velocity and risk being mutilated (Monten, 1985). Monten (1985) adds that he knows of no evidence supporting the idea that fish can survive the extreme pressure changes in a Pelton turbine. Following this, he must assume that all fish passing through a Pelton turbine are injured. Travade and Larinier (1992) support these findings by claiming that the mortality rate in Pelton turbines was 100%. They also state that these turbines are rarely installed on water courses used by migrating fish because they are only used

for very long drops (Travade and Larinier, 1992). Pelton turbines however, have been installed on water catchments throughout Tasmania known to contain freshwater eels.

The mortality rate resulting from turbine entrainment at the Meadowbank Power Station is approximately 45% (Figure 7.27) according to external research. This conservative estimation in no way accounts for any indirect mortality that may occur once eels have successfully passed through the turbine and is only relevant to populations immediately upstream of the Meadowbank Dam. Furthermore, McCleave (2001) states that survival estimates from all studies investigating turbine mortality may lead to over-estimations of the potential spawning success due to the short-term design and desired outcomes of the studies (ie. They do not take into account injuries or shock eels may suffer, which may negatively influence their chances of reaching the spawning grounds).

Established populations within the Lower Derwent and the Nive-Dee system upstream of Lake Meadowbank must face multiple power stations depending on where along the river system the population is located. The further upstream the population, the greater the risk of death or injury by consecutive downstream dams. The Great Lake – South Esk Basin does not consist of a large number of power stations along its watercourse like the Derwent system. Apart from the Poatina Power Station, where it is not possible for eels to survive entrainment due to extremely high head and the use of Pelton turbines, the Trevallyn Power Station is the only other major barrier before migration out to sea is possible. From studies performed on mortality rates of eels passing though Francis turbines worldwide combined with Kaplan estimations, over 50% of eels entering Francis turbines in Tasmania are believed to be killed.

Turbine mortality results indicate that a large proportion of downstream migrants suffer death or injury during downstream migration. There are substantial negative impacts directed toward downstream migrating populations and there is a high requirement for mitigation. ‘Silver’ eel catch rate data indicate periods of peak movement and with the close monitoring of triggers that encourage downstream movement, they may be incorporated into successful mitigation management strategies.

Information gathered through the collation of catch data, environmental conditions and estimated hydro-electric induced mortality rates has allowed the formulation of a predictive downstream mortality model designed to conservatively estimate potential scenarios of mortality (Figure 7.27; Figure 7.28). It must be stressed that estimations from predictive scenarios presented are very conservative. Estimates are based solely on turbine mortality and do not attempt to quantify the levels of mortality incurred by dam spill or riparian release and do not consider indirect levels of mortality. Eel mortality resulting from dam spill is a factor that needs to be investigated in detail.

Efforts throughout the study focused primarily on the 2nd component of objective 1; investigating the effectiveness of past restocking practises by the observation of upstream and downstream populations. Therefore, the assessment of the impacts of hydro-electric structure on downstream migration has not been investigated scientifically through site-specific trials and study. As a result, the mortality equations used to estimate migratory mortality were utilised in order to obtain an idea of the potential severity of the issue of downstream migration. In addition to turbine mortality, there are also other options for downstream migrants including dam spill and riparian valves. However, the majority of water is discharged through turbines for power generation. Although the majority of hydro-electric mortality lies with turbine entrainment, mortality does occur when eels pass over a spillway or through riparian valves. Eels attempting to cross weirs or spillways may suffer from direct (injuries and/or shock) or indirect (increased risk to predation due to injuries and/or shock) fatalities. Studies carried out in the USA and Canada have shown that the mortality rate varies greatly from one location to another; 0% - 4% for the Bonneville and McNary dams (27 m high) on the Columbia River, and 17% - 64% for the dams on the Bake (76 m high) and Cleveland (73 m high). The fatalities have several main causes; hydraulic velocity shearing on weirs and in the turbulence at the foot of the drop, sudden variations in velocity and pressure on impact on the surface of the water. Experiments have revealed the occurrence of significant damage (injuries to the gills, eyes and internal organs) when the speed of the impact of the fish on the surface of the water exceeds 15-16 m/s, whatever its size (Bell and Delacy, 1972). This critical velocity is reached after a fall, which varies according to the size of the fish: around 30-40 m for fish 15-16 cm and 13 m only for fish longer than 60 cm. A risk of indirect mortality accompanies the risks of direct mortality like that of turbine entrainment.

Trauma and disorientation suffered by the fish after the fall make them more susceptible to predation by birds, animals and other fish. The majority of dams around Tasmania are relatively high and generally fall under the high risk category for eels that manage to swim / pass over with the spill.

No literature has been found on the survivability of eels passing through riparian valves but it is anticipated that for the proportion of eels that do get through, there are levels of direct and indirect mortality due to the large pressure changes involved in some locations. At Lake Trevallyn for example an eel passing through the riparian valve will pass through pressure ranging from 4 Atmospheric Absolute (ATA) to 1 ATA in only a few seconds.

Hypothetical operating scenarios presented in the results are conservative estimations of survival that all point to the one conclusion relative to the purpose of this investigation: Hydro-electric dams pose a significant negative impact on downstream migration and ultimately reduce recruitment by preventing large numbers of eels from reaching spawning grounds.

By following these guidelines, insight is gained into the potential levels of mortality incurred at the various power stations around Tasmania depending on populations upstream during peak migration periods. It is important that this information is taken into consideration when developing a restock management plan. For example; there is less merit in transferring elvers into waters located in the upper reaches of a catchment area with no chance of surviving downstream migration due to the numerous power stations distributed along the length of the watercourse. Unless these waters are commercially fished to their full potential, stocking would seem unnecessary and would be deemed as reducing natural recruitment to the State. However, the ecological and conservational values of Tasmania’s lakes also need to be maintained. Many of Tasmania’s endemic fish species evolved with eels as the major predator. A restock management strategy needs to identify and evaluate these issues, so downstream mitigation requirements around the state can be identified and prioritised.

8.3 EVALUATION OF MITIGATION STRATEGIES

8.3.1 Manual Translocation

Whilst elver ladders are viewed as an effective tool to ensure recruitment into lakes and dams severely affected by barriers, until sufficient techniques can be achieved to ensure that acceptable proportions of elvers actively use such devices, ongoing manual translocations will be needed to ensure that conservational, environmental and commercial values are maintained.

The IFS has annually restocked lakes and dams around Tasmania that elvers have been unable to naturally migrate into since the late 1970's. These elvers have predominantly been harvested from below Hydro barriers such as Meadowbank Dam in the south of the State and the Trevallyn tailrace in the north of the State. Without these restocking practises, many of the state's lakes and dams that elvers are unable to freely access would now be devoid of eels.

Harvesting techniques differ between locations due to hydrological characteristics. To harvest elvers at the base of the Meadowbank power station an aluminium trap has been installed with a flow through system design maintaining sufficient oxygen levels whilst providing a consistent attraction to congregating elvers at the base of the dam. The trap consists of two lengths of PVC pipe extruding from each end of the trap lined with matting made of thick polyamide filaments called Enkamat (Figure 8.1 and 8.2).

Figure 8.1. Meadowbank Elver Trap

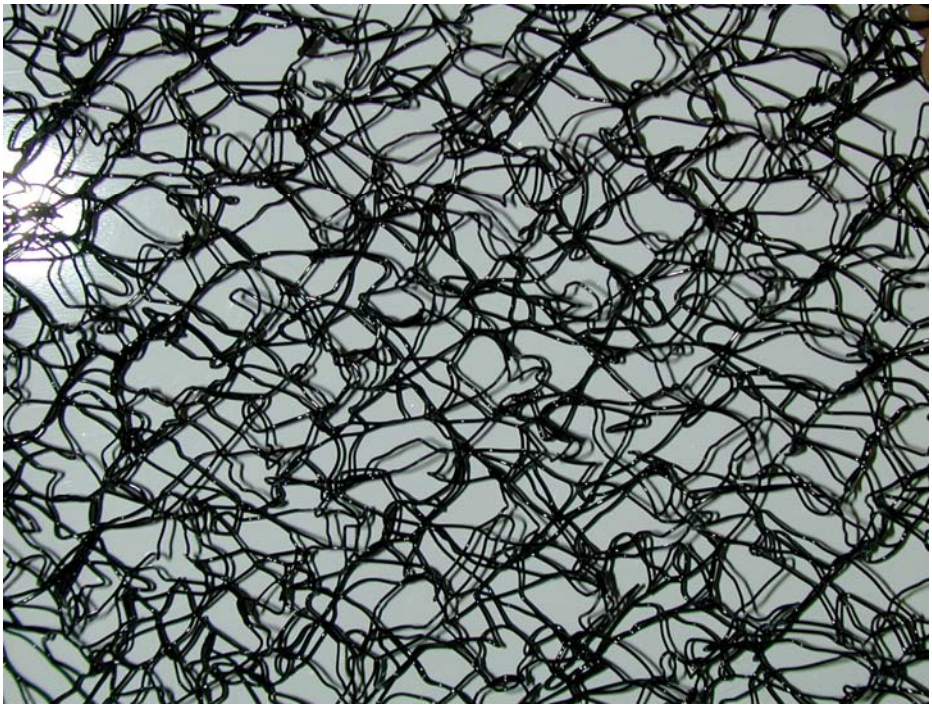

Figure 8.2. Enkamat

Conversely, the Trevallyn Power Station diverts water utilised for power generation through penstocks into the Tamar River at the Trevallyn Tailrace located 3.2 km away from the dam wall (Figure 8.3). The resulting influx of freshwater attracts huge numbers of elvers. Combined with the concentration effect of the surrounding

landscape it has been proven that manual harvesting using large scale fine mesh fyke nets is an effective means of transfer (Figure 8.4).

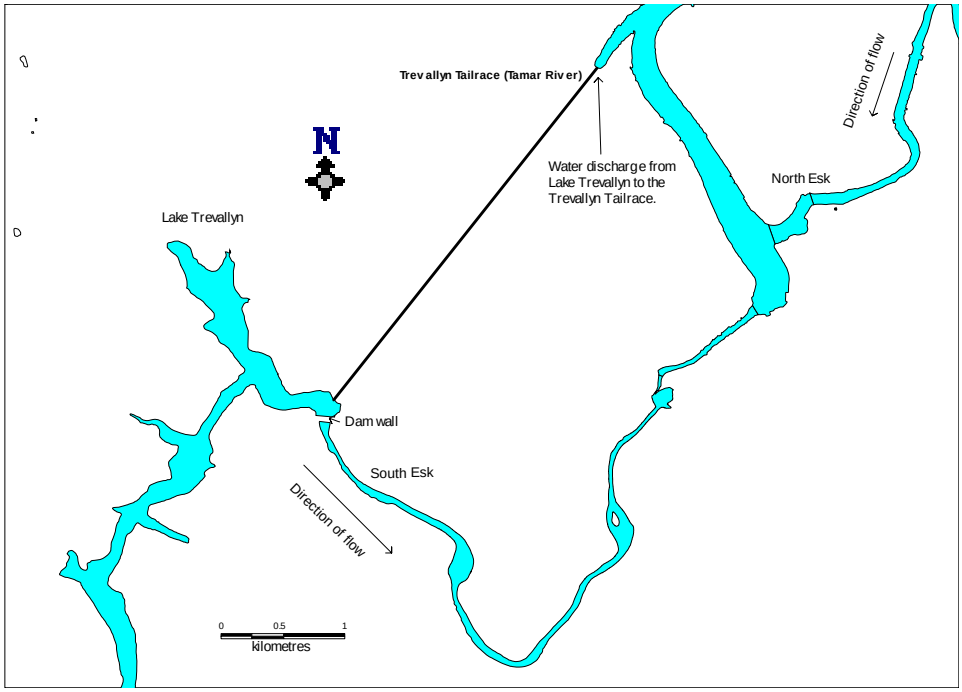

Figure 8.3. Water diversion from the Trevallyn Dam to the Trevallyn Tailrace

Figure 8.4. Elver harvesting at the Trevallyn Tailrace

The IFS annually funds elver harvesting from river systems around Tasmania. These elvers are systematically graded to ensure that they are free from any other fish species. The elvers are then placed into selected dams and lakes around the State to ensure conservational, ecological and commercial values are maintained. Without

harvesting operations at other sites throughout Tasmania, many of the elvers die due to the conditions they are exposed to. They attract predators such as black & pied cormorants, forest ravens, water rats, brown rats, feral cats and silver gulls. They can also become stranded due to sudden water level fluctuations when congregating in unnatural conditions such as in tailraces and at the base of dams.

In Europe, manual translocations are now the preferred option for assisting the safe passage of elvers upstream. It has proven to be much more efficient than implementing elver passes (Boubee, 2002). It is a particularly effective means of transfer in river systems that consist of other upstream barriers (Boubee, 2002). Through trapping or harvesting elvers in Tasmania, quantities can be allocated accordingly between eel culture systems and restock – locally, nationally and internationally. Manual transfers also allow the monitoring of restock in designated areas, the collection of biological data and can cater for multiple species.

8.3.2 Eel and Elver Ladders

A number of elver ladders have been constructed at various dam sites around the world to facilitate upstream elver migration. For example, an elver ladder was installed at the 25 m high Moses-Saunders Dam on the St Lawrence River in Ontario, USA, 1974. Between 1974 and 1978, more than 3.5 million elvers and eels passed through the ladder. The smallest elver was 130 mm in length and weighed 1 g, while the largest eel was 840 mm in length and 1140 g in weight. Approximately 85% of the eels were between 200 and 450 mm in length (Liew, 1982). An elver ladder was also installed at the 63 m high Matahina Dam on the Rangitaiki River, New Zealand that passed more than 15,000 elvers from January to March, 1992 (Gibson and Boubee, 1992).

The IFS and Hydro Tasmania conducted a study during early 2000 of the first purpose built elver ladder in Tasmania, on Trevallyn Dam on the South Esk River. The study involved the monitoring of the effectiveness of the ladder. The ladder was built by Hydro Tasmania in conjunction with the IFS in 1996 and was designed to pass elvers congregating at the base of the dam. The ladder consists of a 90 m long galvanised pipe 150 mm in diameter lined with a mixture of sand and gravel. The effectiveness of the ladder was monitored during early 2000. Throughout the trial, which lasted nearly

one month, only one elver was found to have made it over the dam wall. It became apparent that the ladder does not work effectively. As a result the IFS continues to manually translocate elvers into Lake Trevallyn.

Possible reasons for the elver ladder not working efficiently include:

- Insufficient preliminary surveys to determine where the majority of elvers accumulate at the dam.
- The ladder is situated in an area of high flow making it difficult for elvers to sense the flow of water from the ladder and thus ascend.
- The ladder is constructed out of galvanised metal, which is believed not to be an ideal choice of material to use for fish ladders.
- During periods of hot weather pipe work heats to a level which may deter elvers from entering and/or staying within the ladder.

Eels up to 120 mm long can climb damp vertical surfaces by utilising the effect of surface tension. Eels of all sizes can climb various slopes via surface irregularities or vegetation (Tesch, 1977; Deelder, 1984). Therefore, natural and artificial materials can be used to form ladders to aid fish passage.

The basic requirements for passes are:
(1) a flow of water to attract elvers;
(2) suitable design and placement of the entrance and exit; and
(3) suitable water velocities and/or provision of some form of climbing material to aid ascent.

Eels exhibit strong rheotaxis (attraction to water flows) during migration (McKinnon *et al.* 2000), therefore if there is no naturally attractive flow, or there are other confusing currents nearby (e.g. from tailraces, or riparian outlets), a flow of water down the fish pass, or pumping strong jets of water close to the entrance (attractant flows) are necessary to entice elvers into the pass. Current velocities of about 0.5 ms^{-1}

have been found adequate to stimulate climbing (Boubee, 1995; Knights and White, 1998).

Many fish passes, in a variety of designs, have been built around the world. A major cause of failure of a proportion of these fish passages is poor positioning of the entrance. To be effective, the entrance of an eel pass needs to be positioned where fish are known to congregate. The best position for the entrance of the pass will need to be determined by site inspection and extended day-time and night-time observations (Boubee, 1995; Knights and White, 1998). McCleave (1980) and Mitchell (1989) found that juveniles (defined as 30-80 mm total length) cannot swim against water velocities of >60 cm s^{-1}. Therefore, water flowing down a fish passage must not exceed this velocity if juveniles are to be able to move up a ladder. As each site will differ, consideration needs to be given to the river flow, direction and velocities, water supply, type of structure/barrier (slope and height), and site characteristics, particularly locations of any fish congregations (Boubee, 1995; Knights and White, 1998).

A simple option to aid eel passage is to provide a barrier with a rough or weedy surface during construction or refurbishment of a dam or weir. All (or just the lateral regions) of the downstream face of a sloping weir and its crest can be made climbable using a variety of sizes of stones, rocks or pre-cast cellular blocks (Knights and White, 1998). If possible, the roughened climbing ramp should be sloped to extend above the highest water levels expected. Eels will then be able to ascend in the slower water velocities and upper wetted margins at all water levels. Any smooth surfaces, lips, baffles or other obstacles should have appropriate climbing material attached. Extending the exit of a passage into quieter water, with preferably a rough or weedy bottom, will help eels escape and provide cover. Where the exit is above the upper water level, climbing material should be extended to a lip to allow migrating eels to slip down a smooth vertical or steeply sloping section. Water jets can be used as a flushing mechanism if necessary (Knights and White, 1998).

Where the above solutions are not feasible (for example on high concrete dams), pipe, channel or trough passes, furnishing with one of a variety of climbing materials, can be used. Elver ladders can be built into a barrier as an integrated unit during

construction or major refurbishment of a hydro facility, or attached to current surfaces or suspended by ropes or cables. Ladders should be mounted at 15-30 ^{o} for ease of ascent (Rigaud *et al*, 1988; Legault, 1992). For example, a trough-type ladder on the Moses-Saunders Dam on the St Lawrence River in Ontario, USA was attached to a 29 m high ice-shute which comprised eight zig-zagged sections to reduce the angle of climb from 70 ^{o} to 12 ^{o}. The total length of the ladder was 156 m and eels took 70+ minutes to ascend. Water was pumped down the pass at about 25 cm s^{-1}. Wooden baffles and green willow cuttings or synthetic vegetation were later added to the base of the trough, and resting pools were provided at each bend to further aid ascent (Liew, 1982).

Closed-section passes are prone to blockage therefore screening of inlets and provision of access hatches for cleaning are advisable. Open-section eel ladders are more common (Rigaud *et al.* 1988) but removable covers will exclude debris and provide shade and protection from predators, poachers and vandals. Screening of inlets will prevent entry of debris and protection from physical damage (Knights and White, 1998).

Two main types of climbing materials may be used in an elver ladder – rocks/aggregates or synthetic materials. Rocks and aggregate may be glued into the base of a pipe or open trough to provide a suitable climbing surface. A stream of water running rapidly down the middle of the pipe or trough keeps the inside wet to assist climbing (small eels that can not climb against the flow use the wetted margins) and also provides an attractant flow at the base of the ladder. This design has been used on the Matahina Dam in New Zealand, and detailed design and construction guides are listed in Boubee (1995).

Pipes or troughs may also be lined with a variety of synthetic materials including bottle-brushes, geotextile mats or horticultural netting. Bottle-brushes have been used in tube-passes. These have been claimed not to be size-selective, but migration of short-finned eels appeared to be more successful than that of long-finned eels (I. Johnson, pers. comm. in Knights and White, 1998). For example, a 100 mm diameter PVC pipe filled with 12 mm polypropylene bottle-brushes has been used on the 68 m high Patea Dam on the Waikato River, New Zealand (Mitchell 1984).

Geotextile mats consisting of UV-stabilised synthetic fibres looped and bonded in three-dimensions to form open-weave mats can be laid flat, loosely rolled or pleated for use in channels, or in vertical or steeply angled pipes. However, matting is prone to blockage if densely packed. Furthermore, it tends to be size-selective because the loops are not very distensible and one grade of mesh may be suitable for the passage of elvers, but not for larger juvenile eels (White and Knights, 1994). For example, in Denmark, pipe and box-section passes have been filled with fibrous climbing material or geotextile materials.

Horticultural netting can also be used for packing pipes. It does not have the rigidity of geotextiles, but is robust and cheaper. Commonly available fruit/bean-cage netting of 20 mm mesh was found to be effective for all sizes of migrant eels (White and Knights 1994). Netting can be folded or rolled into loose mats or 'ropes', and fixed to the base of plastic guttering or wooden troughs. Eels and elvers can entwine and climb through the meshes, and also gain traction between the netting and the base of the ladder. Build-up of weed and other debris within the netting does not appear to have any detrimental effect (Knights and White, 1998).

Table 8.1 outlines the costs and benefits of manual transfer practises versus the implementation of an elver ladder versus no action.

Table 8.1: Outline of costs and benefits involved with upstream passage assistance.

Strategy	Initial Costs	Ongoing Costs	Benefits	Disadvantages
Manual Transfers	• Site visits • Sampling • Trap design • Trap construction / implementation • Materials • Labour	• Monitoring and maintenance • Staffing / transfers • Operating costs	• Grading of elvers • Population assessments • Monitoring • Quantified transfers in selected waters • Biological data collection	• Ongoing costs involved • Labour intensive
Elver Ladder	• Site visits • Sampling • Design • Construction • Implementation • Materials • Labour	• Monitoring and maintenance	• Permanent access upstream • Minimal staffing required	• Access only into waters directly upstream • Transfer numbers are much smaller than manual transfers
No Action	**NIL**	• Staffing for seasonal elver mortality at base of dam / Tailrace	• Increased silver eel escapement (Elvers inhabit river and may reach the sea without hydro-electric danger once sexually mature) • Minimal costs	• Heavy juvenile mortality (Predation / strandings) • Ecological implications causing imbalance to the natural biodiversity of waters upstream.

It is difficult to recommend an appropriate course of action for upstream passage of eels. As has been previously discussed, each dam has its own requirements / characteristics that need to be thoroughly assessed before a decision can be made on what strategy is appropriate for a particular dam.

At this point in time, for the two major barriers surveyed (Lake Meadowbank and Lake Trevallyn), the benefits of manual transfers far outweigh the costs and subsequent benefits of implementing an elver ladder. In time it is anticipated that effective ladders will be designed and installed to ensure sufficient quantities of migrating juvenile eels are able to freely access lakes upstream.

8.3.3 Migratory Silver Eel Passes

There are three types of devices, some used in combination, to prevent fish from turbine entrainment at power stations during downstream migration: (1) physical barrier screens; (2) behavioural guidance systems; and (3) capture and release systems. Physical barrier screens place a barrier to prevent entrainment. These measures may include intake screens, bypasses or angled bar racks. Behavioural guidance systems rely on fish behavioural responses to a range of external stimuli, which may include electric, sound, bubble, light or turbulence. A capture and release system attempts to pass fish by collecting fish at points of accumulation in their migration corridor, and release them downstream of the power station (NMFS, 1994; Nordlund, 1996).

Mechanical physical barrier screens are the most common method of excluding fish from turbine inlets, being used by 58% of hydroelectric plants in the USA (Francfort, 1994). The size of the mesh is dependent on the size of the fish to be excluded. Some companies that use these screens arrange them in zig-zag patterns spanning the width of the canal leading to the power station. Water passes through the screens, while fish are guided along the length of the screening and routed to a bypass system that diverts them around the dam/weir (Lamarre *et al*. 1995). However, such screens are prone to blocking, causing hydraulic head loss and impairing generation. Maintenance costs for cleaning blocked screens may be high (Turnpenny, 1999). To combat blocking self-cleaning screens have been designed, including unpowered and water powered versions.

Angled fixed screens and angled drum screens are low velocity screening systems that have gained the most acceptance from fisheries agencies in the Pacific region and north-west of the U.S.A. Water velocity through these screens is typically 0.15 ms^{-1} or >0.15 ms^{-1}. Being set at an angle to the water flow, instead of perpendicular to it significantly increases fish survival rates (Lamarre *et al.* 1995). Angled fixed screens are most commonly made of wedge wire, a series of evenly spaced 2 mm-wide steel bars that taper from front to back. Angled drum screens are named for their cylindrical shape and are installed horizontally, or in an angled arrangement similar to that of angled screens. Drum screens rotate at a slow rate, imperceptible to fish, to prevent the accumulation of debris. At very large dams, for which angled fixed

screens and angled drum screens are not practical options, submerged travelling screens are an option. A submerged travelling screen hangs from the ceiling of the water intake structure into the upper portion of the water column. The screen is set at an angle to the flow, diverting fish from the turbine intake, and into a bypass that carries them over or around the dam (Lamarre *et al.* 1995).

High velocity screens for water velocities ranging from 1.5-3 ms^{-1} have also been used as barriers. The primary advantage of high velocity screens is their small size (they require only 10-20 % of the screen area of low velocity screens), which helps reduce their cost to about half that of low velocity screens. Also, because water velocities are generally higher, passing fish are not as vulnerable to predators as they can be in low velocity screening systems (Lamarre *et al*. 1995).

The Eicher Pressure Screen is a passive high velocity screen, which can be fitted into the turbine penstock. The screen is pivoted and made from 2 mm-thick wedge-wire material fine enough to prevent fish passage. The screen is positioned in the penstock at an angle of 19^{o} relative to the flow and uses a changing porosity to create a constant flow across its surface, reducing the risk of fish impingement. As fish enter the penstock, they are forced into a decreasing area until they must pass into a passage at the end of the Eicher screen. This passage guides the fish into the tailrace, or back into the river. The Eicher screen is self-cleaning by being flipped over on its pivot within the penstock to periodically backflush debris (Turnpenny, 1999).

The first test of an Eicher screen was at the Elwha Hydroelcetric Project in Washington, in a 2.7 m diameter penstock with flow velocities up to 2 ms^{-1}, had a 99 % success rate recorded for salmonids. Matthews and Taylor (1994), also reported trials of the Eicher screen at Punt ledge dam in Canada, which has a 24 MW capacity at a flow of 27.5 ms^{-1}. Previous mortality caused by turbines at the plant was more than 60 % of the anadromous fish run. The first year of testing indicated that fish mortality was reduced to about 1 % (Turnpenny, 1999). The Eicher screen is a low capital and maintenance system, takes up minimal space and is unaffected by forebay level fluctuations, although it must be custom-made (Winchell and Sullivan 1991).

The Electric Power Research Institute (EPRI) has developed an improved high velocity screening system, based on the Eicher screen, called the modular inclined screen (MIS). Made of wedge wire, the MIS is square, and a series of these screens can be installed virtually anywhere upstream of a penstock, angled at 15^{o} to the water flow. The screen's modularity allows it to be used at any type of water intake, and several of the screens can be installed at a single intake to provide fish protection for any amount of flow. Improvements to the system's hydraulics have provided a more uniform flow over the entire screen surface than with other types of screens, such as the Eicher. This modification reduces the likelihood of fish injuries due to screen contact, and is 99 % effective. Like the Eicher screen, the MIS pivots along its centre-line so that it can be flipped within the penstock to clean the screen by backflushing of debris (Lamarre *et al.* 1995; Taft *et al.* 1995).

Bypasses create an alternate route that completely avoids the power station/dam, negating the need for intake screening, or can be used in conjunction with effective screening techniques. However, bypasses require an attraction flow significant enough to attract fish from the main current, and a well positioned fish-friendly hydraulic entrance and exit to facilitate fish passage (Turnpenny, 1999). This option may not be economically viable in hydro-electric schemes if generation flows require reduction to ensure bypass flows are the dominant attracting flow for eel migration.

Mitigation practices associated with downstream migratory triggers could utilise the spilling of dams during those periods when conditions are suitable for downstream migrating eels. This would allow another escapement option and increase the chances of survival. There are however, economic and environmental implications associated with such a proposal including the need for further research.

8.3.4 Behavioural Devices

Due to the high cost of infrastructure development associated with physical screening of migrating eels, there has been substantial effort on developing behavioural devices as a substitute for barrier screens (EPRI, 1986). A behavioural device, as opposed to a physical barrier, depends on volitional taxis (response) from fish to avoid entrainment. The fish diversion efficiency of behavioural screens is, at best, 80-95 %, and often lower, with present scepticism over behavioural devices supported by the

fact that few are currently in use at hydro plants (NMFS, 1994). The major types of behavioural devices include light, sound (acoustic), bubble screens, electric barriers, or combinations of these (Turnpenny, 1999).

Light

Eels are negatively phototactic and generally nocturnal, so the downstream migration of most silver eels occurs at night (Tesch, 1977). A number of authors (including Van Drimmelen, 1951 and Lowe, 1952) used the light-avoidance reaction of eels for fishery purposes and increased their catches by directing eels into nets by using underwater lamps. Several laboratory and field experiments have been conducted to study the reaction of eels to light in order to develop a functional light barrier for use in power station deflection systems. In field experiments, deflection rates for silver eels of up to 85 % were achieved using underwater lights (Hadderingh *et al.* 1992). To gain a better understanding of the behaviour of silver eels at light screens and bypasses, a laboratory study was carried out examining the influence of water velocity, illumination and combinations of both parameters.

These experiments found that silver eels preferred to swim downstream using the highest water velocity, probably to conserve energy (Thorpe *et al.* 1981), but the deflection stimulus by light was stronger than the attraction stimulus of the higher water velocity. These findings are important in relation to the application of underwater lights to deflect downstream migratory eels at hydro-electric power stations. At power stations, the main flow (highest velocity) of water is directed at the intake gates/tower, so it is expected that the majority of downstream migrating eels are in this main stream. As the deflecting stimulus of light can overrule the attracting stimulus of water velocity, eels could be deflected from the main intake flow by a light barrier (Hadderingh, 1999).

Potentially, a row of underwater lights (light screen) could be used to deflect eels in the direction of a bypass. However, because of the permanent nature of water flow in a river, eels deflected sideways by the light will be pushed towards the light again by the current. This process may be repeated a number of times, depending on the length of the light screen and the velocity of the water. So, at each approach towards the light screen, a certain percentage of the migrating eels will pass the light barrier.

Therefore, to deflect a reasonable proportion of eels from being entrained, the angle between the light screen and the flow direction should be $<25^{o}$. At small angles such as these, eels will be less affected by the water velocity and more easily reach the bypass (Hadderingh, 1999).

Acoustic and Bubble Screens

Acoustic screens use an underwater sound stimulus to repel or guide fish, and the design and construction of acoustic screens has advanced greatly over the last decade. Researchers have recorded and analysed fish sound to determine the frequencies, durations and amplitudes to which fish respond. Sounds of various frequencies have been applied successfully, depending on species, including infrasound at < 20 Hz, audible sound in the 20 Hz – 3 kHz band, and ultrasound at > 100 kHz (Turnpenny, 1999). Steelhead trout, chinook salmon and a variety of fish in the herring family have responded well to acoustic screens (Lamarre *et al.* 1995) although the response of anguillids is unknown.

The Bio-Acoustic Fish Fence (BAFF™) uses sound in the sub-500 Hz range, coupled with a bubble curtain in such a way that the sound becomes encapsulated within the bubble sheet. The BAFF has the advantage that the acoustic field is sharply defined, and can be used to guide fish into a bypass (Turnpenny, 1999).

A number of researchers believe that such combinations of behavioural screens are the most successful for fish diversion (Lamarre *et al.* 1995).

Electrical

Electric screens may either be fish barriers that create an impassable electrical barrier, or a fish guidance system that produces a repelling zone. Both consist of DC electrical current passing through water. The electrical circuit is made up of two or more metal electrodes submersed in water with a voltage applied between them. Electric current passing between the electrodes, via the water, produces an electric field. When fish swim into the field, part of the current flows through their bodies and can evoke reactions ranging from a slight twitch to full paralysis. The severity of the reaction depends on the current level, the shock duration and the size of the fish.

The most effective electric field for blocking or guiding fish is one with electric field lines running head-to-tail along the fish, as this orientation transfers the maximum power from the water into the fish's body (Smith-Root, 2000).

An electric screen may consist of a graduated electric field, so that as fish advance into the field, they feel an increasingly unpleasant sensation. When the sensation is too intense, fish are unable to advance further and turn perpendicular to the field to minimise the effects of the electric field, and swim away from the increasing electric field. A number of pulse generators with increasing outputs are arranged to provide the graduated field. Very short DC pulses are used which provide a sensation much like pins and needles and repel fish away from turbine intakes toward open water or an attraction flow leading to a bypass. As with other downstream guidance systems, electric barriers should be located well upstream from intakes and set at an angle to the water flow so that diverted fish are guided towards a bypass (Smith-Root, 2000).

Recent work by Boubee (2001) involving light and electricity experiments which suggested that electricity was much more effective as a guidance system or deterrent. The migrating eels tended to become increasingly tolerant of light with time (Boubee, 2001).

8.3.5 Fish-Friendly Turbine Design

Three types of turbines are used in Hydro Tasmania's power stations: Kaplan (n = 4) and Francis (n = 35) turbines and Pelton wheels (n = 20). Current turbine technology is recognised as causing injury and mortality to entrained fish that pass though the turbines of hydro-electric stations (EPRI, 1992; Franke *et al.*, 1997).

The American Department of Defence has implemented an Advanced Hydropower Turbine System (AHTS) Program that is designed to develop technology that will allow maximum hydro-electric generation with minimal adverse environmental effects such as fish injury and mortality. It is thought that advanced turbine technology could reduce fish mortality resulting from turbine passage to less than 2 %, and at the same time, maintain acceptable dissolved oxygen levels. In many cases, passing fish through environmentally enhanced turbine designs can result in higher overall survival than bypassing fish over spillways (AHTS, 2000).

Recent research into mortality mechanisms for Kaplan turbines identifies mortality as being related to:

- turbulent flows resulting from low efficiency designs or plant operating regimes; the trapping and cutting of fish in the zone of flow passing near the turbine hub when large gaps between blade and hub exist (characterising the lower output operation of the Kaplan turbine);
- strike of fish by turbine blades, or impact of fish on other turbine structures;
- cavitation in turbine water passages;
- abrasion of fish driven into rough turbine surfaces by flow turbulence (Cada and Whitney, 1997); and
- turbulence or impact-induced dizziness enhancing the chance for predation losses as disorientated fish are eaten by birds or fish when they emerge from the tailrace (Fisher *et al.* 1993; Odeh, 1999; Cada and Rinehart, 2000).

In Francis turbines, higher fish mortality has been correlated to the runner entrance (where wicket gates, blades, and the runner's peripheral speed interact), higher peripheral runner speeds and greater wicket gate openings (Franke *et al.* 1997; Odeh, 1999).

The number of turbine runner blades and stay vanes, length of fish compared to the size of the turbine, and quality of flow at the point of operation are all key elements that characterise survival. The location of the fish in the water column and the zones of flow through which fish pass have also been observed to be important in determining survival rates. Fish mortality does not change with differences in operating head (Fisher *et al.* 1993; Odeh, 1999).

Voith Hydro, Inc, USA set out to provide design improvements that can make both Kaplan and Francis turbines more environmentally friendly. The design concepts can be used for both rehabilitating existing turbines, as well as being incorporated into the construction of new turbines in order to improve their compliance with providing safe fish passage. Voith also believes that incorporating the design modifications would

result in more efficient operation, increase in power generation, and reduced operation and maintenance costs (Fisher *et al.* 1993; Odeh, 1999).

Upgraded Kaplan Turbine

An environmentally friendly Kaplan turbine is one that generates power efficiently, passes fish safely and costs less to operate and maintain than previous designs. A list of design concepts was suggested by Voith in order to satisfy these requirements:

- A turbine should be operated at high efficiency with no cavitation and reduced back-roll, reducing the probability for fish injury and decreased runner replacement costs;

- Removing the gaps within a turbine system eliminates the added probability of fish injury and enhances turbine efficiency. Eliminating gaps at the wicket gates, or between the blades and the hub and the discharge ring is believed to minimise fish injury due to grinding. The gaps are removed by changing the shape of the hub and discharge ring from the cylindrical-spherical-conical shape to one that is all spherical, and the blades are recessed into the discharge ring;

- Changing the shape of the discharge ring also eliminates wicket gate overhang, which results in eliminating the gaps between the wicket gates and the discharge ring. Leakage through gaps causes strong vortices with high shear stress that can potentially injure fish. Reducing these leakages also increases the efficiency of the turbine by reducing water losses at the gap;

- Properly placing wicket gates behind hydraulically smooth stay vanes minimises the potential for fish injury due to strike and flow behaviour induced stresses, while maximising turbine efficiency;

- Keep surfaces on the turbine's stay vanes, wicket gates and draft tube cone smooth. Welds on the various parts of a turbine system can be made smoother to reduce abrasion injury;

- Use an advanced control system to operate the turbine components efficiently;

- Electrical conversion equipment can be used to adjust runner rotational speed and generator speed to maintain turbine operation at the "fish friendly" point for any required discharge, while maintaining peak turbine hydraulic efficiency. The addition of this type of equipment is best accompanied by a runner upgrade at the same time;

- Ensure cam optimisation to provide maximum efficiency operation and minimise flow stresses by maintaining turbine blade and wicket gate positions for maximum efficiency, and to minimise fish injury;

- Maintain clean debris racks that minimise flow disturbance and allow surface orientated fish to enter the intake from its upper portion, therefore minimising blade tip strike that may occur when fish are forced to enter at the bottom of the intake; and

- Design the draft tube piers with a round nose to be hydraulically smooth that reduces flow separation and the possibility of a fish strike (Franke, 1997; Odeh, 1999).

Upgraded Francis Turbine

An environmentally friendly Francis turbine is also one that generates power efficiently, passes fish safely and costs less to operate and maintain than previous designs. A list of design concepts was suggested by Voith in order to satisfy these requirements:

- A lower number of blades reduces the probability of strike and maximises the size of flow passages, which also minimises the probability of abrasion damage to fish. A lower number of blades results in having longer blades to maintain the same generating capacity, power production and minimise cavitation;

- Using a thicker blade entrance edge necessitates a runner with fairly flat efficiency performance characteristics related to the head. This means entrance edge will not cavitate at high heads and flow separation may not occur, resulting in minimal flow stress injuries. Also, a thicker blade edge enhances the chance that a fish will be carried around the edge rather than colliding with it, so lowering the probability of strike;

- Eliminating wicket gate overhang reduces gaps that cause vortices created by leakage, prevents fish injury by grinding and increases the turbine efficiency;

- Increasing the distance between the edge of the wicket gate and the runner reduces the probability of fish grinding between trailing edge of the wicket gate and the runner, and can be achieved by enlarging the pin circle diameter;

- Properly placing wicket gates behind hydraulically smooth stay vanes minimises the potential for fish injury due to strike and flow behaviour induced stresses, while maximising turbine efficiency. To upgrade existing turbines with changes to other turbine components;

- Provide smooth surfaces on stay vanes, wicket gates and upper draft tube cones to reduce potential abrasion and descaling damage to fish. This may be achieved by repairing damaged surfaces, using special coatings, and reducing weld roughness;

- Operating the turbine with adjustable rotational runner speeds, may result in reducing the probability of strike, shear stress zones, cavitation and pressure fluctuations; and

- An advanced turbine control system using adjustable speeds, variable speed generator, clean debris racks and optimised multi-unit operation are important conditions to making a turbine unit more “fish friendly” (Odeh, 1999; Cava and Rinehart, 2000).

Modifying penstock designs may also minimise pressure changes experienced by turbine-passed fish by providing them with a more appropriate 'pressure passage'. At power stations with deep intakes, fish are acclimatised to high pressures prior to entering the penstock, and are exposed to much lower pressures at the downstream end of the turbine in a very short period of time. However, with a shallower intake, fish are acclimatised to lower pressures prior to entering the penstock, subject to higher pressures within the penstock and back to a low pressure region within the tailrace. In longer penstocks, pressure changes can be minimised by keeping fish at a similar pressure to that at which they entered the penstock for as long as possible (Odeh, 1999).

New Turbine Design

As part of the AHTS, sponsored by the U.S Department of Energy (DOE), Alden Research Laboratory, Inc. and Northern Research and Engineering Corporation (NREC) conducted a research program to develop a new turbine runner to substantially reduce fish injury and mortality at hydro-electric stations. The new runner has a unique geometry and is 'fish friendly', having characteristics that are superior to those in existing turbine designs that are known to cause fish injury and mortality (Cook *et al.* 2000; Odeh, 1999).

The Alden/NREC team based their concept for the new runner on a commercially available pump that is used to pump fish and vegetables with minimum damage. The chosen single-bladed impeller had a long leading edge, a large flow passage and few gaps. It is clog-free, gentle, and fairly electrically efficient (80% when used for solids handling and 75 % when used for fish handling). Following initial testing, it was found a two-bladed runner was necessary for higher efficiency if a larger diameter was used (Cook *et al.*, 2000; Odeh, 1999).

Among the chief contributing factors to optimising the design were:

1. Avoiding flow separation to minimise losses and turbulence;
2. Keeping pressures above the set minimum and the rate of change of pressure was kept below the set value to prevent fish injury due to decompression;

3. Balancing factors that may affect the peripheral speed – head, blade shape, runner diameter, and the number and length of blades to minimise potential fish injury; and;
4. Minimising high shear stress zones (Cook *et al.* 2000; Odeh, 1999).

Because large flow passages necessitates a lower number of blades, longer blades were used to extract the available energy from the flow. Also, to avoid excess loading and rate of change of velocity and pressure on the blades, they were wrapped around the hub in a helix.

The new runner had to meet the engineering and biological design criteria in order to be considered a viable new concept for further development as a fish-friendly hydro-electric turbine. The final design was a vertical shaft runner with 2 blades, 5.3 m diameter and 4 m long runner. The runner blades are 10 cm thick with a rounded trailing edge. The turbine has a mixed flow inlet with the inlet blade tip angle set tangential to the relative flow, and the exit blade angle set differently at the hub surface compared to the shroud surface (Cook *et al.* 2000; Odeh, 1999).

Predicated performance efficiency is 90 % at a 25 m head and flow of 1000 cfs. This means the new runner should be competitive with traditional turbine operational efficiencies. Peripheral runner speed is 19.2 ms-1, and is fixed by the head and runner diameter. The minimum flow passage is 90 cm (i.e. a sphere 90 cm in diameter can pass through the smallest zones within the runner). Because of the large amounts of water in a flow passage of this size, fish will be kept away from the blades and the probability of injury reduced. A shroud was fixed to the blade edges to rotate along them, eliminating clearances between the runner and fixed surfaces. This eliminates the possibility of fish being caught in gaps that may cause grinding injury.

Computational fluid dynamic (CFD) analysis of the new runner showed that it would perform well, and is not likely to injure fish passing through it. It can be used to replace existing turbine where fish injury is a primary concern, or for plant expansion (Cook *et al.* 2000; Odeh, 1999).

8.4 BENEFITS, FURTHER DEVELOPMENT AND PLANNED OUTCOMES

Information gathered provides fisheries managers and industry stakeholders with a guide to further develop the understanding of areas that require more research. A better understanding of the impacts hydro-electric power stations have on eel migration has benefited fisheries managers, the industry members and also the community. An increased level of confidence can now be applied to elver transfers throughout the State knowing it is an effective option for stock enhancement.

Throughout the course of the study, it has become apparent that information obtained does not warrant specific management recommendations suitable for all Tasmanian water catchments. This is due to the complexities and diversities involved with each individual hydro-electric impoundment found within Tasmania. In regard to the current situation at Meadowbank and Trevallyn, further study is essential before specific mitigation options can be confidently recommended. The various hydrological and biological conditions that occur during seasonal operations of hydro-electric power stations in addition to migratory behaviour should be considered. Larinier (2000) states that it is not simply a question of applying fish passes and accepting them as an effective means of mitigation. Depending on the site in question, the biological objectives of constructing an effective fish pass are different. Research is required at individual sites including long term monitoring of eel behaviour and their relationship with the various hydrological and environmental conditions.

Waters upstream of the two power stations investigated throughout the project hold enhanced populations of eels through the manual transfer of elvers in previous years. Past elver restocking practises have proven to be effective. There are however, problems associated with the random release of captured elvers in waters upstream of power stations around the State. Stocking waters with elvers immediately influences future recruitment potential by limiting the chances of downstream passage and survival. This poses direct implications on future management of eel stocks within hydro-electric impoundments. It is recommended that an elver management plan is developed which prioritises waters requiring restock, depending upon ecological and commercial values, combined with the availability of suitable habitat and the interest of all appropriate stakeholders involved. Outcomes produced will ultimately bring to light barriers requiring further site-specific investigations. It is important to finalise a

transfer policy detailing restock locations before considering any mitigation options for downstream passage.

Simply stocking a dam with elvers and assuming that the fishery will be maintained is not effective, as these fish require habitat and safe downstream passage to sea for the natural breeding cycle to be successfully completed. Without this, eel stocks within Australasia will most probably start to decline (some anecdotal evidence suggests that this may already be occurring) as previously indicated for the eel populations in New Zealand through annual sampling (www.niwa.cri.nz). This is not a State specific issue solely effecting Tasmania. Any management outcomes resulting from this investigation and other studies relating to this issue should be accepted where appropriate and adopted nationally to ensure the sustainability of all state eel fisheries due to the nature of the single breeding stock state of the fishery.

For the purposes of this study, it is not realistic or possible to make detailed recommendations regarding the design and implementation of mitigation strategies for each dam structure in the various river systems of Tasmania. Due to the various site-specific biological and hydrological conditions between sites, mitigation strategies require an integrated management approach with respect for these conditions for the long term effectiveness and efficiency of successful long-term mitigation. For the two stations focused on throughout the study, recommendations regarding the safe upstream transfer of juvenile eels and available mitigation options for downstream passage have been collated and prioritised. There is currently a lack of research and knowledge in regard to downstream fish pass technologies and this issue is in need of research (Larinier, 2000). The issue of downstream migration has only been taken into consideration and past efforts in trying to resolve migration issues has largely been focused on the construction of upstream fish passage facilities including trapping and manual transfer. The complexities involved in developing effective downstream fish passage facilities have also been a contributing factor in the lack of construction of such facilities around the world (Larinier, 2000).

Essentially, manual stockings have proven successful at sites such as Meadowbank and Trevallyn. New Zealand eel fisheries like Australian fisheries have implemented successful trap and transfer operations for elver restock to enhance eel populations

above hydro dams. Similar to this study, New Zealand researchers have concluded that turbine survival of downstream migrating eels is poor (Boubee *et al.* 2002). The focus of research in New Zealand has shifted to the issue of downstream passage (Boubee et al, 2002). This investigation supports past restocking events with the use of manual transfers and similarly highlights the need for further research investigating the implications and complexities involved with the free and safe movement of downstream migrating eels.

However, specific to the information gathered on the Tasmanian watercourses investigated combined with a review of relevant literature, a number of short and long term initiatives have been devised, which may be suitable for Tasmanian river systems.

Upstream migration Initiatives

It is apparent that in order for eel fisheries to be enhanced and maintained within hydro-electric impoundments in Tasmania the following initiatives should apply:

Short Term:

- Continue elver transfer practises;
- Investigate methods to optimise stocking strategies;
- Assess the cost and feasibility of modifying the existing elver pass on Trevallyn dam so that it functions more effectively.

Long Term:

- Identify other dams where elver ladders may be a cost effective mitigation measure that would provide significant ecological or commercial benefits, and design and construct elver ladders in these locations;
- Continue improvements to restock strategies to maximise ecological and commercial values.

Downstream migration Initiatives

Possible strategies that should be investigated regarding the safe passage of downstream migrating eels include:

Short Term:

- Estimate silver eel mortality throughout each Hydro scheme based on estimations completed throughout this study. From these estimates, identify priority locations for reduction of silver eel mortality in catchments with significant eel numbers, including a cost benefit analysis of these options. Determine if prioritisation of areas is affected by changes to restock strategies;
- Conduct a cost benefit analysis of mitigation options for the priority locations identified above, including downstream passage facilitation devices, manual translocation, power station intake deterrent devices, and identify and define the risks associated with inaction;
- Model scenarios for optimal fish passage, including altered turbine use and mitigation of fish entrainment through installation of fish screens or other measures to divert fish from intakes and/or spillways at locations deemed to cause high mortality;
- Determine whether controlled spill events may be a suitable downstream passage facilitation method in priority areas.

Long Term:

- Implement strategies identified from short-term initiatives;
- Investigate the feasibility of replacing current turbines with fish-friendly designs during power station upgrades at high priority locations;
- Design and construct effective intake deterrent devices and migratory eel passes in key catchment locations.

9. CONCLUSIONS

It is commonly acknowledged that Tasmania has the largest juvenile eel resource in Australia. It is essential that such a valuable limited resource is managed in a sustainable manner, which is directly linked to upstream and downstream passage. Without passage past hydro-electric structures, the species could potentially be in serious decline as has occurred in Europe and Asia, and now is beginning to occur in America (Haro *et al.* 2000). Results obtained from this study indicate that ongoing juvenile eel transfers or passage facilitation are required in the hydro-electric impoundments sampled to maintain eel populations. Without these transfers the population of eels within these dams will most likely decrease significantly and this can be attributed to the hydro-electric dams acting as significant barriers to eel migration. These same barriers pose significant impacts to migrating adult eels that have minimal chances of reaching the sea to spawn. It is estimated that the majority of power stations result in approximately 50% direct mortality on those migrating eels passing through turbines. It is important to note however, that this does not take into consideration the likelihood of a heightened chance of mortality to those surviving eels due to spillway, turbine or pressure injuries incurred during entrainment.

For the purposes of this study, it would have been ideal to sample in waters above and below hydro-electric dams closer to 10 years of age. This was not possible because there are no power stations situated on the Tasmania's major river systems of this age. If this was the case, a larger proportion of eels captured would have been older than the age of the dams allowing a more rigorous analysis with regard to the impacts of hydro-electric power stations on eel migration and stocks. Information gathered throughout the course of the study has revealed that further research is required to understand the various issues associated with the successful management of populations of catadromous species within hydro-electric effected river systems. Future initiatives require further site-specific studies throughout Tasmania's multiple Hydro-electric schemes, and this work should also be undertaken at key dams and barriers throughout Australia. Fisheries managers, stakeholders, water authorities and the community need to continue to work together to ensure that sufficient quantities of juvenile and migratory eel can pass hydro barriers in order to prevent the decline in

freshwater eel stocks within Australia. Elver transfers need to continue in appropriate locations but require appropriate management to formulate restock planning. Further recommendations require appropriate restock management planning in order to prioritise individual research requirements for hydro-electric barriers.

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13. APPENDICES

APPENDIX 1: INTELLECTUAL PROPERTY

- Improved techniques for otolith preparation
- Improved techniques for handling and anaesthetising adult eels
- Preliminary CPUE indices as relative abundance of eel in different locations
- Sampling with fine mesh fyke nets obtains representative samples of eel populations
- Sampling with exclusion screen obtains representative samples of eel populations
- Heightened awareness of the negative impacts hydro-electric power stations have on upstream and downstream eel migration
- Evidence of the effectiveness of past elver transfer practises

APPENDIX 2: STAFF EMPLOYED ON THE PROJECT

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APPENDIX 3: RELEVANT INFORMATION

The Derwent Catchment

The River Derwent (Figure 1) begins at Lake St Clair and flows in a south-easterly direction. The system is 187 km in length to the head of the estuary at New Norfolk. The entire Derwent River catchment area covers 8,800 km^2 (Hydro Tas, 2002) Hydro-electric development began in the Derwent River in 1934 when construction commenced on the Tarraleah power station. It was not until 1968 that the final power stations were commissioned resulting in the Derwent River and nine of its tributaries being dammed for hydro-electric generation (Hydro Tas, 2002) The whole Derwent system includes 16 dams, 10 power stations and a large number of weirs, canals, tunnels and pipelines. The 10 power stations produce approximately 27% of Tasmania's electricity (Hydro Tas, 2002). The Clyde River, which is sourced from lakes Sorell and Crescent (both large and productive eel fisheries) is also controlled for the purposes of irrigation. The majority of riverine flows in the catchment are diverted through the power stations and can be characterised as having a modified flow regime (Hydro Tas, 2002).

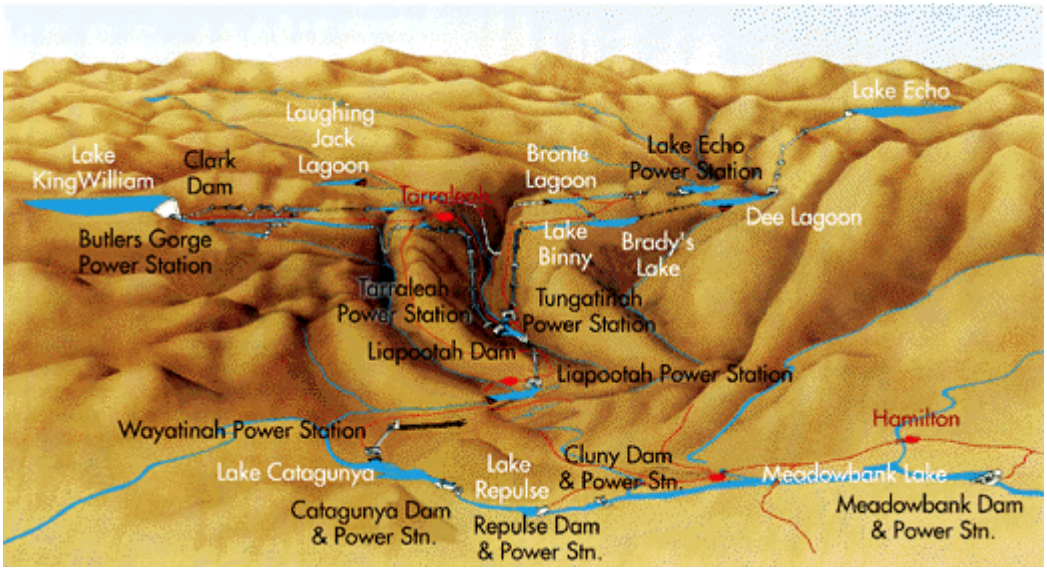

Figure 1. Derwent Catchment Source: Hydro Tas, 2001

The Great Lake catchment, which drains part of Tasmania's Central Plateau, previously contributed water to the Derwent Catchment. Since the construction of the Poatina power scheme in 1965, the majority of water from this catchment is now diverted into the South Esk Basin.

The hydro-electric power developments in the Derwent Catchment that are currently operating form a relatively complex system, which, can be simplified into three main components (Table 1).

The ***Upper Derwent System*** utilises water from the upper Derwent River and its headwaters and from several small diversions, it consists of two storage dams and two power stations.

The ***Nive-Dee System*** generates electricity, using water mostly from the Nive and Dee rivers and includes nine storages and two power stations.

The ***Lower Derwent System*** is a cascade of six storages and 6 power stations on the lower Nive and Derwent rivers and utilises water diverted from both the upper Derwent and Nive-Dee systems.

A fourth part of the Derwent Catchment is the Ouse-Shannon system, the function of which is irrigation storage. The Ouse-Shannon system comprises of three storages and defunct water diversion infrastructure.

Table 1: Power Stations in the Derwent Catchment (Hydro Tas, 2001)

Power Development	Power Station	Date(s) Commissioned	Turbines	Capacity (MW)
Upper Derwent	Butlers Gorge	1951	1 Francis	12.2
	Tarraleah	1938 - 1951	6 Pelton	90
Nive-Dee	Lake Echo	1956	1 Francis	32.4
	Tungatinah	1953 - 1956	5 Francis	125
Lower Derwent	Liapootah	1960	3 Francis	87.3
	Wayatinah	1957	3 Francis	38.3
	Catagunya	1962	2 Francis	48
	Repulse	1968	1 Kaplan	28
	Cluny	1967	1 Kaplan	17
	Meadowbank	1967	1 Kaplan	40

The Derwent River represents Australia's second largest juvenile eel resource (IFS, 2002). The largest harvest of juvenile eels to date occurred during the 1995-1996 season, which saw 3,183 kilograms of elvers harvested. This equates to approximately 1,432,350 individual juvenile eels.

The Upper Derwent System

Lake St Clair represents the beginning of the Derwent river system (Figure 2), there may be a small population of old eels present in the lake but due to hydro-electric construction, any natural recruitment into the lake is believed to be impossible. Eels must successfully negotiate successive hydro-electric structures downstream to reach the sea to spawn.

Figure 2. The beginning of the Derwent River at Lake St Clair.

The next water storage downstream of Lake St Clair is Lake King William (Figure 3). Approximately 177 kg of elvers were stocked into King William during the 1995/1996 season for conservation and biological reasons in light of the fact that no natural recruitment is thought to occur this far up the Derwent system (Hydro Tas, 2002).

In 1947, the arrival of Polish and British migrants facilitated the completion of the 61 m high Clark Dam at Butlers Gorge in 1951, following a shortage of labour during the Second World War. This dam created a large storage for Tasmania's hydro-electric development – Lake King William (Hydro Tas, 2002).

Figure 3. Lake King William / Butlers Gorge

The Butlers Gorge Power station is situated at the base of the dam wall and consists of one Francis turbine with the capacity to produce 12.2 MW (Hydro Tas, 2002). Downstream migrating silver eels must negotiate not only large pressure changes but also the passage through the Francis turbines.

From Butlers Gorge, water then runs down into the Tarraleah power station (Figure 4) through a series of canals and pipelines. The Tarraleah power station consists of 6 Pelton turbines with the last being commissioned in 1951. All six operate with a head of about 290 metres and result in a combined capacity of 90 MW (Hydro Tas, 2002).

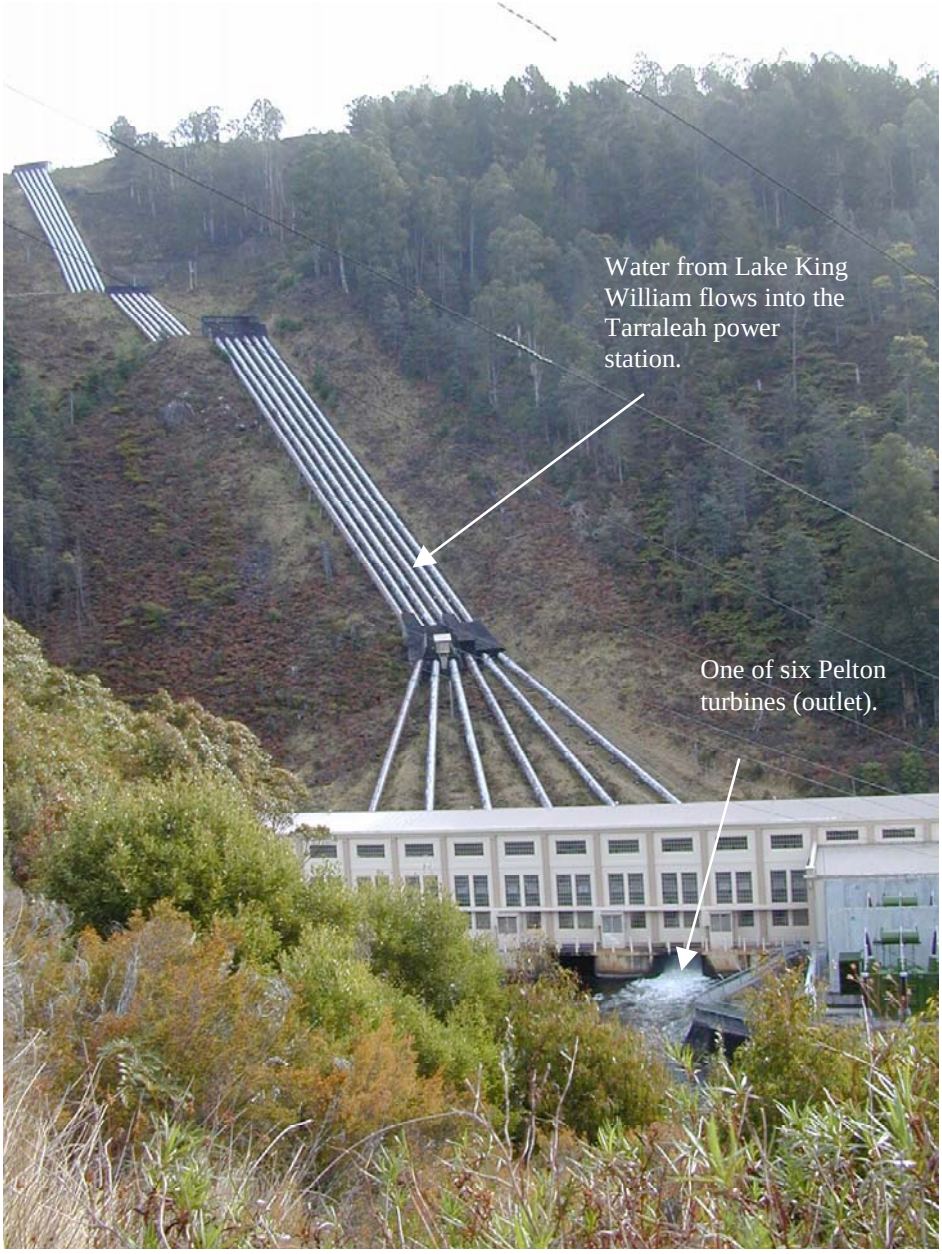

Figure 4.4. Tarraleah Power Station

It is well documented that Pelton turbines result in 100% eel mortality because of the nature of the design (Travade and Larinier, 1992). Therefore, it is highly unlikely that any downstream migrating eels that successfully pass through Butlers Gorge will survive passage through the Tarraleah power station.

The Nive-Dee System

At the end of World War II, electricity demand increased dramatically and in 1947 development of the Nive and Dee catchment areas north of Tarraleah was approved. Pine Tier Dam (Figure 5) was built to store water on the Nive River diverting water via the Bronte Canal into Bronte Lagoon. Bronte Lagoon also collects water from Serpentine Creek, laughing Jack lagoon and the Clarence River (via the Clarence Pipeline) (Hydro Tas, 2002).

Figure 5. Pine Tier Dam

Bronte Lagoon is part of four small storages connected by unlined canals. Water flows from Bronte Lagoon through Bradys Lake, Lake Binney and Tungatinah lagoon. From Tungatinah Lagoon, water is passed through a short tunnel into penstocks and a 300 m drop (Figure 6) into the Tungatinah Power Station (Figure 7). The Tungatinah Power Station is situated in the valley of the Nive River next to the Tarraleah Power Station. The Tungatinah power station consists of 5 Francis Turbines with a combined capacity of 130.5 MW (Hydro Tas, 2002).

Figure 6. Pipelines from Tungatinah Lagoon into the Tungatinah Power Station

Figure 7. Tungatinah Power Station

The Dee River also feeds water into the Tungatinah power station. Lake Echo (Figure 8) was raised with the construction of a rockfill dam across the headwaters of the Dee River and kilometres further south a second rockfill dam across the Dee River forms Dee Lagoon. (Hydro Tas, 2002).

Figure 8. Lake Echo

Water from Lake Echo flows via a flume and canal (Figure 9) before falling 170 m through a steel penstock to the Echo power station at Dee Lagoon. The Lake Echo power station was commissioned in 1956 and contains a Francis turbine driven generator with a capacity of 32.4 MW (Hydro Tas, 2002).

Figure 9. Flume canal to the Lake Echo Power Station

Water from Dee Lagoon is sent in a westerly direction through a tunnel to Bradys Lake. Water from Bronte Lagoon also flows into Bradys Lake which then flows through Tungatinah Lagoon and the Tungatinah power station (Hydro Tas, 2002).

The Lower Derwent System

Developments downstream of the Tarraleah power station are classified as components of the Lower Derwent Power Development. The next six power stations of the Lower Derwent Power Development form a relatively simple step-like series. They all consist of small storages and receive daily inflows from tributaries of the Derwent River as well as flow from the Tungatinah and Tarraleah power stations (Hydro Tas, 2002).

Lake Liapootah is located on the Nive River, below the Tarraleah power station and its outflows are diverted through a 6.6 km tunnel. Water then makes its way to the Liapootah power station via steel penstocks dropping over 100 m. The Liapootah power station consists of 3 generators (Francis turbines), each with a capacity of 29.1 MW. These generators were commissioned in 1960 (Hydro Tas, 2002).

Water from the Liapootah power station flows into Wayatinah Lagoon, which is impounded by a rockfill dam located on the Derwent River, and stores water for hydro-electric generation. Water flows from Wayatinah Lagoon into steel penstocks via tunnels and woodstave pipelines and then drops 56 metres to the Wayatinah Power Station (Figure 10) (Hydro, Tas, 2002).

Figure 10. Wayatinah Power Station

The Wayatinah power station consists of three generators (Francis turbines) commission in 1957 and each has a capacity of 12.75 MW (Hydro Tas, 2002).

From the Wayatinah power station the Derwent River flows into the Lake Catagunya storage, which was formed by a concrete gravity dam, strengthened by a large number of steel cables. Outflows from Lake Catagunya are directed via a wide concrete flume imbedded into the hillside. It then drops 44 metres through twin steel penstocks and into the Catagunya power station situated 5km downstream of Wayatinah. Catagunya power station consists of two 24 MW capacity generators of the Francis design. (Hydro Tas, 2002).

The next stage sees water flow through the remaining 3 power stations before flowing into the head of the Derwent River estuary. The lower three power stations on the

Derwent River were approved by parliament in 1961 and include; Repulse, Cluny and Meadowbank (Figures 11, 12 and 13). Each power station is situated at the foot of concrete dams and each consists of a single Kaplan turbine. The single Kaplan turbine drive generators of these three power stations have a capacity of 28, 17 and 40 MW respectively (Hydro Tas, 2002).

Figure 11. Repulse Power Station

Figure 12. Cluny Power Station

Figure 13. Meadowbank Power Station

After water has completed its passage through the Meadowbank power station, it then continues to flow in a south-easterly direction as the Derwent River and makes its way down to the head of the Derwent River estuary at New Norfolk. This water, which originated at an altitude above 846 m around Lake Echo and 737 m around Lake St Clair flows out of the Meadowbank Power Station at an altitude of 44 m above sea level (Hydro Tas, 2002).

In comparison to a natural watercourse where elvers are able to migrate upstream and sexually mature eels can migrate downstream, the extensive hydro-electric power development on the Derwent River poses direct implications on the migration, distribution and sustainability of Tasmania's freshwater eel resources.

The South Esk – Great Lake Catchment

Three water catchments make up the South Esk Basin, the South Esk, Meander and Macquarie. They join to discharge from a single point, Lake Trevallyn near the start of the Tamar River in the north of the State (Figure 1). Water from the Great Lake catchment is diverted into the South Esk Basin for hydro-electric power generation. The South Esk Basin is the largest water catchment in Tasmania, representing almost 15% of the State's land mass (Hydro Tas, 2002).

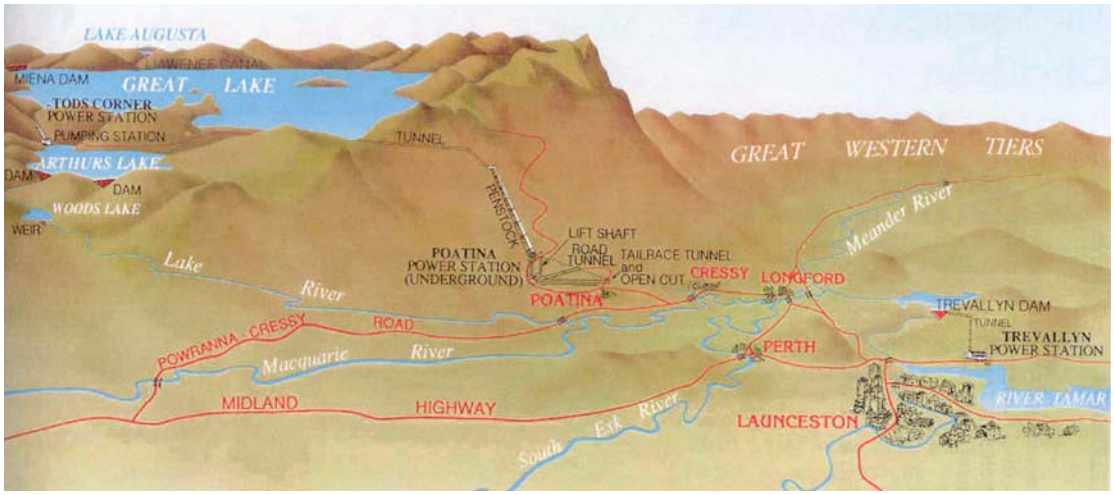

Figure 1. South Esk – Great Lake catchment Source: Hydro Tasmania

The Poatina power scheme utilises water from the Great Lake, Arthurs Lake (originally in the upper Macquarie River sub-catchment) and diversions of the upper Ouse River, the upper Liffey River and Westons Rivulet - upper Brumbys Creek. The Poatina scheme consists of three main storages (Great Lake, Arthurs Lake and Lake Augusta), two power stations (Poatina and Todds Corner) and other water diversion and transfer infrastructure (Table 2). Woods Lake is also associated with the Poatina power scheme, but its primary function is to store water for irrigation. The Poatina power scheme diverts 620 - 730 Mm^3 per year of Great Lake water from the Derwent catchment, via the Poatina power station, into the South Esk catchment (Hydro Tas, 2002)

The Trevallyn power scheme utilises water from the entire South Esk catchment, harnessing the South Esk, Macquarie and Meander Rivers, and re-using water from the Great Lake catchment discharged from the Poatina power station. The scheme

consists of one small storage (Lake Trevallyn) and the Trevallyn power station (Hydro Tas, 2002). Water from the power station is discharged into the Tamar Estuary. This discharged water attracts Australia's largest harvestable congregation of juvenile eels. Up to 3500 kg (approximately 3,500,000 individuals) have been harvested and restocked in a good productive season.

Poatina Power Station

Poatina is the largest power station in the South Esk – Great Lake catchment, and is the second largest in the State. Water from Great Lake is directed through a tunnel in the Great Western Tiers, and falls 835 m through a tunnel and pipe, before entering the power station. The power station is underground and houses six 50MW Pelton turbines. Water from Poatina is discharged into Brumbys Creek, at the tributary of the Macquarie River (Hydro Tas, 2002).

Tods Corner Power Station

The Tods Corner power station is a small automatic power station, housing a single Francis turbine. It was built to take advantage of the fall of water from Arthurs flume down to Great Lake following pumping from Arthurs Lake, to recoup some of the energy used in the pumping process. Water is pumped approximately 140 m up from Arthurs Lake, to the 7.25 km long Arthurs Flume, which transfers the water to the Tods Corner forebay above the south-east corner of Great Lake. Water is taken into the power station from the forebay and discharged into Great Lake (Hydro Tas, 2002).

Trevallyn Power Station

The Trevallyn power station is situated on the Tamar Estuary only 5 km from the centre of Launceston, the largest city in the north of the State. Trevallyn Dam diverts water through a 3.2 km tunnel to the power station, containing four Francis turbines. Water flows from the power station into the Tamar Estuary at sea level (Hydro Tas, 2002).

The five Hydro-controlled storages in the South Esk – Great Lake catchment are Great Lake, Arthurs Lake, Lake Augusta, Lake Trevallyn and Woods Lake. The primary function of the first four lakes is power generation, while water releases from Woods Lake are used to satisfy irrigation requirements on the Lake and lower

Macquarie rivers. Excess water released from Woods Lake may also generate power at the Trevallyn power station if it has not been withdrawn from the system for other uses. Water from Shannon Lagoon is pumped into Great Lake when the lagoon is at high levels, however water may also be released from Shannon Lagoon into the Derwent system for irrigation purposes (Hydro Tas, 2002).

Great Lake

Great Lake is retained by the Miena Dam, a 28 m high rockfill structure across the outflow of the Shannon River. The original lake was much shallower than the current storage, with a maximum depth of only 6 m. Aquatic plant beds were dense throughout the lake, and Tods corner, Lake Elizabeth, Little Lake Breona and Boggy Marsh, which are now inundated by Great Lake were separate water bodies (Hydro Tas, 2002).

Inflows to Great Lake include the upper Ouse River (diverted via Liawenee Canal from Lake Augusta) from the west, Arthurs Lake (via Tods Corner Power Station) from the south-east, the Liffey Diversion (via Pine Lake and Halfmoon Creek) from the north-west, the Brumbys – Westons Rivulet diversion from the north, Shannon Lagoon (via pumps) from the south and several natural streams (Hydro Tas, 2002).

The main outlet of water from Great Lake is through a 5.7 km rock tunnel to the north and down a penstock to the Poatina power station. Water may be released from Great Lake to the Shannon River via discharge gates at Miena Dam. This water then flows through the Derwent catchment (Hydro Tas, 2002).

Arthurs Lake

Arthurs Lake is in the upper South Esk catchment and receives water from its natural catchment. The construction of Arthurs Dam flooded a marsh area and two smaller natural water bodies, Sand Lake and Blue Lake. The natural outflow from Arthurs Lake was the Lake River, which originally drained through Woods Lake into the Macquarie River (Hydro Tas, 2002).

Arthurs Lake is a diversion storage for Great Lake. The outflow from Arthurs Lake is now pumped from Pumphouse Bay, on the lake's south-west corner, to Great Lake

via the Tods Corner power station. Water may be released down the Lake River via a riparian valve and siphons at Arthurs Dam. Arthurs Lake spills only under exceptional circumstances with normal operating procedures preventing this (Hydro Tas, 2002).

Lake Augusta

Lake Augusta is also a diversion storage for Great Lake. It is possible to divert or spill Lake Augusta water into Lake Echo in the Derwent catchment, but this is usually avoided if possible. Lake Augusta receives water from its natural catchment including the Ouse River and James River, which were dammed by Augusta Dam. The lake is also impounded by Augusta Levee and Carter Levee (Hydro Tas, 2002).

Water is released from Lake Augusta into a section of the Ouse River via two large valves, and is then diverted into Liawenee Canal, which transfers the water to Great Lake. Lake Augusta regularly spills during winter into the Ouse River via the Augusta levee (Hydro Tas, 2002).

Lake Trevallyn

Lake Trevallyn is an instream storage that flooded a steep, lightly wooded gully of the South Esk River. The section of the river that was flooded by the Trevallyn Dam was mostly a rock/gravel fastwater, interspersed with several deep pools. Water from the entire South Esk Basin and the associated Great Lake diversion drains into Lake Trevallyn via the South Esk River (Hydro Tas, 2002).

The water stored in Lake Trevallyn is used for electricity generation at the Trevallyn power station. Water leaves the lake through the intake to the power station, which is discharged into the Tamar Estuary. Lake Trevallyn water may also spill or be released into the South Esk River, flowing through the Cataract Gorge and into the Tamar estuary upstream of the tailrace (Hydro Tas, 2002).

Woods Lake

Woods Lake is primarily a storage utilised for irrigation, although these releases may also eventually generate power at Trevallyn, if not withdrawn for irrigation or riparian use. Irrigation releases and spills from Woods Lake go into the Lake River. Inflows to Woods Lake include water from Jacks Creek, which occasionally carries spill from

the Ripple Creek diversion in the Derwent catchment, and the upper Lake River (Hydro Tas, 2002).

Table 2. Structures on the South Esk – Great Lake system (Hydro Tas, 1999)

Scheme	Structure	River	Storage	Crest Length (m)	Height (m)	Construction	Year Completed
Poatina	Miena Dam	Shannon	Great Lake	1140	28	Clay-cored rockfill	1982
	Miena Levee B	N/A	Great Lake	300	6	Clay-cored rockfill	1967
	Arthurs Dam	Lake	Arthurs Lake	475	19	Zoned rockfill with Concrete crest	1965
	Arthurs Levee	N/A	Arthurs Lake	609	7	Clay-cored earthfill	1963
	Augusta Dam	Ouse	Lake Augusta	970	13	Clay-cored rockfill	1953
	Carter Levee	N/A	Lake Augusta	273	2	Clay-cored rockfill	1953
	Augusta Levee	N/A	Lake Augusta	564	3	Clay-cored rockfill	1953
	Augusta Spillway Levee(s)	N/A	Lake Augusta	610	2	Clay-cored rockfill	1953
	Liawenee Weir	Ouse	N/A	25	?	Concrete	1923
	Liawenee Canal Fish Barrier	Liawenee Canal	N/A	20	1.9	Concrete	1999
	Westons Weir	Westons Rivulet	N/A	88	2.8	Concrete	1966
	Brumbys Diversion Weir	Westons Rivulet	N/A	87	0.9	Concrete	1966
	Liffey Weir	Liffey	N/A	2	0.2	Concrete	1964
Trevallyn	Trevallyn Dam	South Esk	Lake Trevallyn	176	33	Concrete gravity	1955
	Brumbys No.1 Control Weir	Brumbys Creek	N/A	135	?	Concrete	1960s
	Brumbys No.2 Control Weir	Brumbys Creek	N/A	100	?	Concrete	1960s
	Brumbys No.3 Control Weir	Brumbys Creek	N/A	55	?	Concrete	1960s
Irrigation Storage	Woods Dam	Lake	Woods Lake	393	7	Clay-cored rockfill	1962

2000/2001 Eel Catch Data

Location	Date	Eel No.	Length (mm)	Weight (g)	Age (YIF)
Meadowbank	28-Nov-00	1	688.0	656.8	22
Meadowbank	28-Nov-00	2	570.0	397.7	22
Meadowbank	28-Nov-00	3	565.0	377.9	19
Meadowbank	28-Nov-00	4	643	432.7	-
Meadowbank	28-Nov-00	5	603	412.1	22
Meadowbank	28-Nov-00	6	660	576.8	-
Meadowbank	28-Nov-00	7	510	222.5	-
Meadowbank	28-Nov-00	8	418	137.9	13
Meadowbank	28-Nov-00	9	598.0	370.1	16
Meadowbank	28-Nov-00	11	829.0	1077.7	30
Meadowbank	28-Nov-00	12	586.0	432.1	21
Meadowbank	28-Nov-00	13	473.0	179.8	18
Meadowbank	28-Nov-00	14	497.0	247.8	17
Meadowbank	28-Nov-00	10	432	132.4	13
Meadowbank	29-Nov-00	755	253	25.2	-
Meadowbank	29-Nov-00	756	197	10.8	4
Meadowbank	29-Nov-00	763	520	287.4	21
Meadowbank	29-Nov-00	764	306	46.9	8
Meadowbank	29-Nov-00	765	228	17	7
Meadowbank	29-Nov-00	766	250	19.3	7
Meadowbank	29-Nov-00	751	613	465.2	41
Meadowbank	29-Nov-00	752	490	231.2	21
Meadowbank	29-Nov-00	753	660	556.1	23
Meadowbank	29-Nov-00	749	289	37	8
Meadowbank	29-Nov-00	768	670	480	17
Meadowbank	29-Nov-00	769	270	28	5
Meadowbank	29-Nov-00	750	183	5.8	-
Meadowbank	29-Nov-00	759	685	612	24
Meadowbank	29-Nov-00	760	634	511.4	15
Meadowbank	29-Nov-00	761	572	437.6	20
Meadowbank	29-Nov-00	762	482	206.4	22
Meadowbank	29-Nov-00	754	600	475	20
Meadowbank	29-Nov-00	767	615	430.2	23
Meadowbank	29-Nov-00	770	495	216	20
Meadowbank	29-Nov-00	771	336	61	8
Meadowbank	29-Nov-00	748	589	384.6	21
Meadowbank	29-Nov-00	757	520	248.2	-
Meadowbank	29-Nov-00	758	525	275.2	14
Meadowbank	29-Nov-00	747	616	500.3	22
Meadowbank	30-Nov-00	17	475	213.4	-
Meadowbank	30-Nov-00	15	633.0	477	19
Meadowbank	30-Nov-00	16	505	241.5	-
Meadowbank	30-Nov-00	44	580.0	346.7	22
Meadowbank	30-Nov-00	45	557.0	301.9	23
Meadowbank	30-Nov-00	46	580.0	378	18
Meadowbank	30-Nov-00	47	362.0	80.6	11
Meadowbank	30-Nov-00	38	648.0	495.1	22
Meadowbank	30-Nov-00	39	596	374	21
Meadowbank	30-Nov-00	33	593.0	453	16
Meadowbank	30-Nov-00	34	438	119.7	19
Meadowbank	30-Nov-00	35	670.0	627	22
Meadowbank	30-Nov-00	22	574.0	306.2	16
Meadowbank	30-Nov-00	20	763	928.5	-
Meadowbank	30-Nov-00	21	544	253.1	28
Meadowbank	30-Nov-00	48	320	56.4	-
Meadowbank	30-Nov-00	31	481.0	212.3	12
Meadowbank	30-Nov-00	50	189	8.2	-
Meadowbank	30-Nov-00	42	662.0	471.7	32
Meadowbank	30-Nov-00	43	318.0	56.9	8
Meadowbank	30-Nov-00	49	422.0	130.8	15
Meadowbank	30-Nov-00	23	840.0	1236.1	28
Meadowbank	30-Nov-00	24	790.0	1338.9	55
Meadowbank	30-Nov-00	25	651.0	551.7	30
Meadowbank	30-Nov-00	26	636	462.8	-
Meadowbank	30-Nov-00	27	598	346.4	-
Meadowbank	30-Nov-00	28	564	343.2	-
Meadowbank	30-Nov-00	29	471	168.7	-
Meadowbank	30-Nov-00	30	657	591.4	-
Meadowbank	30-Nov-00	40	580.0	351.1	19
Meadowbank	30-Nov-00	41	504.0	239.2	27
Meadowbank	30-Nov-00	32	580.0	388.4	22
Meadowbank	30-Nov-00	18	441	123.7	-
Meadowbank	30-Nov-00	19	466	186.1	-
Meadowbank	1-Dec-00	441	368	82.8	16
Meadowbank	1-Dec-00	437	870	1586.2	30
Meadowbank	1-Dec-00	438	595	246	-
Meadowbank	1-Dec-00	439	690	665.7	30
Meadowbank	1-Dec-00	440	542	336.7	21
Meadowbank	1-Dec-00	442	596	406.6	-
Derwent	5-Dec-00	312	475	194.5	28
Derwent	5-Dec-00	313	515	248.2	27
Derwent	5-Dec-00	294	439	152.6	-
Meadowbank	5-Dec-00	314	655	633.6	24
Meadowbank	5-Dec-00	282	617	494.8	27
Meadowbank	5-Dec-00	293	415	134.7	-
Meadowbank	5-Dec-00	315	590	350.6	23
Derwent	6-Dec-00	170	392	113.7	22
Derwent	6-Dec-00	102	532	345.3	48
Derwent	6-Dec-00	122	754	940.7	45
Derwent	6-Dec-00	123	605	459.3	27
Derwent	6-Dec-00	160	870	1401	25
Meadowbank	5-Dec-00	316	615	393.5	-
Meadowbank	5-Dec-00	317	390	96	-
Meadowbank	5-Dec-00	318	360	86	16
Meadowbank	5-Dec-00	319	420	104.9	-
Meadowbank	5-Dec-00	320	398	100.4	-
Meadowbank	5-Dec-00	321	327	52.9	-
Meadowbank	5-Dec-00	322	265	27.5	-
Meadowbank	5-Dec-00	311	555	305	15
Meadowbank	5-Dec-00	289	624	517.4	25
Meadowbank	5-Dec-00	300	822	1172.2	-
Meadowbank	5-Dec-00	301	540	349.5	-
Meadowbank	5-Dec-00	290	641	485.8	31
Meadowbank	5-Dec-00	291	725	940.2	29
Meadowbank	5-Dec-00	292	590	460	40
Meadowbank	5-Dec-00	283	789	922.3	-
Meadowbank	5-Dec-00	284	558	322.7	25
Meadowbank	5-Dec-00	285	416	140.8	18
Meadowbank	5-Dec-00	286	535	325.2	25
Meadowbank	5-Dec-00	287	440	150	22
Derwent	5-Dec-00	280	375	104.8	24
Derwent	5-Dec-00	281	342	55.7	20
Derwent	5-Dec-00	288	424	136.1	22
Derwent	5-Dec-00	323	570	357.3	26
Derwent	5-Dec-00	324	460	177.4	-
Derwent	5-Dec-00	325	393	107.2	-
Derwent	5-Dec-00	326	350	64.7	-
Derwent	5-Dec-00	302	544	282.2	-
Derwent	5-Dec-00	303	450	162.2	-
Derwent	5-Dec-00	304	810	1244.5	-
Derwent	5-Dec-00	305	630	451.3	-
Derwent	5-Dec-00	306	470	190	-
Derwent	5-Dec-00	307	435	218	24
Derwent	5-Dec-00	308	466	176.5	20
Derwent	5-Dec-00	309	320	49.7	11
Derwent	5-Dec-00	310	292	39.3	-
Derwent	6-Dec-00	157	695	719.2	-
Derwent	6-Dec-00	126	566	357.7	36
Derwent	6-Dec-00	127	380	82.5	23
Derwent	6-Dec-00	95	558	394	23
Derwent	6-Dec-00	96	418	131	21
Derwent	6-Dec-00	97	406	101.7	17
Derwent	6-Dec-00	98	420	126.2	30
Derwent	6-Dec-00	99	412	128.1	-
Derwent	6-Dec-00	121	350	80	14
Derwent	6-Dec-00	143	695	724.5	27
Derwent	6-Dec-00	144	470	207.5	30
Derwent	6-Dec-00	145	575	370.1	43
Derwent	6-Dec-00	146	456	185	25
Derwent	6-Dec-00	147	447	173.6	24
Derwent	6-Dec-00	148	545	284.1	23
Derwent	6-Dec-00	149	574	354.7	35
Derwent	6-Dec-00	150	527	276.5	17
Derwent	6-Dec-00	151	427	157.4	17
Derwent	6-Dec-00	152	488	243.9	18
Derwent	6-Dec-00	153	459	174.5	22
Derwent	6-Dec-00	154	540	272.5	21
Derwent	6-Dec-00	155	601	434.9	24
Derwent	6-Dec-00	156	451	208.6	17
Meadowbank	6-Dec-00	134	335	67.2	-
Meadowbank	6-Dec-00	135	360	76.8	-
Meadowbank	6-Dec-00	136	422	127.5	8
Meadowbank	6-Dec-00	137	602	420.8	35
Meadowbank	6-Dec-00	138	537	264	16
Meadowbank	6-Dec-00	139	475	169.1	-
Meadowbank	6-Dec-00	140	539	278.9	-
Meadowbank	6-Dec-00	141	247	23.1	7
Meadowbank	6-Dec-00	142	396	99.1	8
Meadowbank	6-Dec-00	158	365	97.8	13
Meadowbank	6-Dec-00	159	456	175.5	9
Meadowbank	6-Dec-00	100	612	478.5	26
Meadowbank	6-Dec-00	101	170	7.6	4
Meadowbank	6-Dec-00	103	348	54.5	22
Meadowbank	6-Dec-00	124	708	931	34
Meadowbank	6-Dec-00	125	492	253	34
Derwent	6-Dec-00	92	369	80.3	-
Derwent	6-Dec-00	93	295	42.8	17
Derwent	6-Dec-00	90	870	1559	44
Derwent	6-Dec-00	91	497	287	-
Derwent	6-Dec-00	162	650	553.1	39
Derwent	6-Dec-00	163	502	224.3	24
Derwent	6-Dec-00	164	549	354.2	20
Derwent	6-Dec-00	165	680	630.2	24
Derwent	6-Dec-00	166	527	321.1	20
Derwent	6-Dec-00	167	543	293.6	23
Derwent	6-Dec-00	168	424	135.7	16
Derwent	6-Dec-00	169	416	147.2	-
Meadowbank	9-Jan-01	407	600	428.6	-
Meadowbank	9-Jan-01	428	514	273.7	21
Derwent	9-Jan-01	420	297	42.6	-
Derwent	9-Jan-01	421	642	503.8	27
Derwent	9-Jan-01	413	748	822.8	33

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Derwent	6-Dec-00	161	395	125.8	16	Derwent	9-Jan-01	414	574	401	21
Derwent	6-Dec-00	104	415	138.7	23	Derwent	9-Jan-01	415	580	334.1	27
Derwent	6-Dec-00	105	420	137.5	25	Derwent	9-Jan-01	416	492	211	24
Derwent	6-Dec-00	106	360	75.5	16	Derwent	9-Jan-01	417	418	116.3	23
Derwent	6-Dec-00	107	323	59.2	19	Derwent	9-Jan-01	418	445	177.5	-
Derwent	6-Dec-00	128	726	700	28	Derwent	9-Jan-01	419	330	63.1	22
Derwent	6-Dec-00	129	430	116.2	21	Derwent	9-Jan-01	423	840	1415.2	38
Derwent	6-Dec-00	130	630	513.8	30	Derwent	9-Jan-01	424	455	170.3	18
Derwent	6-Dec-00	131	390	105	17	Derwent	9-Jan-01	425	285	35.3	9
Derwent	6-Dec-00	132	515	319	28	Derwent	9-Jan-01	403	792	1119.4	28
Derwent	6-Dec-00	133	443	156	35	Derwent	9-Jan-01	404	481	220	27
Derwent	6-Dec-00	94	461	181.2	33	Derwent	9-Jan-01	405	396	86.9	-
Derwent	6-Dec-00	108	646	479	33	Derwent	9-Jan-01	408	782	1021.2	38
Derwent	6-Dec-00	109	640	552.9	33	Derwent	9-Jan-01	409	483	215.3	23
Derwent	6-Dec-00	110	585	436.5	23	Derwent	9-Jan-01	410	409	126.4	-
Derwent	6-Dec-00	111	567	474	22	Derwent	9-Jan-01	411	311	44.4	16
Derwent	6-Dec-00	112	402	114	22	Derwent	9-Jan-01	412	246	21.6	10
Derwent	6-Dec-00	113	392	114	19	Derwent	9-Jan-01	406	257	25.4	8
Derwent	6-Dec-00	114	530	286.8	25	Derwent	9-Jan-01	402	787	1228.2	22
Derwent	6-Dec-00	115	370	103.1	-	Meadowbank	9-Jan-01	422	628	448.3	22
Derwent	6-Dec-00	116	470	198.2	14	Derwent	9-Jan-01	426	476	147.1	33
Derwent	6-Dec-00	117	360	89.9	-	Derwent	9-Jan-01	427	370	84.6	22
Derwent	6-Dec-00	118	408	109.9	17	Meadowbank	10-Jan-01	177	420	104	21
Derwent	6-Dec-00	119	329	67.2	10	Meadowbank	10-Jan-01	192	695	633.5	21
Derwent	6-Dec-00	120	303	51	12	Meadowbank	10-Jan-01	183	735	745.6	31
Derwent	7-Dec-00	62	422	144.2	17	Derwent	10-Jan-01	178	545	305	17
Derwent	7-Dec-00	63	492	211.3	23	Derwent	10-Jan-01	179	435	133.3	31
Derwent	7-Dec-00	64	565	354	28	Derwent	10-Jan-01	180	400	97.7	39
Derwent	7-Dec-00	71	722	845.7	-	Derwent	10-Jan-01	181	300	43.1	-
Derwent	7-Dec-00	72	561	348	-	Derwent	10-Jan-01	172	625	413.6	30
Derwent	7-Dec-00	73	651	661.3	-	Meadowbank	10-Jan-01	194	550	274.9	21
Derwent	7-Dec-00	74	661	606	-	Meadowbank	10-Jan-01	195	500	201.1	20
Derwent	7-Dec-00	75	579	433	-	Derwent	10-Jan-01	173	605	412.5	32
Derwent	7-Dec-00	76	390	111.1	10	Derwent	10-Jan-01	174	680	710.8	46
Derwent	7-Dec-00	69	630	530.5	-	Derwent	10-Jan-01	175	525	290.6	23
Derwent	7-Dec-00	70	460	187.6	25	Derwent	10-Jan-01	176	415	118.5	25
Derwent	7-Dec-00	58	537	305	21	Derwent	10-Jan-01	182	630	427.2	37
Meadowbank	7-Dec-00	52	516.0	277.5	22	Meadowbank	10-Jan-01	191	355	75.2	8
Meadowbank	7-Dec-00	53	716.0	731.5	31	Derwent	10-Jan-01	184	785	1007.3	35
Meadowbank	7-Dec-00	54	601	402.7	24	Derwent	10-Jan-01	185	490	158.5	22
Derwent	7-Dec-00	65	371	74.5	17	Derwent	10-Jan-01	187	400	100.3	14
Derwent	7-Dec-00	66	670	573.5	18	Derwent	10-Jan-01	188	585	343.5	23
Derwent	7-Dec-00	67	496	272.5	-	Derwent	10-Jan-01	189	430	124.5	25
Derwent	7-Dec-00	68	860	1334.3	39	Derwent	10-Jan-01	190	340	64.7	16
Derwent	7-Dec-00	59	700	846.5	36	Meadowbank	10-Jan-01	193	520	200.5	12
Derwent	7-Dec-00	60	516	290	19	Derwent	10-Jan-01	171	680	493.1	22
Derwent	7-Dec-00	61	425	137	22	Meadowbank	10-Jan-01	186	710	648.6	24
Meadowbank	7-Dec-00	57	688	658.1	12	Meadowbank	11-Jan-01	454	565	321	19
Meadowbank	7-Dec-00	56	785	924	21	Meadowbank	11-Jan-01	462	570	475	19
Meadowbank	7-Dec-00	55	656	479.2	-	Meadowbank	11-Jan-01	463	641	520.3	34
Meadowbank	7-Dec-00	51	602.0	360	32	Meadowbank	11-Jan-01	449	610	444.2	21
Derwent	7-Dec-00	89	557	325.3	25	Meadowbank	11-Jan-01	455	375	90.6	11
Derwent	7-Dec-00	86	315	45.6	9	Derwent	11-Jan-01	448	748	743.6	23
Derwent	7-Dec-00	85	646	503.8	33	Derwent	11-Jan-01	444	475	193.5	29
Derwent	7-Dec-00	87	531	302.1	30	Meadowbank	11-Jan-01	464	556	370.5	16
Derwent	7-Dec-00	88	420	122.7	16	Meadowbank	11-Jan-01	461	456	147.8	16
Derwent	7-Dec-00	77	905	2030	38	Derwent	11-Jan-01	458	685	710.4	25
Derwent	7-Dec-00	78	380	105.3	12	Derwent	11-Jan-01	445	615	292.7	-
Derwent	7-Dec-00	79	402	115.1	-	Meadowbank	11-Jan-01	456	380	86.3	10
Derwent	7-Dec-00	80	450	162	-	Meadowbank	11-Jan-01	457	360	73	9
Derwent	7-Dec-00	81	375	89.8	24	Derwent	11-Jan-01	443	366	90.9	-
Derwent	7-Dec-00	82	403	123	-	Meadowbank	11-Jan-01	459	714	652.2	22
Derwent	7-Dec-00	83	333	59.1	16	Meadowbank	11-Jan-01	460	620	481.5	19
Derwent	7-Dec-00	84	296	47.1	-	Meadowbank	11-Jan-01	450	552	349.6	24
Derwent	8-Dec-00	496	577	422.7	42	Meadowbank	11-Jan-01	451	367	95.7	13
Meadowbank	8-Dec-00	429	730	691.7	21	Meadowbank	11-Jan-01	452	400	105.6	15
Derwent	8-Dec-00	493	560	320	27	Derwent	11-Jan-01	453	355	73.8	16
Derwent	8-Dec-00	494	495	230.6	30	Derwent	11-Jan-01	446	486	213	22
Derwent	8-Dec-00	498	534	307.3	34	Derwent	11-Jan-01	447	423	139	18
Derwent	8-Dec-00	489	840	1470	45	Meadowbank	17-Jan-01	602	520	281.3	28
Meadowbank	8-Dec-00	431	575	365.1	22	Meadowbank	17-Jan-01	603	465	170.1	20
Meadowbank	8-Dec-00	433	690	731.1	24	Meadowbank	17-Jan-01	604	315	52.9	10
Meadowbank	8-Dec-00	434	630	430.2	-	Derwent	17-Jan-01	600	402	113.9	21
Meadowbank	8-Dec-00	435	670	387.2	16	Meadowbank	17-Jan-01	559	478	201.2	33
Meadowbank	8-Dec-00	436	395	110.4	-	Meadowbank	17-Jan-01	560	588	380.7	17
Meadowbank	8-Dec-00	430	513	218.9	15	Meadowbank	17-Jan-01	561	472	204	13
Meadowbank	8-Dec-00	432	740	737.7	25	Derwent	17-Jan-01	608	535	329.6	22
Derwent	8-Dec-00	495	549	308.4	26	Derwent	17-Jan-01	609	570	357.4	38
Derwent	8-Dec-00	490	648	572	-	Derwent	17-Jan-01	610	430	135.5	27
Derwent	8-Dec-00	491	468	209.5	29	Derwent	17-Jan-01	611	395	97.5	-
Derwent	8-Dec-00	492	466	206.4	19	Derwent	17-Jan-01	599	360	92.4	14
Derwent	8-Dec-00	497	461	186.7	29	Meadowbank	17-Jan-01	565	675	664.6	25
Derwent	8-Dec-00	488	916	2281.7	34	Meadowbank	17-Jan-01	566	605	397.8	20
Meadowbank	17-Jan-01	567	594	427.7	26	Meadowbank	18-Jan-01	396	807	1108.5	44
Meadowbank	17-Jan-01	568	662	624.2	14	Meadowbank	18-Jan-01	390	622	496.4	38
Meadowbank	17-Jan-01	569	581	393.4	18	Meadowbank	18-Jan-01	364	475	178.8	13
Meadowbank	17-Jan-01	570	560	339	17	Meadowbank	18-Jan-01	365	452	154.4	-
Meadowbank	17-Jan-01	571	470	170.5	15	Meadowbank	18-Jan-01	393	350	74.4	12
Meadowbank	17-Jan-01	572	550	320.4	22	Meadowbank	18-Jan-01	394	222	18	-
Meadowbank	17-Jan-01	573	404	115	12	Meadowbank	18-Jan-01	395	230	18.3	7
Meadowbank	17-Jan-01	574	406	123	17	Derwent	18-Jan-01	392	515	265.7	19
Meadowbank	17-Jan-01	575	454	180.8	8	Meadowbank	18-Jan-01	354	955	1634.9	-
Meadowbank	17-Jan-01	555	543	304.5	18	Meadowbank	18-Jan-01	355	760	960.3	-

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Derwent	17-Jan-01	605	508	294.2	30	Meadowbank	18-Jan-01	356	764	793.4	-
Derwent	17-Jan-01	606	522	260.9	26	Meadowbank	18-Jan-01	357	544	307.6	-
Derwent	17-Jan-01	607	455	165.3	24	Meadowbank	18-Jan-01	358	525	291.2	-
Derwent	17-Jan-01	598	430	144.8	21	Meadowbank	18-Jan-01	359	580	378	-
Meadowbank	17-Jan-01	556	580	395.2	28	Meadowbank	18-Jan-01	360	718	538.6	-
Meadowbank	17-Jan-01	557	492	229.5	26	Meadowbank	18-Jan-01	361	580	658.5	-
Meadowbank	17-Jan-01	558	340	69	6	Meadowbank	18-Jan-01	362	405	125.4	-
Meadowbank	17-Jan-01	562	774	945.4	42	Meadowbank	18-Jan-01	363	455	178	-
Meadowbank	17-Jan-01	563	496	206.7	18	Meadowbank	18-Jan-01	366	561	398.7	25
Derwent	17-Jan-01	597	643	818	30	Meadowbank	18-Jan-01	367	459	173	20
Meadowbank	17-Jan-01	481	825	1168.4	-	Meadowbank	18-Jan-01	368	415	127.2	16
Meadowbank	17-Jan-01	482	595	417.7	-	Meadowbank	18-Jan-01	369	410	118	-
Meadowbank	17-Jan-01	483	620	501.3	21	Meadowbank	18-Jan-01	397	616	470.6	26
Meadowbank	17-Jan-01	484	600	423.4	22	Meadowbank	18-Jan-01	398	394	100.9	33
Meadowbank	17-Jan-01	485	453	172.9	10	Derwent	18-Jan-01	298	645	587.5	-
Meadowbank	17-Jan-01	486	395	90.3	22	Derwent	18-Jan-01	299	640	545.3	-
Meadowbank	17-Jan-01	487	305	44	-	Meadowbank	19-Jan-01	332	560	354.4	28
Meadowbank	17-Jan-01	538	720	716.7	21	Derwent	19-Jan-01	336	550	344.5	30
Meadowbank	17-Jan-01	539	670	661.1	23	Derwent	19-Jan-01	337	500	242.3	26
Meadowbank	17-Jan-01	540	720	765.3	25	Derwent	19-Jan-01	338	482	223.7	23
Meadowbank	17-Jan-01	541	294	40.8	7	Derwent	19-Jan-01	339	410	140.2	36
Meadowbank	17-Jan-01	542	272	29	-	Derwent	19-Jan-01	340	415	126.3	20
Meadowbank	17-Jan-01	543	240	19.6	4	Derwent	19-Jan-01	341	135	3	-
Meadowbank	17-Jan-01	564	686	603	19	Derwent	19-Jan-01	342	90	0.5	-
Derwent	17-Jan-01	601	480	198.5	30	Derwent	19-Jan-01	333	480	207.6	27
Meadowbank	17-Jan-01	544	850	1168.2	36	Derwent	19-Jan-01	334	420	110.2	-
Meadowbank	17-Jan-01	545	690	701.1	25	Derwent	19-Jan-01	345	430	160.9	21
Meadowbank	17-Jan-01	546	690	766	39	Derwent	19-Jan-01	344	480	146.6	22
Meadowbank	17-Jan-01	547	555	378.4	21	Meadowbank	19-Jan-01	335	545	328.2	39
Meadowbank	17-Jan-01	548	524	295.1	10	Meadowbank	19-Jan-01	328	540	272	23
Meadowbank	17-Jan-01	549	495	244.5	21	Meadowbank	19-Jan-01	329	570	332.2	33
Meadowbank	17-Jan-01	550	510	268.8	23	Meadowbank	19-Jan-01	330	375	92.8	7
Meadowbank	17-Jan-01	551	785	1018.3	21	Meadowbank	19-Jan-01	331	158	3.4	-
Meadowbank	17-Jan-01	552	747	843.9	25	Meadowbank	19-Jan-01	327	445	164.2	22
Meadowbank	17-Jan-01	553	680	596.7	23	Derwent	19-Jan-01	343	630	514.5	39
Meadowbank	17-Jan-01	554	491	215	-	Meadowbank	30-Jan-01	478	566	340.3	23
Derwent	17-Jan-01	590	745	1036	35	Derwent	30-Jan-01	634	795	1392.1	29
Derwent	17-Jan-01	591	840	1273.3	34	Derwent	30-Jan-01	635	656	586.4	28
Derwent	17-Jan-01	592	680	706	28	Derwent	30-Jan-01	617	960	1953.2	37
Derwent	17-Jan-01	593	648	517.9	35	Derwent	30-Jan-01	618	790	1095.8	32
Derwent	17-Jan-01	594	592	434.2	31	Derwent	30-Jan-01	619	544	312.2	-
Derwent	17-Jan-01	595	700	557.8	36	Derwent	30-Jan-01	620	517	218.9	27
Derwent	17-Jan-01	596	528	305	30	Derwent	30-Jan-01	621	450	194	26
Meadowbank	18-Jan-01	371	381	101.9	14	Derwent	30-Jan-01	622	409	113.4	28
Meadowbank	18-Jan-01	372	292	38.4	13	Derwent	30-Jan-01	623	480	209.3	30
Derwent	18-Jan-01	296	785	1116.2	31	Derwent	30-Jan-01	624	820	1556.9	36
Derwent	18-Jan-01	297	630	631.9	29	Derwent	30-Jan-01	636	520	271.3	29
Meadowbank	18-Jan-01	375	670	533.3	-	Derwent	30-Jan-01	616	341	67.4	22
Meadowbank	18-Jan-01	376	605	478.6	28	Meadowbank	30-Jan-01	479	615	533	31
Meadowbank	18-Jan-01	377	671	639	18	Meadowbank	30-Jan-01	480	584	335	24
Meadowbank	18-Jan-01	378	772	862.6	24	Derwent	30-Jan-01	625	612	354.4	27
Meadowbank	18-Jan-01	379	396	107.1	9	Derwent	30-Jan-01	626	655	681.5	40
Meadowbank	18-Jan-01	380	413	129.1	-	Derwent	30-Jan-01	627	393	110.6	-
Meadowbank	18-Jan-01	381	171	6.8	-	Derwent	30-Jan-01	628	305	46.3	9
Derwent	18-Jan-01	295	235	16.4	-	Meadowbank	30-Jan-01	476	605	438.6	17
Meadowbank	18-Jan-01	346	840	1322	27	Derwent	30-Jan-01	612	459	215.2	28
Meadowbank	18-Jan-01	347	675	630.5	19	Derwent	30-Jan-01	613	408	135	29
Meadowbank	18-Jan-01	348	675	638.5	17	Derwent	30-Jan-01	614	332	60.7	16
Meadowbank	18-Jan-01	349	600	414	11	Derwent	30-Jan-01	615	382	88.2	22
Meadowbank	18-Jan-01	350	585	401.2	-	Derwent	30-Jan-01	637	635	496.9	32
Meadowbank	18-Jan-01	351	473	175.3	-	Derwent	30-Jan-01	638	464	179.6	33
Meadowbank	18-Jan-01	352	406	117.1	-	Meadowbank	30-Jan-01	477	580	389.2	13
Meadowbank	18-Jan-01	353	260	28.2	-	Derwent	30-Jan-01	629	792	1110.9	44
Meadowbank	18-Jan-01	387	608	403.8	40	Derwent	30-Jan-01	630	537	288.5	23
Meadowbank	18-Jan-01	388	572	323.5	28	Derwent	30-Jan-01	631	514	242.2	25
Meadowbank	18-Jan-01	389	298	34.6	10	Derwent	30-Jan-01	632	474	201.1	-
Meadowbank	18-Jan-01	399	545	314.5	30	Derwent	30-Jan-01	633	473	204.9	23
Meadowbank	18-Jan-01	400	552	324.1	32	Derwent	30-Jan-01	639	884	1504.8	36
Meadowbank	18-Jan-01	401	305	46.9	11	Derwent	30-Jan-01	640	639	630.5	36
Meadowbank	18-Jan-01	391	555	342.8	29	Derwent	30-Jan-01	641	528	285.9	22
Meadowbank	18-Jan-01	373	338	57.7	7	Derwent	30-Jan-01	642	470	209.1	22
Meadowbank	18-Jan-01	374	310	36.1	6	Derwent	30-Jan-01	643	765	1062.6	-
Meadowbank	18-Jan-01	370	566	398.5	34	Derwent	30-Jan-01	644	508	248.1	25
Meadowbank	18-Jan-01	382	707	791.7	22	Derwent	30-Jan-01	645	423	117.7	17
Meadowbank	18-Jan-01	383	550	311.4	23	Derwent	30-Jan-01	646	542	315	32
Meadowbank	18-Jan-01	384	391	94.2	6	Derwent	30-Jan-01	647	597	412.1	34
Meadowbank	18-Jan-01	385	288	44.3	6	Derwent	30-Jan-01	648	550	341.5	26
Meadowbank	18-Jan-01	386	235	19.8	7	Derwent	30-Jan-01	649	378	93.5	15
Meadowbank	31-Jan-01	579	622	491	26	Meadowbank	1-Feb-01	210	625	458.2	27
Derwent	31-Jan-01	470	820	1101.1	31	Derwent	1-Feb-01	273	448	147.9	-
Meadowbank	31-Jan-01	585	787	981	30	Derwent	1-Feb-01	249	760	1058.3	38
Meadowbank	31-Jan-01	586	566	330.7	35	Derwent	1-Feb-01	250	769	1041.5	-
Meadowbank	31-Jan-01	587	502	244.2	20	Derwent	1-Feb-01	251	576	448.9	38
Meadowbank	31-Jan-01	588	619	387.1	31	Derwent	1-Feb-01	252	518	300	28
Meadowbank	31-Jan-01	589	451	148.4	13	Derwent	1-Feb-01	253	424	153.3	20
Derwent	31-Jan-01	473	415	151.6	27	Derwent	1-Feb-01	254	460	196.6	28
Derwent	31-Jan-01	474	454	141.4	23	Derwent	1-Feb-01	255	457	194	28
Derwent	31-Jan-01	475	340	66.9	14	Meadowbank	1-Feb-01	205	535	295.3	28
Derwent	31-Jan-01	471	510	291.3	28	Meadowbank	1-Feb-01	206	375	100.7	18
Derwent	31-Jan-01	472	350	77.2	21	Meadowbank	1-Feb-01	196	625	466.6	-
Derwent	31-Jan-01	465	820	1244.5	-	Meadowbank	1-Feb-01	198	530	274.5	-
Derwent	31-Jan-01	466	660	599.8	34	Meadowbank	1-Feb-01	199	405	114.5	-
Derwent	31-Jan-01	467	590	418.5	28	Meadowbank	1-Feb-01	202	680	461.9	30

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Derwent	31-Jan-01	468	555	293.2	-	Derwent	1-Feb-01	272	585	398	29
Derwent	31-Jan-01	469	490	216.6	23	Derwent	1-Feb-01	270	597	427	22
Meadowbank	31-Jan-01	578	441	160.4	23	Derwent	1-Feb-01	271	727	863.6	50
Meadowbank	31-Jan-01	580	769	808.3	36	Derwent	1-Feb-01	269	536	270	26
Meadowbank	31-Jan-01	581	781	964.5	40	Meadowbank	1-Feb-01	197	735	758.1	-
Meadowbank	31-Jan-01	582	588	332.5	38	Derwent	1-Feb-01	245	875	1602.9	28
Meadowbank	31-Jan-01	583	535	279.9	19	Derwent	1-Feb-01	246	784	1223.7	-
Meadowbank	31-Jan-01	584	549	315.8	24	Meadowbank	2-Feb-01	237	598	433.3	22
Derwent	31-Jan-01	532	735	932.4	33	Meadowbank	2-Feb-01	238	460	191.6	14
Derwent	31-Jan-01	533	558	342.2	25	Meadowbank	2-Feb-01	222	560	319.7	23
Derwent	31-Jan-01	534	600	426	12	Meadowbank	2-Feb-01	213	435	160.4	11
Derwent	31-Jan-01	535	591	418.8	29	Meadowbank	2-Feb-01	214	635	471.6	34
Derwent	31-Jan-01	536	454	168	19	Meadowbank	2-Feb-01	215	779	907.2	31
Derwent	31-Jan-01	537	610	431.6	28	Meadowbank	2-Feb-01	216	639	517.8	45
Derwent	31-Jan-01	520	527	300.5	-	Meadowbank	2-Feb-01	217	439	160.8	10
Meadowbank	31-Jan-01	577	592	372.3	23	Meadowbank	2-Feb-01	218	580	378.6	31
Derwent	31-Jan-01	525	531	282	37	Meadowbank	2-Feb-01	219	585	385.8	34
Derwent	31-Jan-01	526	563	334.8	37	Meadowbank	2-Feb-01	220	579	338	23
Derwent	31-Jan-01	527	371	93.1	15	Meadowbank	2-Feb-01	221	480	214.3	17
Derwent	31-Jan-01	528	415	121.7	22	Derwent	2-Feb-01	277	460	168	13
Derwent	31-Jan-01	529	471	184.2	18	Derwent	2-Feb-01	275	530	304.7	19
Derwent	31-Jan-01	530	441	130	26	Derwent	2-Feb-01	276	580	386.3	22
Derwent	31-Jan-01	531	354	63	12	Meadowbank	2-Feb-01	223	650	500.3	20
Derwent	31-Jan-01	521	762	1025.5	40	Meadowbank	2-Feb-01	240	566	369.6	19
Meadowbank	31-Jan-01	576	550	322	21	Meadowbank	2-Feb-01	241	419	126.7	13
Derwent	31-Jan-01	499	847	1223.5	39	Meadowbank	2-Feb-01	242	606	415.3	-
Derwent	31-Jan-01	500	665	718.9	38	Meadowbank	2-Feb-01	232	520	235.8	21
Derwent	31-Jan-01	501	695	609.6	36	Meadowbank	2-Feb-01	233	515	222.3	17
Derwent	31-Jan-01	502	375	82.9	14	Meadowbank	2-Feb-01	234	380	95.8	11
Derwent	31-Jan-01	503	680	587.1	37	Meadowbank	2-Feb-01	235	422	134.5	16
Derwent	31-Jan-01	504	526	263.8	24	Meadowbank	2-Feb-01	236	418	117	15
Derwent	31-Jan-01	505	434	155.2	30	Meadowbank	2-Feb-01	239	590	399.2	24
Derwent	31-Jan-01	506	486	173.8	30	Meadowbank	2-Feb-01	244	681	605.8	-
Derwent	31-Jan-01	507	405	109.6	21	Meadowbank	2-Feb-01	224	255	27	10
Derwent	31-Jan-01	508	775	991.3	30	Derwent	2-Feb-01	278	411	122.1	14
Derwent	31-Jan-01	509	745	891.7	47	Derwent	2-Feb-01	279	479	200.6	30
Derwent	31-Jan-01	510	632	498.3	29	Meadowbank	2-Feb-01	243	635	441.1	42
Derwent	31-Jan-01	511	609	507.5	-	Meadowbank	2-Feb-01	225	650	568.7	-
Derwent	31-Jan-01	512	617	545.2	-	Meadowbank	2-Feb-01	226	530	293.5	23
Derwent	31-Jan-01	513	683	692	-	Meadowbank	2-Feb-01	227	515	249	16
Derwent	31-Jan-01	514	647	506.8	-	Meadowbank	2-Feb-01	228	740	794.3	27
Derwent	31-Jan-01	515	555	359.6	-	Meadowbank	2-Feb-01	229	590	459.8	37
Derwent	31-Jan-01	516	643	551.1	-	Meadowbank	2-Feb-01	230	595	469.9	31
Derwent	31-Jan-01	517	510	288	-	Meadowbank	2-Feb-01	231	665	470.3	32
Derwent	31-Jan-01	518	485	149.7	-	Derwent	2-Feb-01	274	496	208.2	30
Derwent	31-Jan-01	519	420	143.9	-	Derwent	8-Feb-01	695	658	670.5	-
Derwent	31-Jan-01	522	567	343.1	31	Derwent	8-Feb-01	697	708	752.2	23
Derwent	31-Jan-01	523	431	139.3	15	Derwent	8-Feb-01	658	905	1915.1	35
Derwent	31-Jan-01	524	390	93.1	14	Derwent	8-Feb-01	659	545	302.5	25
Meadowbank	1-Feb-01	203	700	678.7	24	Derwent	8-Feb-01	660	460	245.8	19
Meadowbank	1-Feb-01	204	600	470.5	16	Derwent	8-Feb-01	661	405	131.6	-
Derwent	1-Feb-01	256	620	459.1	26	Meadowbank	8-Feb-01	709	591	474.5	32
Derwent	1-Feb-01	257	640	545.1	25	Derwent	8-Feb-01	689	816	1208.1	22
Derwent	1-Feb-01	258	610	539.6	24	Derwent	8-Feb-01	690	739	1000.8	26
Derwent	1-Feb-01	259	690	717.3	33	Derwent	8-Feb-01	656	765	924.7	30
Derwent	1-Feb-01	260	560	370.9	-	Derwent	8-Feb-01	657	850	1521.8	-
Derwent	1-Feb-01	261	495	226.3	28	Derwent	8-Feb-01	698	661	608.3	23
Derwent	1-Feb-01	262	655	572.8	22	Derwent	8-Feb-01	699	367	89.4	-
Derwent	1-Feb-01	263	440	156.1	-	Derwent	8-Feb-01	700	313	50.5	12
Derwent	1-Feb-01	264	505	234.9	31	Derwent	8-Feb-01	701	257	25.7	10
Derwent	1-Feb-01	265	790	1158	46	Derwent	8-Feb-01	702	190	10.2	4
Derwent	1-Feb-01	266	455	197.3	34	Derwent	8-Feb-01	696	396	112.7	17
Derwent	1-Feb-01	267	530	295	-	Meadowbank	8-Feb-01	710	437	164.8	19
Derwent	1-Feb-01	268	615	503.1	37	Derwent	8-Feb-01	685	605	491.9	-
Meadowbank	1-Feb-01	212	745	901	37	Derwent	8-Feb-01	686	442	181.6	24
Meadowbank	1-Feb-01	207	700	657.7	26	Derwent	8-Feb-01	687	385	113.6	18
Derwent	1-Feb-01	247	901	1589.5	-	Derwent	8-Feb-01	688	325	38.3	18
Derwent	1-Feb-01	248	463	155.5	23	Derwent	8-Feb-01	650	614	454.2	26
Meadowbank	1-Feb-01	201	500	225.3	17	Derwent	8-Feb-01	651	650	550.1	-
Meadowbank	1-Feb-01	200	285	36.6	-	Derwent	8-Feb-01	652	494	211.4	20
Meadowbank	1-Feb-01	211	581	370.2	23	Derwent	8-Feb-01	653	462	207	20
Meadowbank	1-Feb-01	208	590	419.6	20	Derwent	8-Feb-01	654	460	154.3	-
Meadowbank	1-Feb-01	209	791	1099.1	36	Derwent	8-Feb-01	655	375	108.1	17
Derwent	8-Feb-01	704	675	711.6	24	Plenty	27-Feb-01	820	230	17.7	5
Derwent	8-Feb-01	705	646	569.4	25	Ouse	27-Feb-01	828	519	270.3	20
Derwent	8-Feb-01	706	320	46.6	11	Plenty	27-Feb-01	812	420	152.1	-
Meadowbank	8-Feb-01	694	572	425.3	33	Plenty	27-Feb-01	813	361	95	20
Meadowbank	8-Feb-01	691	680	704.1	29	Plenty	27-Feb-01	814	227	18.9	6
Meadowbank	8-Feb-01	692	568	275.4	21	Plenty	27-Feb-01	815	868	1490	-
Meadowbank	8-Feb-01	693	475	211.7	14	Plenty	27-Feb-01	816	580	397.7	23
Derwent	8-Feb-01	703	427	140.7	10	Plenty	27-Feb-01	817	443	133.1	15
Derwent	8-Feb-01	662	995	2170	37	Ouse	27-Feb-01	833	512	259.7	23
Derwent	8-Feb-01	663	720	891	35	Plenty	27-Feb-01	832	774	1061.7	34
Derwent	8-Feb-01	664	575	455.5	24	Plenty	27-Feb-01	823	650	581.4	29
Derwent	8-Feb-01	683	733	986.2	35	Plenty	27-Feb-01	824	515	280.6	22
Derwent	8-Feb-01	684	825	1408.9	27	Plenty	27-Feb-01	825	420	156.4	-
Meadowbank	8-Feb-01	707	439	154	14	Plenty	27-Feb-01	826	362	89.9	-
Meadowbank	8-Feb-01	708	401	112.4	-	Ouse	27-Feb-01	830	450	139.7	17
Derwent	9-Feb-01	677	783	1083.5	37	Ouse	28-Feb-01	877	426	139.7	11
Derwent	9-Feb-01	681	600	415.2	25	Plenty	28-Feb-01	899	497	218.1	-
Derwent	9-Feb-01	682	540	339.7	23	Plenty	28-Feb-01	900	285	34.4	8
Derwent	9-Feb-01	711	614	495.4	30	Ouse	28-Feb-01	880	639	487	20
Derwent	9-Feb-01	712	535	317.8	24	Ouse	28-Feb-01	879	460	173.8	-

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Derwent	9-Feb-01	713	575	303.2	24	Plenty	28-Feb-01	904	346	64.6	17
Derwent	9-Feb-01	714	402	126	24	Plenty	28-Feb-01	901	467	193.7	25
Derwent	9-Feb-01	715	288	37	9	Plenty	28-Feb-01	902	279	31.9	8
Derwent	9-Feb-01	717	753	917.2	30	Plenty	28-Feb-01	903	248	22	6
Derwent	9-Feb-01	680	703	767.8	18	Plenty	28-Feb-01	898	350	69	23
Meadowbank	9-Feb-01	716	590	360	20	Ouse	28-Feb-01	878	700	767.4	34
Meadowbank	9-Feb-01	720	521	299.6	22	Ouse	1-Mar-01	1010	625	501.4	18
Meadowbank	9-Feb-01	727	555	346.4	30	Ouse	1-Mar-01	1011	715	611.8	35
Derwent	9-Feb-01	676	570	423.7	26	Plenty	1-Mar-01	886	467	197.9	-
Derwent	9-Feb-01	726	534	281	21	Plenty	1-Mar-01	888	650	600.1	25
Derwent	9-Feb-01	728	786	910.4	23	Plenty	1-Mar-01	889	447	159	34
Derwent	9-Feb-01	729	516	263.3	25	Plenty	1-Mar-01	890	262	30.2	11
Derwent	9-Feb-01	670	700	650.6	-	Plenty	1-Mar-01	887	386	113.8	-
Derwent	9-Feb-01	671	615	500.5	23	Plenty	1-Mar-01	884	382	101.1	-
Derwent	9-Feb-01	672	270	37.7	8	Plenty	1-Mar-01	885	383	101.7	23
Meadowbank	9-Feb-01	718	608	450.1	31	Plenty	1-Mar-01	882	564	379	28
Meadowbank	9-Feb-01	719	474	210.4	24	Plenty	1-Mar-01	883	489	216.5	17
Derwent	9-Feb-01	721	730	786.9	41	Plenty	1-Mar-01	881	780	1019.6	29
Derwent	9-Feb-01	722	556	356.2	23	Plenty	2-Mar-01	870	634	518.5	31
Derwent	9-Feb-01	723	560	313.9	21	Plenty	2-Mar-01	868	390	109.2	23
Derwent	9-Feb-01	724	466	202.3	17	Plenty	2-Mar-01	869	376	76.1	13
Derwent	9-Feb-01	725	326	58.7	8	Plenty	2-Mar-01	871	501	234.8	22
Derwent	9-Feb-01	673	448	190.1	26	Plenty	2-Mar-01	872	434	154.4	20
Derwent	9-Feb-01	674	342	62.5	15	Plenty	2-Mar-01	873	635	468.6	21
Derwent	9-Feb-01	667	760	858.7	31	Plenty	2-Mar-01	874	516	281.2	-
Derwent	9-Feb-01	668	353	79.6	-	Plenty	2-Mar-01	875	498	208.4	21
Derwent	9-Feb-01	669	310	51.6	9	Plenty	2-Mar-01	876	428	139.7	21
Derwent	9-Feb-01	665	795	1367.5	22	Plenty	2-Mar-01	867	351	75.6	26
Derwent	9-Feb-01	666	415	140.4	9	Ouse	6-Mar-01	941	572	365.8	35
Derwent	9-Feb-01	678	520	247.2	20	Ouse	6-Mar-01	891	730	855.5	28
Derwent	9-Feb-01	679	460	176.6	-	Ouse	6-Mar-01	892	554	306.8	-
Meadowbank	9-Feb-01	732	500	226.2	27	Ouse	6-Mar-01	938	692	636	-
Meadowbank	9-Feb-01	730	545	327.5	35	Ouse	6-Mar-01	939	436	155.9	19
Meadowbank	9-Feb-01	731	555	329.6	30	Ouse	6-Mar-01	940	355	75.6	16
Meadowbank	9-Feb-01	733	562	366.5	30	Ouse	6-Mar-01	949	362	81.2	18
Derwent	9-Feb-01	675	452	201	24	Ouse	6-Mar-01	895	440	133.3	-
Derwent	15-Feb-01	738	683	751.5	32	Ouse	6-Mar-01	942	390	125.2	21
Derwent	15-Feb-01	737	452	166.9	20	Plenty	6-Mar-01	950	525	317.6	22
Meadowbank	15-Feb-01	742	577	385.5	28	Plenty	6-Mar-01	945	529	292.9	32
Meadowbank	15-Feb-01	741	612	412.2	-	Plenty	6-Mar-01	946	301	52.8	-
Meadowbank	15-Feb-01	734	585	392.9	26	Plenty	6-Mar-01	947	342	53.7	21
Meadowbank	15-Feb-01	735	466	204.1	26	Plenty	6-Mar-01	948	342	69.2	22
Meadowbank	15-Feb-01	736	437	173.8	17	Plenty	6-Mar-01	954	450	173.2	21
Meadowbank	15-Feb-01	745	458	197.1	15	Plenty	6-Mar-01	955	477	206.1	20
Meadowbank	15-Feb-01	744	609	326.1	31	Plenty	6-Mar-01	956	600	435.2	36
Meadowbank	15-Feb-01	746	487	209.1	20	Plenty	6-Mar-01	943	323	43.6	18
Derwent	15-Feb-01	739	737	935.2	29	Plenty	6-Mar-01	944	296	40.1	15
Derwent	15-Feb-01	743	540	283.8	26	Ouse	6-Mar-01	893	575	371.3	18
Meadowbank	15-Feb-01	740	454	171.3	25	Ouse	6-Mar-01	896	512	215.5	-
Pine Tier	20-Feb-01	772	720	857	25	Plenty	6-Mar-01	957	325	48.6	18
Pine Tier	22-Feb-01	773	333	72	21	Plenty	6-Mar-01	958	461	175.5	23
Pine Tier	23-Feb-01	775	433	161.3	-	Plenty	6-Mar-01	951	472	185.8	18
Pine Tier	23-Feb-01	776	345	66.4	9	Plenty	6-Mar-01	952	434	130.8	20
Pine Tier	23-Feb-01	774	257	19.3	18	Plenty	6-Mar-01	953	354	73.3	11
Ouse	27-Feb-01	827	630	479.9	24	Ouse	6-Mar-01	894	698	674.9	29
Plenty	27-Feb-01	822	493	Not valid	-	Ouse	6-Mar-01	897	730	866.3	-
Ouse	27-Feb-01	831	680	597.7	19	Plenty	7-Mar-01	996	400	104.9	20
Plenty	27-Feb-01	818	348	70	19	Ouse	7-Mar-01	989	650	662	17
Ouse	27-Feb-01	829	546	302.9	-	Plenty	7-Mar-01	1000	378	103	20
Ouse	27-Feb-01	834	786	986.3	27	Ouse	7-Mar-01	991	650	609.1	27
Ouse	27-Feb-01	835	688	737.6	-	Ouse	7-Mar-01	993	615	437.9	20
Ouse	27-Feb-01	836	523	187.8	22	Ouse	7-Mar-01	994	566	335.6	16
Plenty	27-Feb-01	821	853	1228.2	30	Ouse	7-Mar-01	995	500	214	22
Plenty	27-Feb-01	808	352	77.5	19	Plenty	7-Mar-01	1001	496	257.5	27
Plenty	27-Feb-01	809	366	95.9	19	M'Bank Trap	13-Dec-00	916	186	5.31	5
Plenty	27-Feb-01	810	430	152.3	22	M'Bank Trap	13-Dec-00	917	185	6.96	4
Plenty	27-Feb-01	811	386	127.6	-	M'Bank Trap	13-Dec-00	918	187	5.91	9
Plenty	27-Feb-01	819	438	178.7	22	M'Bank Trap	13-Dec-00	919	178	5.09	4
Ouse	7-Mar-01	990	660	580	15	M'Bank Trap	13-Dec-00	920	166	4.53	3
Plenty	8-Mar-01	1003	338	105.2	20	Plenty	7-Mar-01	999	585	498	32
Plenty	8-Mar-01	1004	317	58	9	Ouse	7-Mar-01	992	690	730	30
Plenty	8-Mar-01	1005	242	21.4	9	Plenty	7-Mar-01	997	460	163.2	14
Plenty	8-Mar-01	1008	577	373.1	-	Plenty	7-Mar-01	998	255	23.6	7
Plenty	8-Mar-01	1009	370	92.4	20	M'Bank Trap	13-Dec-00	921	145	2.53	1
Plenty	8-Mar-01	1007	328	62.7	-	M'Bank Trap	13-Dec-00	922	149	3.02	3
Plenty	8-Mar-01	1006	337	63.5	19	M'Bank Trap	13-Dec-00	923	144	2.33	3
Plenty	8-Mar-01	1002	420	144.4	32	M'Bank Trap	13-Dec-00	924	137	2.52	2
Meadowbank	22-Mar-01	1043	645	616.8	20	M'Bank Trap	13-Dec-00	925	134	1.59	2
Meadowbank	23-Mar-01	1042	684	583	26	M'Bank Trap	13-Dec-00	926	128	1.92	1
Meadowbank	23-Mar-01	1044	795	1101.6	39	M'Bank Trap	13-Dec-00	927	139	2.48	1
M'Bank Trap	13-Dec-00	777	434	104.4	15	M'Bank Trap	13-Dec-00	928	139	2.41	2
M'Bank Trap	13-Dec-00	778	331	42.2	10	M'Bank Trap	13-Dec-00	929	136	2.01	2
M'Bank Trap	13-Dec-00	779	306	36.3	9	M'Bank Trap	13-Dec-00	930	126	1.58	2
M'Bank Trap	13-Dec-00	780	304	37.5	11	M'Bank Trap	13-Dec-00	931	123	1.49	1
M'Bank Trap	13-Dec-00	781	300	34.8	12	M'Bank Trap	13-Dec-00	932	124	1.19	3
M'Bank Trap	13-Dec-00	782	250	20.9	8	M'Bank Trap	13-Dec-00	933	118	1.11	0.5
M'Bank Trap	13-Dec-00	783	245	18.4	7	M'Bank Trap	13-Dec-00	934	126	1.61	4
M'Bank Trap	13-Dec-00	784	215	11.5	7	M'Bank Trap	13-Dec-00	935	129	1.47	3
M'Bank Trap	13-Dec-00	785	202	10.9	-	M'Bank Trap	13-Dec-00	936	123	1.29	4
M'Bank Trap	13-Dec-00	786	229	11.1	5	M'Bank Trap	13-Dec-00	937	109	0.84	1
M'Bank Trap	13-Dec-00	787	217	11.4	5	M'Bank Trap	18-Dec-00	959	290	30	9
M'Bank Trap	13-Dec-00	788	188	6.8	6	M'Bank Trap	18-Dec-00	960	279	24	7
M'Bank Trap	13-Dec-00	789	175	6.2	6	M'Bank Trap	18-Dec-00	961	225	14.9	7

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M'Bank Trap	13-Dec-00	790	186	5.3	6	M'Bank Trap	18-Dec-00	962	212	10.5	9
M'Bank Trap	13-Dec-00	791	174	4.7	5	M'Bank Trap	18-Dec-00	963	190	8.3	5
M'Bank Trap	13-Dec-00	792	163	4.6	7	M'Bank Trap	18-Dec-00	964	186	6.8	6
M'Bank Trap	13-Dec-00	793	165	5	-	M'Bank Trap	18-Dec-00	965	181	6.3	7
M'Bank Trap	13-Dec-00	794	159	3.8	6	M'Bank Trap	18-Dec-00	966	169	5	2
M'Bank Trap	13-Dec-00	795	159	3.4	5	M'Bank Trap	18-Dec-00	967	164	4.6	4
M'Bank Trap	13-Dec-00	796	146	3.2	-	M'Bank Trap	18-Dec-00	968	145	3.8	4
M'Bank Trap	13-Dec-00	797	144	3.2	2	M'Bank Trap	18-Dec-00	969	164	4.9	4
M'Bank Trap	13-Dec-00	798	152	2.8	3	M'Bank Trap	18-Dec-00	970	167	5.37	3
M'Bank Trap	13-Dec-00	799	154	3.7	2	M'Bank Trap	18-Dec-00	971	183	5.08	5
M'Bank Trap	13-Dec-00	800	164	3.4	6	M'Bank Trap	18-Dec-00	972	158	3.97	3
M'Bank Trap	13-Dec-00	801	148	2.6	4	M'Bank Trap	18-Dec-00	973	152	3.6	3
M'Bank Trap	13-Dec-00	802	136	2	-	M'Bank Trap	18-Dec-00	974	150	3.07	3
M'Bank Trap	13-Dec-00	803	126	1.6	2	M'Bank Trap	18-Dec-00	975	163	3.51	1
M'Bank Trap	13-Dec-00	804	114	1.2	1	M'Bank Trap	18-Dec-00	976	165	4.09	1
M'Bank Trap	13-Dec-00	805	115	1	5	M'Bank Trap	18-Dec-00	977	134	2.21	1
M'Bank Trap	13-Dec-00	806	105	0.9	-	M'Bank Trap	18-Dec-00	978	143	2.23	1
M'Bank Trap	14-Dec-00	837	367	57.2	8	M'Bank Trap	18-Dec-00	979	133	2.19	1
M'Bank Trap	14-Dec-00	838	335	54.7	9	M'Bank Trap	18-Dec-00	980	125	1.23	-
M'Bank Trap	14-Dec-00	839	336	47.7	12	M'Bank Trap	18-Dec-00	981	125	1.5	0.5
M'Bank Trap	14-Dec-00	840	248	19.1	6	M'Bank Trap	18-Dec-00	982	140	2.66	3
M'Bank Trap	14-Dec-00	841	246	12.6	6	M'Bank Trap	18-Dec-00	983	125	1.68	4
M'Bank Trap	14-Dec-00	842	254	20.1	8	M'Bank Trap	18-Dec-00	984	123	1.28	2
M'Bank Trap	14-Dec-00	843	255	18.7	7	M'Bank Trap	18-Dec-00	985	122	1.47	1
M'Bank Trap	14-Dec-00	844	250	12.4	6	M'Bank Trap	18-Dec-00	986	120	1.24	1
M'Bank Trap	14-Dec-00	845	222	10.7	6	M'Bank Trap	18-Dec-00	987	113	0.83	0.5
M'Bank Trap	14-Dec-00	846	212	10.1	6	M'Bank Trap	18-Dec-00	988	115	0.8	1
M'Bank Trap	14-Dec-00	847	172	4.3	3	M'Bank Trap	13-Dec-00	1012	394	125.4	27
M'Bank Trap	14-Dec-00	848	170	4.3	6	M'Bank Trap	13-Dec-00	1013	369	75.1	8
M'Bank Trap	14-Dec-00	849	152	2.7	4	M'Bank Trap	13-Dec-00	1014	348	53.3	7
M'Bank Trap	14-Dec-00	850	160	3.3	6	M'Bank Trap	13-Dec-00	1015	328	42.5	10
M'Bank Trap	14-Dec-00	851	155	3.12	4	M'Bank Trap	13-Dec-00	1016	273	32.9	6
M'Bank Trap	14-Dec-00	852	150	2.96	2	M'Bank Trap	13-Dec-00	1017	290	28.3	-
M'Bank Trap	14-Dec-00	853	136	2.12	3	M'Bank Trap	13-Dec-00	1018	248	22	8
M'Bank Trap	14-Dec-00	854	147	2.11	5	M'Bank Trap	13-Dec-00	1019	265	25.1	6
M'Bank Trap	14-Dec-00	855	144	2.07	-	M'Bank Trap	13-Dec-00	1020	235	16.1	6
M'Bank Trap	14-Dec-00	856	136	2	1	M'Bank Trap	13-Dec-00	1021	230	13.7	10
M'Bank Trap	14-Dec-00	857	132	1.4	4	M'Bank Trap	13-Dec-00	1022	240	18.9	9
M'Bank Trap	14-Dec-00	858	130	1.31	4	M'Bank Trap	13-Dec-00	1023	220	12.7	2
M'Bank Trap	14-Dec-00	859	129	1.25	4	M'Bank Trap	13-Dec-00	1024	198	8.3	1
M'Bank Trap	14-Dec-00	860	128	1.24	1	M'Bank Trap	13-Dec-00	1025	190	6.4	8
M'Bank Trap	14-Dec-00	861	125	1.34	-	M'Bank Trap	13-Dec-00	1026	180	6.4	5
M'Bank Trap	14-Dec-00	862	114	0.9	2	M'Bank Trap	13-Dec-00	1027	181	5.8	6
M'Bank Trap	14-Dec-00	863	122	1.1	-	M'Bank Trap	13-Dec-00	1028	165	6.2	4
M'Bank Trap	14-Dec-00	864	124	1.4	5	M'Bank Trap	13-Dec-00	1029	169	5.8	3
M'Bank Trap	14-Dec-00	865	110	0.77	3	M'Bank Trap	13-Dec-00	1030	160	3.7	4
M'Bank Trap	14-Dec-00	866	97	0.61	-	M'Bank Trap	13-Dec-00	1031	165	3.2	8
M'Bank Trap	13-Dec-00	905	362	53.9	13	M'Bank Trap	13-Dec-00	1032	130	2.2	2
M'Bank Trap	13-Dec-00	906	319	36.89	13	M'Bank Trap	13-Dec-00	1033	140	2.7	2
M'Bank Trap	13-Dec-00	907	287	32.65	13	M'Bank Trap	13-Dec-00	1034	142	1.9	2
M'Bank Trap	13-Dec-00	908	285	34.23	8	M'Bank Trap	13-Dec-00	1035	140	2.4	-
M'Bank Trap	13-Dec-00	909	262	15.65	9	M'Bank Trap	13-Dec-00	1036	128	1.4	4
M'Bank Trap	13-Dec-00	910	248	19.24	7	M'Bank Trap	13-Dec-00	1037	117	1.1	-
M'Bank Trap	13-Dec-00	911	249	19.96	3	M'Bank Trap	13-Dec-00	1038	127	1.6	1
M'Bank Trap	13-Dec-00	912	223	13.7	5	M'Bank Trap	13-Dec-00	1039	126	1.5	-
M'Bank Trap	13-Dec-00	913	190	6.98	6	M'Bank Trap	13-Dec-00	1040	121	1.2	-
M'Bank Trap	13-Dec-00	914	191	8.88	4	M'Bank Trap	13-Dec-00	1041	111	0.8	-
M'Bank Trap	13-Dec-00	915	184	6.7	3						

2001/2002 Eel Catch Data

Location	Date	Eel No.	Length (mm)	Weight (g)	Age (YIF)	Location	Date	Eel No.	Length (mm)	Weight (g)	Age (YIF)
North Esk	30-Oct-01	1	535	240	18	North Esk	7-Nov-01	526	682	736	30
North Esk	30-Oct-01	2	470	180	-	North Esk	7-Nov-01	527	661	588	29
North Esk	30-Oct-01	3	265	30	11	North Esk	7-Nov-01	528	575	404	25
North Esk	30-Oct-01	4	420	140	25	North Esk	7-Nov-01	529	690	662	27
Trevallyn	30-Oct-01	5	285	40	10	North Esk	7-Nov-01	530	514	328	23
North Esk	30-Oct-01	6	375	85	18	North Esk	7-Nov-01	531	582	356	20
North Esk	30-Oct-01	7	480	190	18	North Esk	7-Nov-01	532	515	263	13
North Esk	30-Oct-01	8	540	280	21	North Esk	7-Nov-01	533	598	466	25
North Esk	30-Oct-01	9	345	70	12	North Esk	7-Nov-01	534	644	447	23
North Esk	30-Oct-01	10	420	140	27	North Esk	7-Nov-01	535	681	591	17
North Esk	30-Oct-01	11	455	160	18	North Esk	7-Nov-01	536	627	481	23
North Esk	30-Oct-01	12	545	320	26	North Esk	7-Nov-01	537	660	532	27
North Esk	30-Oct-01	13	115	-	-	North Esk	7-Nov-01	538	506	198	25
North Esk	30-Oct-01	14	415	120	6	North Esk	7-Nov-01	539	617	455	23
North Esk	30-Oct-01	15	335	55	30	North Esk	7-Nov-01	540	597	498	22
North Esk	30-Oct-01	16	3101	60	15	North Esk	7-Nov-01	541	611	476	23
North Esk	30-Oct-01	17	420	100	14	North Esk	7-Nov-01	542	412	181	15
North Esk	30-Oct-01	18	225	15	13	North Esk	7-Nov-01	543	178	3	2
North Esk	30-Oct-01	19	435	230	28	North Esk	7-Nov-01	544	687	688	22
North Esk	30-Oct-01	20	515	275	29	North Esk	7-Nov-01	545	470	193	28
North Esk	30-Oct-01	21	340	65	12	North Esk	7-Nov-01	546	493	228	25
North Esk	30-Oct-01	22	325	115	19	North Esk	7-Nov-01	547	477	226	21
North Esk	30-Oct-01	23	405	55	25	North Esk	7-Nov-01	548	371	88	13
North Esk	30-Oct-01	24	755	810	28	North Esk	7-Nov-01	549	349	72	12
North Esk	30-Oct-01	25	450	185	23	North Esk	7-Nov-01	550	487	213	11
Trevallyn	31-Oct-01	26	640	515	12	North Esk	7-Nov-01	551	549	315	22
Trevallyn	31-Oct-01	27	780	1005	19	North Esk	7-Nov-01	552	641	402	13
Trevallyn	31-Oct-01	28	805	1100	25	North Esk	7-Nov-01	553	404	120	24
North Esk	31-Oct-01	29	470	165	28	North Esk	7-Nov-01	554	469	169	28
North Esk	31-Oct-01	30	180	5	-	North Esk	7-Nov-01	608	690	791	28
North Esk	31-Oct-01	31	480	205	24	North Esk	7-Nov-01	609	603	462	23
North Esk	31-Oct-01	32	440	160	18	North Esk	7-Nov-01	610	618	373	30
North Esk	31-Oct-01	33	350	80	12	North Esk	7-Nov-01	611	614	433	21
North Esk	31-Oct-01	34	240	15	-	North Esk	7-Nov-01	612	517	301	22
North Esk	31-Oct-01	35	610	430	-	North Esk	7-Nov-01	613	532	268	21
North Esk	31-Oct-01	36	520	295	28	North Esk	7-Nov-01	614	398	106	26
North Esk	31-Oct-01	37	670	560	34	North Esk	7-Nov-01	615	475	234	20
North Esk	31-Oct-01	38	580	420	24	North Esk	7-Nov-01	616	645	491	19
North Esk	31-Oct-01	39	340	60	16	North Esk	7-Nov-01	617	598	420	24
North Esk	31-Oct-01	40	415	135	20	North Esk	7-Nov-01	618	691	622	30
North Esk	31-Oct-01	41	615	435	22	North Esk	7-Nov-01	619	730	823	29
North Esk	31-Oct-01	42	580	315	23	North Esk	7-Nov-01	620	582	382	25
North Esk	31-Oct-01	43	570	290	33	North Esk	7-Nov-01	621	535	244	12
North Esk	31-Oct-01	44	425	165	14	North Esk	7-Nov-01	622	340	61	15
North Esk	31-Oct-01	45	430	110	-	North Esk	7-Nov-01	623	432	116	-
North Esk	31-Oct-01	46	450	175	24	North Esk	7-Nov-01	624	338	56	20
North Esk	31-Oct-01	47	665	590	-	North Esk	7-Nov-01	625	329	47	15
North Esk	31-Oct-01	48	730	655	22	North Esk	7-Nov-01	626	667	658	37
North Esk	31-Oct-01	49	570	305	31	North Esk	7-Nov-01	627	699	715	32
North Esk	31-Oct-01	50	600	325	24	North Esk	7-Nov-01	628	691	478	14
North Esk	31-Oct-01	51	435	145	20	North Esk	7-Nov-01	629	675	520	25
North Esk	1-Nov-01	52	370	105	8	North Esk	7-Nov-01	630	510	224	11
North Esk	1-Nov-01	53	630	460	26	North Esk	7-Nov-01	631	545	263	18
North Esk	1-Nov-01	54	690	705	25	North Esk	7-Nov-01	632	562	355	27
North Esk	1-Nov-01	55	565	290	19	North Esk	7-Nov-01	633	553	356	26
Trevallyn	1-Nov-01	56	860	1290	-	North Esk	7-Nov-01	634	792	739	37
North Esk	1-Nov-01	57	550	325	25	North Esk	7-Nov-01	635	539	276	24
North Esk	1-Nov-01	58	780	945	22	North Esk	7-Nov-01	636	700	653	29
Trevallyn	1-Nov-01	59	570	320	23	North Esk	7-Nov-01	637	636	413	31
Trevallyn	1-Nov-01	60	880	570	16	North Esk	8-Nov-01	155	657	592	22
North Esk	1-Nov-01	61	725	805	36	North Esk	8-Nov-01	156	574	371	20
North Esk	1-Nov-01	62	655	500	28	North Esk	8-Nov-01	157	546	268	3
North Esk	1-Nov-01	63	720	790	30	North Esk	8-Nov-01	158	565	327	17
North Esk	1-Nov-01	64	195	10	1	North Esk	8-Nov-01	159	655	553	25
North Esk	1-Nov-01	65	570	370	20	North Esk	8-Nov-01	160	558	364	16
North Esk	1-Nov-01	66	740	715	31	North Esk	8-Nov-01	161	639	483	22
North Esk	1-Nov-01	67	680	640	25	North Esk	8-Nov-01	162	455	157	16
North Esk	1-Nov-01	68	510	250	19	North Esk	8-Nov-01	163	694	717	27
North Esk	1-Nov-01	69	330	65	13	North Esk	8-Nov-01	164	699	753	28
North Esk	1-Nov-01	70	670	510	21	North Esk	8-Nov-01	165	420	145	18
North Esk	1-Nov-01	71	450	230	17	North Esk	8-Nov-01	166	274	36	6
North Esk	1-Nov-01	72	530	305	-	North Esk	8-Nov-01	167	204	13	-
North Esk	1-Nov-01	73	490	240	23	North Esk	8-Nov-01	168	560	396	31
North Esk	1-Nov-01	74	580	430	26	North Esk	8-Nov-01	169	233	126	20
North Esk	1-Nov-01	75	670	565	26	North Esk	8-Nov-01	170	433	186	17
North Esk	2-Nov-01	370	204	11	-	North Esk	8-Nov-01	171	674	710	29
North Esk	2-Nov-01	371	236	18	3	North Esk	8-Nov-01	172	686	719	27
North Esk	2-Nov-01	372	403	129	31	North Esk	8-Nov-01	173	644	521	21
North Esk	2-Nov-01	373	503	278	-	North Esk	8-Nov-01	174	627	550	19
North Esk	2-Nov-01	374	521	294	25	North Esk	8-Nov-01	175	600	450	29
North Esk	2-Nov-01	375	556	342	25	North Esk	8-Nov-01	176	576	586	36
North Esk	2-Nov-01	376	591	339	26	Trevallyn	8-Nov-01	593	746	977	-
Trevallyn	2-Nov-01	377	668	54	21	Trevallyn	8-Nov-01	594	674	620	19
Trevallyn	2-Nov-01	378	447	197	12	Trevallyn	8-Nov-01	595	701	860	21
North Esk	2-Nov-01	379	282	43	15	Trevallyn	8-Nov-01	596	479	235	10
North Esk	2-Nov-01	380	389	106	15	Trevallyn	8-Nov-01	597	534	320	12
Trevallyn	2-Nov-01	381	314	52	6	Trevallyn	8-Nov-01	598	305	55	4
North Esk	7-Nov-01	525	726	859	29	Trevallyn	8-Nov-01	599	758	957	16
Trevallyn	8-Nov-01	600	614	523	12	Meadowbank	15-Nov-01	740	603	398	17
Trevallyn	8-Nov-01	601	304	53	11	Meadowbank	15-Nov-01	741	725	892	25
Trevallyn	8-Nov-01	602	518	292	10	Derwent	15-Nov-01	742	260	28	10
Trevallyn	8-Nov-01	603	763	1076	23	Derwent	15-Nov-01	743	422	155	18
Trevallyn	8-Nov-01	604	317	73	7	Derwent	15-Nov-01	744	386	124	15
Trevallyn	8-Nov-01	605	511	250	14	Derwent	15-Nov-01	745	483	244	18
Trevallyn	8-Nov-01	606	617	476	12	Derwent	15-Nov-01	746	545	379	23
Trevallyn	8-Nov-01	607	802	1183	21	Derwent	15-Nov-01	747	270	35	10
North Esk	9-Nov-01	448	462	177	22	Derwent	15-Nov-01	748	526	319	19
North Esk	9-Nov-01	449	215	14	3	Derwent	15-Nov-01	749	374	95	16
North Esk	9-Nov-01	450	313	55	13	Derwent	15-Nov-01	750	269	30	10

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North Esk	9-Nov-01	451	302	41	-	Derwent	15-Nov-01	751	249	29	7
North Esk	9-Nov-01	452	719	629	27	Derwent	15-Nov-01	752	235	21	9
North Esk	9-Nov-01	453	729	675	24	Derwent	15-Nov-01	753	109	17	0.5
North Esk	9-Nov-01	454	649	505	39	Derwent	15-Nov-01	754	91	1.04	-
North Esk	9-Nov-01	455	715	891	40	Derwent	15-Nov-01	755	185	9.3	3
North Esk	9-Nov-01	456	638	511	22	Derwent	15-Nov-01	756	469	187	29
North Esk	9-Nov-01	457	690	732	26	Derwent	15-Nov-01	757	580	366	28
North Esk	9-Nov-01	458	648	548	31	Derwent	15-Nov-01	758	136	3.5	2
North Esk	9-Nov-01	459	267	503	3	Derwent	15-Nov-01	759	814	1221	21
North Esk	9-Nov-01	460	349	66	11	Derwent	15-Nov-01	760	364	101	15
North Esk	9-Nov-01	461	602	390	31	Derwent	15-Nov-01	761	234	20	11
North Esk	9-Nov-01	462	665	391	23	Derwent	16-Nov-01	113	371	85	11
North Esk	9-Nov-01	463	601	385	20	Derwent	16-Nov-01	114	384	88	13
North Esk	9-Nov-01	464	385	114	13	Derwent	16-Nov-01	115	94	1	0.5
North Esk	9-Nov-01	465	620	408	17	Derwent	16-Nov-01	116	319	8	9
North Esk	9-Nov-01	466	664	525	23	Derwent	16-Nov-01	117	286	41	10
North Esk	9-Nov-01	467	570	342	18	Derwent	16-Nov-01	118	193	12	2
North Esk	9-Nov-01	468	698	725	23	Derwent	16-Nov-01	119	332	69	9
North Esk	9-Nov-01	469	689	552	22	Derwent	16-Nov-01	120	412	144	18
North Esk	9-Nov-01	470	628	437	17	Derwent	16-Nov-01	121	260	25	7
North Esk	9-Nov-01	471	322	54	2	Derwent	16-Nov-01	122	152	5	1
North Esk	9-Nov-01	472	668	751	28	Derwent	16-Nov-01	123	331	65	21
North Esk	9-Nov-01	473	358	69	10	Derwent	16-Nov-01	124	332	64	10
North Esk	9-Nov-01	474	623	401	7	Derwent	16-Nov-01	125	445	180	16
North Esk	9-Nov-01	475	225	17	2	Derwent	16-Nov-01	126	406	144	9
North Esk	9-Nov-01	476	536	310	25	Derwent	16-Nov-01	127	305	52	20
North Esk	9-Nov-01	477	603	464	30	Derwent	16-Nov-01	128	369	107	11
North Esk	9-Nov-01	478	586	381	21	Derwent	16-Nov-01	129	316	58	-
North Esk	9-Nov-01	479	573	346	19	Derwent	16-Nov-01	130	116	2	-
North Esk	9-Nov-01	480	647	485	17	Derwent	16-Nov-01	131	309	54	14
North Esk	9-Nov-01	481	150	5	-	Derwent	16-Nov-01	132	203	11	5
North Esk	9-Nov-01	482	536	327	29	Derwent	16-Nov-01	133	288	36	7
North Esk	9-Nov-01	483	645	641	-	Derwent	16-Nov-01	134	364	86	11
North Esk	9-Nov-01	484	239	18	1	Derwent	16-Nov-01	135	103	1	0.5
North Esk	9-Nov-01	485	334	63	17	Derwent	16-Nov-01	136	96	1	-
North Esk	9-Nov-01	486	406	135	16	Meadowbank	16-Nov-01	137	207	12	5
North Esk	9-Nov-01	487	336	690	4	Meadowbank	16-Nov-01	138	347	75	5
North Esk	9-Nov-01	488	338	59	19	Meadowbank	16-Nov-01	139	266	32	7
North Esk	9-Nov-01	489	639	553	27	Meadowbank	16-Nov-01	140	697	776	20
Trevallyn	9-Nov-01	638	824	1314	16	Meadowbank	16-Nov-01	141	721	808	20
Trevallyn	9-Nov-01	639	636	598	18	Meadowbank	16-Nov-01	142	651	575	25
Trevallyn	9-Nov-01	640	724	991	16	Meadowbank	16-Nov-01	143	694	639	28
Trevallyn	9-Nov-01	641	697	666	48	Meadowbank	16-Nov-01	144	583	439	20
Trevallyn	9-Nov-01	642	785	1209	20	Meadowbank	16-Nov-01	145	654	605	22
Trevallyn	9-Nov-01	643	732	902	15	Meadowbank	16-Nov-01	146	347	76	14
Trevallyn	9-Nov-01	644	710	899	20	Meadowbank	16-Nov-01	147	687	820	25
Trevallyn	9-Nov-01	645	284	35	8	Meadowbank	16-Nov-01	148	545	347	16
Derwent	14-Nov-01	705	466	180	15	Meadowbank	16-Nov-01	149	365	91	7
Derwent	14-Nov-01	706	517	253	21	Meadowbank	16-Nov-01	150	163	6	3
Derwent	14-Nov-01	707	303	50	12	Meadowbank	16-Nov-01	151	628	515	25
Derwent	14-Nov-01	708	337	65	16	Meadowbank	16-Nov-01	152	485	206	10
Derwent	14-Nov-01	709	490	217	19	Meadowbank	16-Nov-01	153	304	38	6
Meadowbank	14-Nov-01	787	349	71	17	Meadowbank	16-Nov-01	154	239	39	8
Meadowbank	14-Nov-01	788	589	383	15	Meadowbank	20-Nov-01	404	695	739	18
Meadowbank	14-Nov-01	789	396	95	21	Meadowbank	20-Nov-01	405	552	306	19
Meadowbank	14-Nov-01	790	469	215	14	Meadowbank	20-Nov-01	406	628	532	19
Meadowbank	14-Nov-01	791	429	156	9	Meadowbank	20-Nov-01	407	505	255	15
Meadowbank	14-Nov-01	792	334	63	6	Meadowbank	20-Nov-01	408	440	139	10
Meadowbank	14-Nov-01	793	480	205	11	Meadowbank	20-Nov-01	409	379	102	16
Meadowbank	14-Nov-01	794	756	925	24	Meadowbank	20-Nov-01	410	537	289	20
Meadowbank	15-Nov-01	723	603	462	20	Meadowbank	20-Nov-01	411	627	484	20
Meadowbank	15-Nov-01	724	565	366	19	Meadowbank	20-Nov-01	412	620	511	21
Meadowbank	15-Nov-01	725	439	162	17	Meadowbank	20-Nov-01	413	467	484	19
Meadowbank	15-Nov-01	726	557	333	14	Meadowbank	20-Nov-01	414	618	484	19
Meadowbank	15-Nov-01	727	337	77	9	Derwent	20-Nov-01	555	525	288	23
Meadowbank	15-Nov-01	728	521	567	39	Derwent	20-Nov-01	556	378	95	22
Meadowbank	15-Nov-01	729	374	82	9	Derwent	20-Nov-01	557	491	251	18
Meadowbank	15-Nov-01	730	412	139	18	Derwent	20-Nov-01	558	345	63	22
Meadowbank	15-Nov-01	731	501	244	18	Derwent	20-Nov-01	559	470	225	25
Meadowbank	15-Nov-01	732	285	40	6	Derwent	20-Nov-01	560	391	112	21
Meadowbank	15-Nov-01	733	423	153	8	Derwent	20-Nov-01	561	440	221	22
Meadowbank	15-Nov-01	734	535	307	18	Derwent	20-Nov-01	562	314	42	11
Meadowbank	15-Nov-01	735	330	63	7	Derwent	20-Nov-01	563	397	99	11
Meadowbank	15-Nov-01	736	304	48	6	Derwent	20-Nov-01	564	369	92	19
Meadowbank	15-Nov-01	737	312	62	6	Derwent	20-Nov-01	565	324	60	11
Meadowbank	15-Nov-01	738	629	566	19	Derwent	21-Nov-01	655	338	98	21
Meadowbank	15-Nov-01	739	304	46	8	Derwent	21-Nov-01	656	421	132	20
Derwent	21-Nov-01	657	165	7	-	Meadowbank	22-Nov-01	779	604	468	19
Derwent	21-Nov-01	658	402	111	21	Meadowbank	22-Nov-01	780	532	314	-
Derwent	21-Nov-01	659	293	43	11	Meadowbank	22-Nov-01	781	696	761	20
Derwent	21-Nov-01	660	249	27	10	Meadowbank	22-Nov-01	782	826	175	25
Derwent	21-Nov-01	661	175	8	19	Meadowbank	22-Nov-01	783	891	839	28
Derwent	21-Nov-01	662	67	0.2	-	Meadowbank	22-Nov-01	784	585	389	16
Derwent	21-Nov-01	663	135	3	0.5	Meadowbank	22-Nov-01	785	691	602	19
Derwent	21-Nov-01	664	518	285	20	Meadowbank	22-Nov-01	786	846	1537	22
Derwent	21-Nov-01	665	262	32	11	Derwent	23-Nov-01	312	866	1654	28
Derwent	21-Nov-01	666	250	28	-	Derwent	23-Nov-01	313	286	42	10
Derwent	21-Nov-01	667	315	43	10	Derwent	23-Nov-01	314	485	239	14
Derwent	21-Nov-01	668	286	41	12	Derwent	23-Nov-01	315	450	190	22
Derwent	21-Nov-01	669	348	72	11	Derwent	23-Nov-01	316	418	147	18
Derwent	21-Nov-01	670	335	55	17	Derwent	23-Nov-01	317	345	85	18
Derwent	21-Nov-01	671	281	43	11	Derwent	23-Nov-01	318	335	75	15
Derwent	21-Nov-01	672	302	48	11	Derwent	23-Nov-01	319	353	60	12
Derwent	21-Nov-01	673	406	137	13	Derwent	23-Nov-01	320	140	3	1
Derwent	21-Nov-01	674	191	12	8	Derwent	23-Nov-01	321	288	42	7
Derwent	21-Nov-01	675	57	0.101	-	Derwent	23-Nov-01	322	235	18	10
Derwent	21-Nov-01	676	61	0.15	0.5	Derwent	23-Nov-01	323	503	278	23
Meadowbank	21-Nov-01	677	328	59	12	Derwent	23-Nov-01	324	555	379	20
Derwent	21-Nov-01	678	293	48	10	Derwent	23-Nov-01	325	299	49	11
Derwent	21-Nov-01	679	251	24	12	Derwent	23-Nov-01	326	567	1029	31

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Derwent	21-Nov-01	680	260	29	12	Derwent	23-Nov-01	327	530	65	11
Derwent	21-Nov-01	681	328	62	9	Derwent	23-Nov-01	328	574	410	22
Derwent	21-Nov-01	682	310	48	10	Derwent	23-Nov-01	329	470	210	21
Derwent	21-Nov-01	683	280	34	12	Derwent	23-Nov-01	330	409	116	12
Derwent	21-Nov-01	684	389	103	20	Derwent	23-Nov-01	331	324	55	10
Meadowbank	21-Nov-01	685	442	157	15	Derwent	23-Nov-01	332	324	61	11
Derwent	21-Nov-01	686	551	390	19	Derwent	23-Nov-01	333	324	58	11
Derwent	21-Nov-01	687	478	226	19	Derwent	23-Nov-01	334	310	45	12
Derwent	21-Nov-01	688	373	94	11	Derwent	23-Nov-01	335	376	103	19
Meadowbank	21-Nov-01	689	578	383	17	Derwent	23-Nov-01	336	371	87	18
Meadowbank	21-Nov-01	690	501	237	14	Derwent	23-Nov-01	337	326	55	18
Derwent	21-Nov-01	691	533	371	21	Derwent	23-Nov-01	338	447	158	22
Derwent	21-Nov-01	692	479	256	28	Derwent	23-Nov-01	339	338	72	11
Derwent	21-Nov-01	693	599	545	24	Derwent	23-Nov-01	340	253	24	10
Derwent	21-Nov-01	694	497	295	22	Derwent	23-Nov-01	341	259	30	8
Derwent	21-Nov-01	695	362	95	15	Derwent	23-Nov-01	342	293	40	12
Derwent	21-Nov-01	696	380	100	12	Derwent	23-Nov-01	343	384	88	17
Derwent	21-Nov-01	697	352	79	13	Derwent	23-Nov-01	344	254	27	8
Trevallyn	27-Nov-01	698	476	202	19	Derwent	23-Nov-01	345	240	19	10
Trevallyn	27-Nov-01	699	412	122	16	Derwent	23-Nov-01	346	355	91	17
Trevallyn	27-Nov-01	700	483	203	23	Derwent	23-Nov-01	347	64	-	-
Trevallyn	27-Nov-01	701	452	179	17	Derwent	23-Nov-01	348	252	22	-
Trevallyn	27-Nov-01	702	540	327	23	Meadowbank	23-Nov-01	762	552	240	21
Trevallyn	27-Nov-01	703	616	554	25	Meadowbank	23-Nov-01	763	585	344	16
Trevallyn	27-Nov-01	704	709	640	16	Meadowbank	23-Nov-01	764	620	505	19
Derwent	22-Nov-01	76	305	42	10	Meadowbank	23-Nov-01	765	730	811	19
Derwent	22-Nov-01	77	190	14	2	Meadowbank	23-Nov-01	766	689	703	29
Derwent	22-Nov-01	78	320	62	12	Meadowbank	23-Nov-01	767	794	1017	-
Derwent	22-Nov-01	79	105	15	0.5	Meadowbank	23-Nov-01	768	717	670	30
Derwent	22-Nov-01	80	305	58	9	Meadowbank	23-Nov-01	769	699	246	11
Derwent	22-Nov-01	81	590	397	22	Meadowbank	23-Nov-01	770	303	49	6
Derwent	22-Nov-01	82	861	1391	26	Derwent	23-Nov-01	771	487	205	15
Derwent	22-Nov-01	83	763	861	32	Derwent	23-Nov-01	772	464	169	23
Derwent	22-Nov-01	84	390	106	12	Meadowbank	23-Nov-01	773	562	350	22
Derwent	22-Nov-01	85	492	227	17	Meadowbank	23-Nov-01	774	439	147	15
Derwent	22-Nov-01	86	366	94	30	Meadowbank	23-Nov-01	775	334	68	10
Derwent	22-Nov-01	87	440	167	21	Trevallyn	27-Nov-01	177	412	150	13
Derwent	22-Nov-01	88	364	71	16	Trevallyn	27-Nov-01	178	540	345	12
Derwent	22-Nov-01	89	481	218	20	North Esk	27-Nov-01	179	368	75	18
Derwent	22-Nov-01	90	436	223	18	North Esk	27-Nov-01	180	380	115	16
Derwent	22-Nov-01	91	434	156	17	North Esk	27-Nov-01	181	742	850	28
Derwent	22-Nov-01	92	279	30	9	North Esk	27-Nov-01	182	708	720	28
Derwent	22-Nov-01	93	246	20	12	North Esk	27-Nov-01	183	484	295	15
Derwent	22-Nov-01	94	205	11	10	North Esk	27-Nov-01	184	647	570	21
Derwent	22-Nov-01	95	379	92	10	North Esk	27-Nov-01	185	662	475	24
Derwent	22-Nov-01	96	96	1	0.5	North Esk	27-Nov-01	186	611	430	29
Derwent	22-Nov-01	97	67	0.2	0.5	North Esk	27-Nov-01	187	473	200	13
Derwent	22-Nov-01	98	58	-	0.5	North Esk	27-Nov-01	188	578	415	20
Derwent	22-Nov-01	99	509	251	23	North Esk	27-Nov-01	189	337	60	9
Derwent	22-Nov-01	100	402	132	17	North Esk	27-Nov-01	190	391	100	16
Derwent	22-Nov-01	101	139	4	2	North Esk	27-Nov-01	191	332	50	12
Derwent	22-Nov-01	102	260	28	9	North Esk	27-Nov-01	192	365	85	13
Derwent	22-Nov-01	103	350	76	9	North Esk	27-Nov-01	193	305	50	15
Derwent	22-Nov-01	104	326	56	12	North Esk	27-Nov-01	194	338	65	15
Derwent	22-Nov-01	105	319	54	18	North Esk	27-Nov-01	195	362	50	1
Derwent	22-Nov-01	106	249	28	8	North Esk	27-Nov-01	196	483	175	16
Derwent	22-Nov-01	107	98	1	0.5	North Esk	27-Nov-01	197	479	190	16
Derwent	22-Nov-01	108	288	37	9	North Esk	27-Nov-01	198	460	165	18
Derwent	22-Nov-01	109	264	29	10	North Esk	27-Nov-01	199	574	275	20
Derwent	22-Nov-01	110	301	46	11	North Esk	27-Nov-01	200	618	400	16
Derwent	22-Nov-01	111	255	29	7	North Esk	27-Nov-01	201	301	50	9
Derwent	22-Nov-01	112	172	8	2	North Esk	27-Nov-01	202	436	135	10
Meadowbank	22-Nov-01	776	621	434	25	North Esk	27-Nov-01	203	419	145	13
Meadowbank	22-Nov-01	777	495	248	19	North Esk	27-Nov-01	204	328	50	14
Meadowbank	22-Nov-01	778	398	120	13	North Esk	27-Nov-01	205	353	75	13
North Esk	27-Nov-01	206	590	70	23	North Esk	30-Nov-01	440	301	46	10
Trevallyn	28-Nov-01	207	459	205	13	North Esk	30-Nov-01	441	328	68	15
Trevallyn	28-Nov-01	208	265	35	3	North Esk	30-Nov-01	442	231	18	-
Trevallyn	28-Nov-01	209	268	30	8	North Esk	30-Nov-01	443	526	274	22
Trevallyn	28-Nov-01	210	432	155	9	North Esk	30-Nov-01	444	441	176	18
Trevallyn	28-Nov-01	211	392	105	8	North Esk	30-Nov-01	445	452	183	-
Trevallyn	28-Nov-01	212	593	450	19	North Esk	30-Nov-01	446	373	122	17
Trevallyn	28-Nov-01	213	792	1210	25	North Esk	30-Nov-01	447	349	90	-
Trevallyn	28-Nov-01	214	560	420	21	North Esk	4-Dec-01	241	614	425	-
Trevallyn	28-Nov-01	215	392	105	11	North Esk	4-Dec-01	242	525	250	-
Trevallyn	28-Nov-01	216	302	40	11	North Esk	4-Dec-01	243	224	730	-
North Esk	28-Nov-01	217	705	740	24	North Esk	4-Dec-01	244	523	315	-
North Esk	28-Nov-01	218	420	160	16	North Esk	4-Dec-01	245	508	245	-
North Esk	28-Nov-01	219	256	25	9	North Esk	4-Dec-01	246	532	265	-
North Esk	28-Nov-01	220	192	10	1	North Esk	4-Dec-01	247	418	135	-
North Esk	28-Nov-01	221	640	430	24	North Esk	4-Dec-01	248	404	115	-
North Esk	28-Nov-01	222	425	140	21	North Esk	4-Dec-01	249	584	430	-
North Esk	28-Nov-01	223	350	84	12	North Esk	4-Dec-01	250	530	240	-
North Esk	28-Nov-01	224	356	70	5	North Esk	4-Dec-01	251	693	610	-
North Esk	28-Nov-01	225	354	80	13	North Esk	4-Dec-01	252	523	275	-
North Esk	28-Nov-01	226	634	455	13	North Esk	4-Dec-01	253	476	215	-
North Esk	28-Nov-01	227	534	385	21	North Esk	4-Dec-01	254	471	180	-
North Esk	28-Nov-01	228	293	100	12	North Esk	4-Dec-01	255	400	105	-
North Esk	28-Nov-01	229	362	85	19	North Esk	4-Dec-01	256	708	670	-
North Esk	28-Nov-01	230	300	40	12	North Esk	4-Dec-01	257	534	245	-
North Esk	28-Nov-01	231	406	130	16	North Esk	4-Dec-01	258	438	180	-
North Esk	28-Nov-01	232	358	115	16	North Esk	4-Dec-01	259	342	75	-
North Esk	28-Nov-01	233	274	110	15	North Esk	4-Dec-01	260	716	710	-
Trevallyn	29-Nov-01	234	359	400	12	North Esk	4-Dec-01	261	635	480	-
Trevallyn	29-Nov-01	235	815	1295	22	North Esk	4-Dec-01	349	445	159	14
Trevallyn	29-Nov-01	236	498	245	14	North Esk	4-Dec-01	350	442	172	12
Trevallyn	29-Nov-01	237	740	810	20	North Esk	4-Dec-01	351	389	116	15
Trevallyn	29-Nov-01	238	549	315	10	North Esk	4-Dec-01	352	472	217	25
Trevallyn	29-Nov-01	239	461	150	10	North Esk	4-Dec-01	353	495	233	19
Trevallyn	29-Nov-01	240	438	155	-	North Esk	4-Dec-01	354	356	88	13

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North Esk	29-Nov-01	566	757	734	25	North Esk	4-Dec-01	355	405	129	19
North Esk	29-Nov-01	567	584	385	15	North Esk	4-Dec-01	356	693	729	40
North Esk	29-Nov-01	568	436	165	17	North Esk	4-Dec-01	357	531	342	28
North Esk	29-Nov-01	569	418	125	20	North Esk	4-Dec-01	358	399	100	16
North Esk	29-Nov-01	570	377	115	20	North Esk	4-Dec-01	359	542	374	19
North Esk	29-Nov-01	571	386	135	22	North Esk	4-Dec-01	360	473	94	15
North Esk	29-Nov-01	572	382	109	26	North Esk	4-Dec-01	361	720	758	28
North Esk	29-Nov-01	573	351	73	12	North Esk	4-Dec-01	362	475	194	16
North Esk	29-Nov-01	574	440	161	26	North Esk	4-Dec-01	363	357	86	13
North Esk	29-Nov-01	575	410	113	15	North Esk	4-Dec-01	364	514	234	13
North Esk	29-Nov-01	576	390	107	17	North Esk	4-Dec-01	365	411	155	19
North Esk	29-Nov-01	577	349	65	18	North Esk	4-Dec-01	366	245	23	-
North Esk	29-Nov-01	578	281	26	11	North Esk	4-Dec-01	367	603	425	21
North Esk	29-Nov-01	579	311	51	12	North Esk	4-Dec-01	368	344	86	15
Trevallyn	30-Nov-01	390	943	1972	48	North Esk	4-Dec-01	369	308	40	-
Trevallyn	30-Nov-01	391	572	415	21	Trevallyn	4-Dec-01	646	609	621	19
Trevallyn	30-Nov-01	392	750	901	14	Trevallyn	4-Dec-01	647	416	154	10
Trevallyn	30-Nov-01	393	734	953	12	Trevallyn	4-Dec-01	648	529	306	20
Trevallyn	30-Nov-01	394	602	722	19	Trevallyn	4-Dec-01	649	578	457	12
Trevallyn	30-Nov-01	395	523	313	17	Trevallyn	4-Dec-01	650	504	282	7
Trevallyn	30-Nov-01	396	467	227	17	Trevallyn	4-Dec-01	651	672	671	21
Trevallyn	30-Nov-01	397	421	139	13	Trevallyn	4-Dec-01	652	739	861	12
Trevallyn	30-Nov-01	398	184	9	3	Trevallyn	4-Dec-01	653	629	562	15
Trevallyn	30-Nov-01	399	482	10	3	Trevallyn	4-Dec-01	654	754	974	24
Trevallyn	30-Nov-01	400	664	610	21	Trevallyn	5-Dec-01	580	1049	2719	27
Trevallyn	30-Nov-01	401	623	502	21	Trevallyn	5-Dec-01	581	575	470	20
Trevallyn	30-Nov-01	402	648	586	14	Trevallyn	5-Dec-01	582	604	491	20
Trevallyn	30-Nov-01	403	805	1059	20	Trevallyn	5-Dec-01	583	625	504	13
North Esk	30-Nov-01	415	610	459	24	Trevallyn	5-Dec-01	584	745	1018	24
North Esk	30-Nov-01	416	487	274	22	Trevallyn	5-Dec-01	585	477	236	13
North Esk	30-Nov-01	417	306	56	12	Trevallyn	5-Dec-01	586	430	193	8
North Esk	30-Nov-01	418	311	62	12	Trevallyn	5-Dec-01	587	505	296	13
North Esk	30-Nov-01	419	287	42	12	Trevallyn	5-Dec-01	588	637	612	28
North Esk	30-Nov-01	420	356	84	17	Trevallyn	5-Dec-01	589	404	150	14
North Esk	30-Nov-01	421	474	180	20	Trevallyn	5-Dec-01	590	618	570	21
North Esk	30-Nov-01	422	485	223	23	Trevallyn	5-Dec-01	591	524	333	13
North Esk	30-Nov-01	423	308	46	8	Trevallyn	5-Dec-01	592	514	294	-
North Esk	30-Nov-01	424	391	131	19	North Esk	5-Dec-01	710	359	97	13
North Esk	30-Nov-01	425	365	96	12	North Esk	5-Dec-01	711	604	411	20
North Esk	30-Nov-01	426	420	140	20	North Esk	5-Dec-01	712	388	122	16
North Esk	30-Nov-01	427	418	139	12	North Esk	5-Dec-01	713	579	315	27
North Esk	30-Nov-01	428	385	119	16	North Esk	5-Dec-01	714	280	35	-
North Esk	30-Nov-01	429	431	143	18	North Esk	5-Dec-01	715	451	193	18
North Esk	30-Nov-01	430	517	299	18	North Esk	5-Dec-01	716	549	254	20
North Esk	30-Nov-01	431	247	25	-	North Esk	5-Dec-01	717	588	446	-
North Esk	30-Nov-01	432	683	695	22	North Esk	5-Dec-01	718	550	304	-
North Esk	30-Nov-01	433	699	737	25	North Esk	5-Dec-01	719	436	138	14
North Esk	30-Nov-01	434	485	181	19	North Esk	5-Dec-01	720	342	77	12
North Esk	30-Nov-01	435	407	118	18	North Esk	5-Dec-01	721	560	412	25
North Esk	30-Nov-01	436	418	137	18	North Esk	5-Dec-01	722	1009	141	37
North Esk	30-Nov-01	437	743	966	22	North Esk	6-Dec-01	262	561	301	16
North Esk	30-Nov-01	438	405	126	18	North Esk	6-Dec-01	263	607	487	23
North Esk	30-Nov-01	439	452	174	23	North Esk	6-Dec-01	264	704	1072	25
North Esk	6-Dec-01	265	604	458	26	North Esk	7-Dec-01	523	491	229	22
North Esk	6-Dec-01	266	624	472	-	North Esk	7-Dec-01	524	548	335	22
North Esk	6-Dec-01	267	490	194	20	North Esk	15-Jan-02	1084	656	529.5	-
North Esk	6-Dec-01	268	320	61	12	North Esk	15-Jan-02	1085	496	210.3	22
North Esk	6-Dec-01	269	328	68	11	North Esk	15-Jan-02	1086	360	102.9	13
North Esk	6-Dec-01	270	660	612	26	North Esk	15-Jan-02	1087	525	288.9	17
North Esk	6-Dec-01	271	524	310	31	North Esk	15-Jan-02	1088	568	238.9	25
North Esk	6-Dec-01	272	377	105	20	North Esk	15-Jan-02	1089	269	30.4	15
North Esk	6-Dec-01	273	344	47	17	North Esk	15-Jan-02	1090	583	356.5	-
North Esk	6-Dec-01	274	653	567	20	North Esk	15-Jan-02	1091	328	68.1	15
North Esk	6-Dec-01	275	623	590	32	North Esk	15-Jan-02	1092	329	62.3	13
North Esk	6-Dec-01	276	566	394	18	North Esk	15-Jan-02	1093	473	179.3	18
North Esk	6-Dec-01	277	571	430	25	North Esk	15-Jan-02	1094	435	166.5	19
North Esk	6-Dec-01	278	561	409	23	North Esk	15-Jan-02	1095	459	144.8	21
North Esk	6-Dec-01	279	492	253	23	North Esk	15-Jan-02	1096	340	59.5	16
North Esk	6-Dec-01	280	349	96	12	North Esk	15-Jan-02	1097	473	210.5	21
North Esk	6-Dec-01	281	624	503	23	North Esk	15-Jan-02	1098	545	257.9	26
North Esk	6-Dec-01	282	498	234	13	North Esk	15-Jan-02	1099	416	99.6	19
North Esk	6-Dec-01	283	418	152	16	North Esk	15-Jan-02	1100	404	133.2	22
North Esk	6-Dec-01	284	452	140	17	North Esk	15-Jan-02	1101	341	51	14
North Esk	6-Dec-01	285	398	112	21	North Esk	15-Jan-02	1102	320	54.5	13
North Esk	6-Dec-01	286	375	96	13	North Esk	15-Jan-02	1103	341	80.7	12
North Esk	6-Dec-01	287	284	48	13	North Esk	15-Jan-02	1104	362	90.4	15
North Esk	6-Dec-01	288	463	191	13	North Esk	15-Jan-02	1105	317	43.3	13
North Esk	6-Dec-01	289	373	115	14	North Esk	15-Jan-02	1106	324	54.5	15
North Esk	6-Dec-01	290	386	112	18	North Esk	15-Jan-02	1107	322	51.3	13
North Esk	6-Dec-01	291	324	61	10	North Esk	15-Jan-02	1108	494	184.2	24
North Esk	6-Dec-01	292	545	340	24	North Esk	15-Jan-02	1109	501	221	24
North Esk	6-Dec-01	293	478	219	18	North Esk	15-Jan-02	1110	446	164.7	21
North Esk	6-Dec-01	294	430	153	18	North Esk	15-Jan-02	1111	444	144	17
North Esk	6-Dec-01	295	328	60	13	North Esk	15-Jan-02	1112	437	147.7	15
North Esk	6-Dec-01	296	400	120	18	North Esk	15-Jan-02	1113	407	113.8	18
North Esk	6-Dec-01	297	364	86	10	North Esk	15-Jan-02	1114	334	61.8	15
North Esk	6-Dec-01	298	621	454	16	North Esk	15-Jan-02	1115	297	33	13
North Esk	6-Dec-01	299	637	525	28	North Esk	15-Jan-02	1116	235	20.3	11
North Esk	6-Dec-01	300	601	380	18	North Esk	15-Jan-02	1117	254	24	-
North Esk	6-Dec-01	301	450	182	18	North Esk	15-Jan-02	1118	612	40.7	14
North Esk	6-Dec-01	302	380	118	14	North Esk	15-Jan-02	1119	466	193.3	17
North Esk	6-Dec-01	303	432	144	16	North Esk	15-Jan-02	1120	556	327.5	17
Trevallyn	6-Dec-01	304	731	917	22	North Esk	15-Jan-02	1121	443	160.4	-
Trevallyn	6-Dec-01	305	500	213	12	North Esk	15-Jan-02	1122	369	76.6	12
Trevallyn	6-Dec-01	306	464	211	13	North Esk	15-Jan-02	1123	355	76.4	17
Trevallyn	6-Dec-01	307	581	456	14	North Esk	15-Jan-02	1124	332	57.7	18
Trevallyn	6-Dec-01	308	578	347	19	North Esk	15-Jan-02	1125	280	36.6	11
Trevallyn	6-Dec-01	309	191	10	3	North Esk	15-Jan-02	1126	197	10.3	9
Trevallyn	6-Dec-01	310	395	118	11	Trevallyn	15-Jan-02	1167	605	511.8	16
Trevallyn	6-Dec-01	311	472	217	10	Trevallyn	15-Jan-02	1168	737	928.8	19

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Trevallyn	7-Dec-01	382	507	299	11	Trevallyn	15-Jan-02	1169	760	1012.3	19
Trevallyn	7-Dec-01	383	615	518	20	Trevallyn	15-Jan-02	1170	750	937.9	18
Trevallyn	7-Dec-01	384	476	215	10	Trevallyn	15-Jan-02	1171	384	110.9	8
Trevallyn	7-Dec-01	385	546	360	17	Trevallyn	15-Jan-02	1172	405	142.8	9
Trevallyn	7-Dec-01	386	564	374	13	Trevallyn	15-Jan-02	1173	786	1015.1	44
Trevallyn	7-Dec-01	387	644	510	14	North Esk	16-Jan-02	947	645	538.9	33
Trevallyn	7-Dec-01	388	500	294	13	North Esk	16-Jan-02	948	504	263.8	17
Trevallyn	7-Dec-01	389	622	529	19	North Esk	16-Jan-02	949	646	259.3	16
North Esk	7-Dec-01	490	362	76	16	North Esk	16-Jan-02	950	564	299.7	22
North Esk	7-Dec-01	491	641	444	18	North Esk	16-Jan-02	951	580	446.5	16
North Esk	7-Dec-01	492	365	130	18	North Esk	16-Jan-02	952	493	239.7	23
North Esk	7-Dec-01	493	434	154	23	North Esk	16-Jan-02	953	610	382.4	16
North Esk	7-Dec-01	494	314	59	13	North Esk	16-Jan-02	954	574	342.6	24
North Esk	7-Dec-01	495	736	761	14	North Esk	16-Jan-02	955	487	232.9	20
North Esk	7-Dec-01	496	417	110	15	North Esk	16-Jan-02	956	488	234.4	18
North Esk	7-Dec-01	497	352	88	15	North Esk	16-Jan-02	957	408	136.8	20
North Esk	7-Dec-01	498	365	107	15	North Esk	16-Jan-02	958	386	126.5	15
North Esk	7-Dec-01	499	739	941	-	North Esk	16-Jan-02	959	447	167	19
North Esk	7-Dec-01	500	487	190	12	North Esk	16-Jan-02	960	423	119.2	19
North Esk	7-Dec-01	501	439	154	19	North Esk	16-Jan-02	961	416	140.5	18
North Esk	7-Dec-01	502	397	149	13	North Esk	16-Jan-02	962	359	83.6	12
North Esk	7-Dec-01	503	617	452	20	North Esk	16-Jan-02	963	350	86.5	23
North Esk	7-Dec-01	504	417	134	19	North Esk	16-Jan-02	964	340	63.8	11
North Esk	7-Dec-01	505	560	375	24	North Esk	16-Jan-02	965	270	35.7	11
North Esk	7-Dec-01	506	353	72	13	North Esk	16-Jan-02	966	244	23.1	10
North Esk	7-Dec-01	507	390	126	15	North Esk	16-Jan-02	967	629	418.1	-
North Esk	7-Dec-01	508	372	87	19	North Esk	16-Jan-02	968	636	461.9	49
North Esk	7-Dec-01	509	239	19	6	North Esk	16-Jan-02	969	399	127.2	13
North Esk	7-Dec-01	510	497	236	22	North Esk	16-Jan-02	970	384	99.4	13
North Esk	7-Dec-01	511	293	41	8	North Esk	16-Jan-02	971	511	299.7	17
North Esk	7-Dec-01	512	526	289	13	North Esk	16-Jan-02	972	434	166.9	15
North Esk	7-Dec-01	513	536	294	24	North Esk	16-Jan-02	973	334	77.8	13
North Esk	7-Dec-01	514	629	651	31	North Esk	16-Jan-02	974	344	64.1	14
North Esk	7-Dec-01	515	619	432	30	North Esk	16-Jan-02	975	347	78.6	15
North Esk	7-Dec-01	516	629	473	-	North Esk	16-Jan-02	976	452	137.1	19
North Esk	7-Dec-01	517	668	585	26	North Esk	16-Jan-02	977	297	48	13
North Esk	7-Dec-01	518	612	482	24	North Esk	16-Jan-02	978	344	86.6	12
North Esk	7-Dec-01	519	324	546	16	North Esk	16-Jan-02	979	278	32.6	12
North Esk	7-Dec-01	520	523	274	22	North Esk	16-Jan-02	980	466	182.7	23
North Esk	7-Dec-01	521	510	269	26	North Esk	16-Jan-02	981	328	71.5	12
North Esk	7-Dec-01	522	519	294	22	North Esk	16-Jan-02	982	458	169	15
North Esk	16-Jan-02	983	354	77	17	North Esk	17-Jan-02	1213	284	31.6	10
North Esk	16-Jan-02	984	295	38.3	14	North Esk	17-Jan-02	1214	261	31.6	11
North Esk	16-Jan-02	985	274	34.2	10	North Esk	17-Jan-02	1215	308	51.6	12
North Esk	16-Jan-02	986	279	33.3	11	North Esk	17-Jan-02	1216	464	120.7	19
North Esk	16-Jan-02	987	592	463.6	22	North Esk	17-Jan-02	1217	275	35.1	12
North Esk	16-Jan-02	988	717	698.6	18	North Esk	17-Jan-02	1218	189	9.5	7
North Esk	16-Jan-02	989	557	311.7	17	North Esk	17-Jan-02	1219	277	34.5	13
North Esk	16-Jan-02	990	485	189.1	-	North Esk	18-Jan-02	1051	613	489.3	25
North Esk	16-Jan-02	991	341	76.5	14	North Esk	18-Jan-02	1052	364	956.6	19
North Esk	16-Jan-02	992	462	172.6	22	North Esk	18-Jan-02	1053	381	85.8	16
North Esk	16-Jan-02	993	425	145.4	15	North Esk	18-Jan-02	1054	329	61.3	16
North Esk	16-Jan-02	994	378	100.8	14	North Esk	18-Jan-02	1055	393	123.8	17
North Esk	16-Jan-02	995	366	87.7	18	North Esk	18-Jan-02	1056	361	76.1	16
North Esk	16-Jan-02	996	276	38.3	12	North Esk	18-Jan-02	1057	373	90.8	9
North Esk	16-Jan-02	997	290	42	11	North Esk	18-Jan-02	1058	434	139.6	16
North Esk	16-Jan-02	998	69	0.3	0.5	North Esk	18-Jan-02	1059	578	343.1	29
North Esk	16-Jan-02	999	440	138.7	11	North Esk	18-Jan-02	1060	519	265.6	20
North Esk	16-Jan-02	1000	309	50	9	North Esk	18-Jan-02	1061	383	97.3	15
North Esk	16-Jan-02	1001	457	144.9	22	North Esk	18-Jan-02	1062	371	99.72	15
North Esk	16-Jan-02	1002	428	121.4	19	North Esk	18-Jan-02	1063	225	57.8	9
North Esk	16-Jan-02	1003	355	86.2	13	North Esk	18-Jan-02	1064	305	53.7	13
North Esk	16-Jan-02	1004	372	85.5	18	North Esk	18-Jan-02	1065	254	26.8	-
North Esk	16-Jan-02	1005	303	55.4	12	North Esk	18-Jan-02	1066	670	575.9	21
North Esk	16-Jan-02	1006	223	15.9	7	North Esk	18-Jan-02	1067	515	208.3	21
North Esk	16-Jan-02	1007	350	87.1	15	North Esk	18-Jan-02	1068	471	175.2	26
North Esk	16-Jan-02	1008	326	61	12	North Esk	18-Jan-02	1069	365	96.9	15
North Esk	16-Jan-02	1009	298	47.5	11	North Esk	18-Jan-02	1070	606	397.2	19
North Esk	16-Jan-02	1010	304	45.7	13	North Esk	18-Jan-02	1071	577	399.7	21
North Esk	16-Jan-02	1011	414	128	24	North Esk	18-Jan-02	1072	430	152.6	25
North Esk	16-Jan-02	1012	345	64.2	12	North Esk	18-Jan-02	1073	349	77.3	25
North Esk	16-Jan-02	1013	564	32.9	36	North Esk	18-Jan-02	1074	470	199.4	19
North Esk	16-Jan-02	1014	334	61.9	14	North Esk	18-Jan-02	1075	440	136	22
North Esk	16-Jan-02	1015	282	35.8	13	North Esk	18-Jan-02	1076	390	93.5	17
North Esk	16-Jan-02	1016	375	99.3	12	North Esk	18-Jan-02	1077	338	67.4	10
North Esk	16-Jan-02	1017	272	32.4	12	North Esk	18-Jan-02	1078	294	44.7	12
North Esk	16-Jan-02	1018	328	48.4	15	North Esk	18-Jan-02	1079	343	72.9	14
North Esk	16-Jan-02	1019	234	18.7	13	North Esk	18-Jan-02	1080	294	42.5	12
North Esk	16-Jan-02	1020	238	18.1	11	North Esk	18-Jan-02	1081	340	70.6	13
Trevallyn	16-Jan-02	795	677	700	14	North Esk	18-Jan-02	1082	292	37.6	12
Trevallyn	16-Jan-02	796	676	620	13	North Esk	18-Jan-02	1083	63	0.2	-
Trevallyn	16-Jan-02	797	892	1485	20	Trevallyn	18-Jan-02	1127	640	514.1	15
Trevallyn	16-Jan-02	798	811	1080	25	Trevallyn	18-Jan-02	1128	466	192.3	14
Trevallyn	17-Jan-02	799	734	805	20	Trevallyn	18-Jan-02	1129	745	978.8	20
Trevallyn	17-Jan-02	800	770	905	23	Trevallyn	18-Jan-02	1130	780	1009.4	21
Trevallyn	17-Jan-02	801	655	575	13	North Esk	22-Jan-02	806	410	118.6	22
Trevallyn	17-Jan-02	802	834	1480	24	North Esk	22-Jan-02	807	540	249.9	22
Trevallyn	17-Jan-02	803	691	695	13	North Esk	22-Jan-02	808	410	115.9	16
Trevallyn	17-Jan-02	804	403	135	13	North Esk	22-Jan-02	809	435	174.8	18
Trevallyn	17-Jan-02	805	505	270	22	North Esk	22-Jan-02	810	435	187.9	19
North Esk	17-Jan-02	1174	480	221.8	26	North Esk	22-Jan-02	811	385	98.9	15
North Esk	17-Jan-02	1175	508	216.1	24	North Esk	22-Jan-02	812	452	182	27
North Esk	17-Jan-02	1176	346	76.5	12	North Esk	22-Jan-02	813	586	345.4	26
North Esk	17-Jan-02	1177	542	278.6	22	North Esk	22-Jan-02	814	625	65.3	21
North Esk	17-Jan-02	1178	435	163.5	15	North Esk	22-Jan-02	815	665	555.5	27
North Esk	17-Jan-02	1179	300	54.3	13	North Esk	22-Jan-02	816	374	93.3	19
North Esk	17-Jan-02	1180	633	518	25	North Esk	22-Jan-02	817	423	159.9	-
North Esk	17-Jan-02	1181	533	285	26	North Esk	22-Jan-02	818	360	96.7	19
North Esk	17-Jan-02	1182	402	121.3	19	North Esk	22-Jan-02	819	527	272	-
North Esk	17-Jan-02	1183	254	23.6	9	North Esk	22-Jan-02	820	420	127.3	15

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North Esk	17-Jan-02	1184	597	407	19	North Esk	22-Jan-02	821	518	309	22
North Esk	17-Jan-02	1185	515	212.5	21	North Esk	22-Jan-02	822	540	326	17
North Esk	17-Jan-02	1186	415	145.5	19	North Esk	22-Jan-02	823	454	186	13
North Esk	17-Jan-02	1187	371	100.8	15	North Esk	22-Jan-02	824	354	89	21
North Esk	17-Jan-02	1188	365	74.5	18	North Esk	22-Jan-02	825	486	221	18
North Esk	17-Jan-02	1189	387	89.9	17	North Esk	22-Jan-02	826	447	172.7	19
North Esk	17-Jan-02	1190	390	84.8	16	North Esk	22-Jan-02	827	530	348.2	22
North Esk	17-Jan-02	1191	405	126.2	14	North Esk	22-Jan-02	828	756	891	-
North Esk	17-Jan-02	1192	505	273.4	-	North Esk	22-Jan-02	829	344	75.1	12
North Esk	17-Jan-02	1193	378	85.9	17	North Esk	22-Jan-02	830	499	277.5	25
North Esk	17-Jan-02	1194	484	236.7	17	North Esk	22-Jan-02	831	336	74.2	15
North Esk	17-Jan-02	1195	395	122.3	16	North Esk	22-Jan-02	832	396	116.4	18
North Esk	17-Jan-02	1196	435	140.3	15	North Esk	22-Jan-02	833	555	290	5
North Esk	17-Jan-02	1197	310	64.7	12	North Esk	22-Jan-02	834	475	209.4	23
North Esk	17-Jan-02	1198	349	74.9	15	North Esk	22-Jan-02	835	660	496.9	13
North Esk	17-Jan-02	1199	306	55.8	11	North Esk	22-Jan-02	836	685	663.2	23
North Esk	17-Jan-02	1200	318	62.2	9	North Esk	22-Jan-02	837	280	31.5	6
North Esk	17-Jan-02	1201	304	51	15	North Esk	22-Jan-02	838	502	197.6	16
North Esk	17-Jan-02	1202	483	204.4	18	North Esk	22-Jan-02	839	539	292.4	18
North Esk	17-Jan-02	1203	365	88.8	17	North Esk	22-Jan-02	840	484	242.7	24
North Esk	17-Jan-02	1204	251	25.1	12	North Esk	22-Jan-02	841	255	20.6	12
North Esk	17-Jan-02	1205	464	206.6	22	North Esk	22-Jan-02	842	545	292.5	24
North Esk	17-Jan-02	1206	459	172.8	19	North Esk	22-Jan-02	843	590	408.1	29
North Esk	17-Jan-02	1207	270	35	11	North Esk	22-Jan-02	844	385	133.7	18
North Esk	17-Jan-02	1208	301	51.2	12	North Esk	22-Jan-02	845	732	702.4	33
North Esk	17-Jan-02	1209	457	122.5	-	North Esk	22-Jan-02	846	80	0.4	0.5
North Esk	17-Jan-02	1210	242	21.1	11	North Esk	22-Jan-02	847	420	173.3	14
North Esk	17-Jan-02	1211	257	30.2	9	North Esk	22-Jan-02	848	572	386.4	20
North Esk	17-Jan-02	1212	256	31.8	9	North Esk	22-Jan-02	849	425	134.5	22
North Esk	22-Jan-02	850	399	112.7	15	Meadowbank	5-Feb-02	1165	651	501	24
North Esk	22-Jan-02	851	455	143.9	21	Meadowbank	5-Feb-02	1166	453	168.6	16
North Esk	22-Jan-02	852	66	0.2	-	Derwent	6-Feb-02	1021	788	1119.7	32
North Esk	22-Jan-02	853	64	0.2	-	Derwent	6-Feb-02	1022	258	295.2	7
Trevallyn	22-Jan-02	1136	543	323.3	6	Derwent	6-Feb-02	1023	802	1257.2	37
Trevallyn	22-Jan-02	1137	745	920.4	15	Derwent	6-Feb-02	1024	506	268.2	16
Trevallyn	22-Jan-02	1138	461	182.9	4	Derwent	6-Feb-02	1025	319	61.8	-
Trevallyn	22-Jan-02	1139	739	830.4	16	Derwent	6-Feb-02	1026	343	82.9	10
North Esk	23-Jan-02	1220	450	157.7	20	Derwent	6-Feb-02	1027	333	68.1	12
North Esk	23-Jan-02	1221	400	139.6	20	Derwent	6-Feb-02	1028	292	44.5	9
North Esk	23-Jan-02	1222	503	214.1	23	Derwent	6-Feb-02	1029	115	2	0.5
North Esk	23-Jan-02	1223	360	82.2	25	Derwent	6-Feb-02	1030	85	0.7	0.5
North Esk	23-Jan-02	1224	555	396.8	21	Derwent	6-Feb-02	1031	94	0.8	24
North Esk	23-Jan-02	1225	495	213.4	21	Derwent	6-Feb-02	1032	82	0.5	23
North Esk	23-Jan-02	1226	72	0.3	-	Derwent	6-Feb-02	1033	83	0.6	8
North Esk	23-Jan-02	1227	64	0.2	0.5	Derwent	6-Feb-02	1034	567	367.9	8
North Esk	23-Jan-02	1228	448	184.1	22	Derwent	6-Feb-02	1035	444	197.2	11
North Esk	23-Jan-02	1229	581	342.2	22	Derwent	6-Feb-02	1036	362	101.5	7
North Esk	23-Jan-02	1230	323	74.3	15	Derwent	6-Feb-02	1037	235	21.6	16
Trevallyn	23-Jan-02	1231	449	206.4	27	Derwent	6-Feb-02	1038	457	227.5	8
Trevallyn	23-Jan-02	1232	105	105	-	Derwent	6-Feb-02	1039	527	307	11
North Esk	23-Jan-02	1233	528	363.6	13	Derwent	6-Feb-02	1040	357	86.9	11
North Esk	23-Jan-02	1234	61	0.2	0.5	Derwent	6-Feb-02	1041	637	617.9	0.5
North Esk	23-Jan-02	1235	65	0.3	-	Derwent	6-Feb-02	1042	475	263	0.5
North Esk	23-Jan-02	1236	490	207.9	24	Derwent	6-Feb-02	1043	303	51.2	0.5
North Esk	23-Jan-02	1237	569	387.4	29	Derwent	6-Feb-02	1044	340	81.7	23
North Esk	23-Jan-02	1238	451	224.4	18	Derwent	6-Feb-02	1045	221	17.1	13
North Esk	23-Jan-02	1239	486	261.5	23	Derwent	6-Feb-02	1046	245	29.5	8
North Esk	23-Jan-02	1240	66	0.7	0.5	Derwent	6-Feb-02	1047	400	107.7	7
North Esk	23-Jan-02	1241	615	519.6	20	Derwent	6-Feb-02	1048	315	64	19
North Esk	23-Jan-02	1242	462	199.3	12	Derwent	6-Feb-02	1049	361	845	17
North Esk	23-Jan-02	1243	322	57.8	11	Derwent	6-Feb-02	1050	318	62.3	11
North Esk	23-Jan-02	1244	519	250.9	21	Meadowbank	6-Feb-02	1156	677	501.5	18
North Esk	23-Jan-02	1245	365	108.1	21	Meadowbank	6-Feb-02	1157	433	165.9	14
North Esk	23-Jan-02	1246	441	188.6	20	Meadowbank	6-Feb-02	1158	322	64.5	18
North Esk	23-Jan-02	1247	361	91.8	19	Meadowbank	6-Feb-02	1159	368	95.5	8
North Esk	23-Jan-02	1248	358	96.6	16	Meadowbank	6-Feb-02	1160	185	10.2	3
North Esk	23-Jan-02	1249	367	97.9	21	Meadowbank	6-Feb-02	1161	448	174	21
North Esk	23-Jan-02	1250	474	204.7	18	Meadowbank	6-Feb-02	1162	561	369.3	17
North Esk	23-Jan-02	1251	345	73.9	16	Meadowbank	7-Feb-02	854	717	704.7	19
North Esk	23-Jan-02	1252	297	50.8	9	Meadowbank	7-Feb-02	855	543	352.7	26
North Esk	23-Jan-02	1253	405	162.3	18	Meadowbank	7-Feb-02	856	410	134.6	15
North Esk	23-Jan-02	1254	65	0.25	0.5	Meadowbank	7-Feb-02	857	417	136.7	13
North Esk	23-Jan-02	1255	60	0.12	0.5	Meadowbank	7-Feb-02	858	510	200.7	22
North Esk	23-Jan-02	1256	422	147.9	16	Meadowbank	7-Feb-02	859	323	64.1	7
North Esk	23-Jan-02	1257	368	86.9	12	Meadowbank	7-Feb-02	860	285	48	6
North Esk	23-Jan-02	1258	457	208.2	18	Meadowbank	7-Feb-02	861	277	39.8	9
North Esk	23-Jan-02	1259	402	1.2	-	Meadowbank	7-Feb-02	862	360	81.5	17
North Esk	23-Jan-02	1260	66	0.3	-	Meadowbank	7-Feb-02	863	642	489.4	22
North Esk	23-Jan-02	1261	458	187.4	23	Meadowbank	7-Feb-02	864	398	109.4	10
Trevallyn	23-Jan-02	1131	532	236.4	7	Meadowbank	7-Feb-02	865	379	87.9	10
Trevallyn	23-Jan-02	1132	637	540.2	17	Meadowbank	7-Feb-02	866	487	248.7	15
Trevallyn	23-Jan-02	1133	408	130.4	4	Meadowbank	7-Feb-02	867	453	169.9	19
Trevallyn	23-Jan-02	1134	775	996	21	Meadowbank	7-Feb-02	868	375	88.1	12
Trevallyn	23-Jan-02	1135	881	1334.1	21	Derwent	7-Feb-02	869	508	294	22
North Esk	24-Jan-02	1140	412	119.8	22	Derwent	7-Feb-02	870	536	306.6	20
North Esk	24-Jan-02	1141	484	216.1	14	Derwent	7-Feb-02	871	407	144.2	20
North Esk	24-Jan-02	1142	672	636.1	17	Derwent	7-Feb-02	872	415	141.9	14
North Esk	24-Jan-02	1143	455	181.5	22	Derwent	7-Feb-02	873	394	103.8	21
North Esk	24-Jan-02	1144	605	341	11	Derwent	7-Feb-02	874	378	99.6	24
North Esk	24-Jan-02	1145	480	176.3	19	Derwent	7-Feb-02	875	356	73.7	12
North Esk	24-Jan-02	1146	471	235.8	33	Derwent	7-Feb-02	876	357	81.1	9
North Esk	24-Jan-02	1147	568	327.6	35	Derwent	7-Feb-02	877	644	544.6	22
North Esk	24-Jan-02	1148	380	95.6	-	Derwent	7-Feb-02	878	462	207.4	-
North Esk	24-Jan-02	1149	381	103.6	13	Derwent	7-Feb-02	879	322	48.5	11
North Esk	24-Jan-02	1150	471	189.1	17	Derwent	7-Feb-02	880	569	413	19
North Esk	24-Jan-02	1151	210	16.4	11	Derwent	7-Feb-02	881	735	939.8	39
North Esk	24-Jan-02	1152	448	180.4	25	Derwent	7-Feb-02	882	480	243.8	25
Trevallyn	24-Jan-02	1153	345	56.9	5	Derwent	7-Feb-02	883	498	256.6	19
North Esk	24-Jan-02	1154	330	71.2	11	Derwent	7-Feb-02	884	277	34.4	-
North Esk	24-Jan-02	1155	55	0.1	0.5	Derwent	7-Feb-02	885	246	24.4	8

2001/2002 Eel Catch Data

Derwent	5-Feb-02	932	925	1779.9	37
Derwent	5-Feb-02	933	537	321.2	19
Derwent	5-Feb-02	934	386	108.8	11
Derwent	5-Feb-02	935	481	248.4	22
Derwent	5-Feb-02	936	373	94.9	20
Derwent	5-Feb-02	937	219	15.8	3
Derwent	5-Feb-02	938	657	579.1	26
Derwent	5-Feb-02	939	411	132.9	24
Derwent	5-Feb-02	940	316	53.7	9
Derwent	5-Feb-02	941	92	44.2	8
Derwent	5-Feb-02	942	319	57.1	8
Derwent	5-Feb-02	943	298	43.2	10
Derwent	5-Feb-02	944	318	56.6	13
Derwent	5-Feb-02	945	92	1.1	0.5
Derwent	5-Feb-02	946	71	0.4	0.5
Meadowbank	5-Feb-02	1163	550	400.1	22
Meadowbank	5-Feb-02	1164	549	336.2	20
Meadowbank	8-Feb-02	903	290	39.7	9
Meadowbank	8-Feb-02	904	264	27.2	8
Meadowbank	8-Feb-02	905	693	746.6	24
Meadowbank	8-Feb-02	906	616	540.6	29
Meadowbank	8-Feb-02	907	568	394.5	19
Meadowbank	8-Feb-02	908	665	601.1	19
Derwent	8-Feb-02	909	340	68.2	8
Meadowbank	8-Feb-02	910	450	140.7	18
Meadowbank	8-Feb-02	911	471	203	20
Meadowbank	8-Feb-02	912	461	190	11
Meadowbank	8-Feb-02	913	671	647.1	20
Derwent	8-Feb-02	914	431	160.1	11
Derwent	8-Feb-02	915	417	112.9	12
Derwent	8-Feb-02	916	714	934.8	27
Derwent	8-Feb-02	917	858	1575.4	27
Derwent	8-Feb-02	918	518	287	20
Derwent	8-Feb-02	919	253	27.9	8
Derwent	8-Feb-02	920	262	32.6	8
Derwent	8-Feb-02	921	734	951.6	28
Derwent	8-Feb-02	922	261	93.3	20
Derwent	8-Feb-02	923	262	31.2	8
Derwent	8-Feb-02	924	282	38	7
Derwent	8-Feb-02	925	355	83.6	11
Meadowbank	8-Feb-02	926	387	106.1	10
Meadowbank	8-Feb-02	927	378	89.8	25
Derwent	8-Feb-02	928	328	64	12
Derwent	8-Feb-02	929	232	16.2	8
Derwent	8-Feb-02	930	214	14.8	7
Derwent	8-Feb-02	931	82	52	-
Arthurs	13-Feb-02	1307	1055	2204.1	50
Meadowbank	5-Mar-02	1297	585	389.6	18
Meadowbank	5-Mar-02	1298	687	642.1	31
Meadowbank	5-Mar-02	1299	432	167.6	16
Meadowbank	5-Mar-02	1300	700	854	38
Meadowbank	5-Mar-02	1301	598	341.7	20
Derwent	5-Mar-02	1302	406	131	12
Derwent	5-Mar-02	1303	392	108.1	14
Meadowbank	5-Mar-02	1304	537	313.3	23
Meadowbank	5-Mar-02	1305	612	450.9	22
Derwent	5-Mar-02	1306	99	1.1	0.5
Meadowbank	6-Mar-02	1272	770	1020.6	31
Meadowbank	6-Mar-02	1273	508	255.6	-
Meadowbank	6-Mar-02	1274	559	383.4	24
Derwent	6-Mar-02	1275	457	202.4	24
Derwent	6-Mar-02	1276	279	38.7	-
Derwent	6-Mar-02	1277	526	320.2	24
Derwent	6-Mar-02	1278	90	1.1	0.5
Meadowbank	6-Mar-02	1279	795	1058.1	-
Meadowbank	6-Mar-02	1280	597	491.47	31
Meadowbank	6-Mar-02	1281	590	381.5	-
Meadowbank	6-Mar-02	1282	504	270	21
Meadowbank	6-Mar-02	1283	490	236.3	21
Meadowbank	6-Mar-02	1284	651	514.2	28
Derwent	6-Mar-02	1285	411	120	14
Derwent	6-Mar-02	1286	441	172.7	23
Derwent	6-Mar-02	1287	329	68	15
Derwent	6-Mar-02	1288	90	0.8	-
Derwent	7-Mar-02	1289	300	50.6	12
Derwent	7-Mar-02	1290	382	98.4	16
Meadowbank	7-Mar-02	1291	545	337.1	30
Meadowbank	7-Mar-02	1292	396	1165	27
Derwent	7-Mar-02	1293	334	57.7	12
Meadowbank	7-Mar-02	1294	510	243.9	-
Meadowbank	7-Mar-02	1295	450	175.1	17
Derwent	7-Mar-02	1296	112	1.8	0.5
Derwent	8-Mar-02	1262	630	561.7	35
Meadowbank	8-Mar-02	1263	678	692.1	36
Meadowbank	8-Mar-02	1264	437	144.9	17
Derwent	8-Mar-02	1265	501	235.4	25
Derwent	8-Mar-02	1266	314	55.3	10
Derwent	8-Mar-02	1267	727	862.4	27
Derwent	8-Mar-02	1268	320	60.6	-
Derwent	8-Mar-02	1269	216	16.1	-
Derwent	8-Mar-02	1270	231	19.3	9
Derwent	8-Mar-02	1271	713	831.2	27
Derwent	7-Feb-02	886	238	20.8	7
Derwent	7-Feb-02	887	401	128.5	14
Derwent	7-Feb-02	888	275	36.6	-
Derwent	7-Feb-02	889	84	0.78	-
Derwent	7-Feb-02	890	230	20.13	5
Derwent	7-Feb-02	891	355	83.5	10
Derwent	7-Feb-02	892	300	54.1	10
Derwent	7-Feb-02	893	310	57.8	11
Derwent	7-Feb-02	894	260	27.2	9
Derwent	7-Feb-02	895	177	88.3	7
Derwent	7-Feb-02	896	249	26.1	9
Derwent	7-Feb-02	897	257	25.9	8
Derwent	7-Feb-02	898	271	36.4	9
Meadowbank	8-Feb-02	899	617	443.2	25
Meadowbank	8-Feb-02	900	498	282	20
Meadowbank	8-Feb-02	901	335	57.9	9
Meadowbank	8-Feb-02	902	633	512.9	22

2001/2002 'Silver' Eel Catch Data

Eel No.	Length (mm)	Weight (g)	Years in Freshwater
1	860	1420	25
2	715	725	25
3	870	1585	25
4	738	890	-
5	812	1235	26
6	935	1895	-
7	774	1095	22
8	710	715	24
9	685	725	22
10	725	865	19
11	785	1085	20
12	640	680	19
13	762	1135	15
14	770	765	37
15	750	815	17
16	792	1055	28
17	760	1080	18
18	900	1610	28
19	771	1020	44
20	882	1625	25
21	940	2035	28
22	925	1790	-
23	785	1290	26
24	785	1030	27
25	678	690	23
26	780	1275	-
27	822	1185	24
28	690	680	23
29	780	970	37
30	670	735	20
31	850	1345	30
32	775	990	19
33	840	955	-
34	882	1525	26
35	754	930	27
36	750	1020	26
37	840	1245	20
38	730	770	19
39	803	950	36
40	662	580	20
41	690	735	19
42	656	645	14
43	864	1465	50
44	632	580	11
45	749	1040	26
46	779	1275	-
47	669	650	11
48	795	1120	29
49	753	1115	-
50	753	895	18
51	834	1450	50
52	700	705	15
53	711	600	13
54	690	740	19
55	908	1430	12
56	770	970	24
57	851	1510	22
58	713	800	17
59	800	1065	34
60	785	1070	26
61	980	2040	30
62	930	1505	22
63	846	1615	25
64	851	1350	33
65	803	1065	21
66	712	690	-
67	840	1210	31
68	1005	2435	26

Analysis of Variance Results

Derwent River / Lake Meadowbank CPUE (2000/2001)

N:	34
Multiple R:	0.229
Squared multiple R:	0.053

Analysis of Variance

Source	Sum-of-squares	df	Mean-square	F-ratio	P
Derwent System	0.502	1	0.502	1.779	0.192
Error	9.041	32	0.283		

Least squares means

Location	LS Mean	SE	N
Derwent River	0.798	0.129	17
Lake Meadowbank	0.555	0.129	17

Derwent River / Lake Meadowbank CPUE (2001/2002)

N:	30
Multiple R:	0.442
Squared multiple R:	0.196

Analysis of Variance

Source	Sum-of-squares	df	Mean-square	F-ratio	P
Derwent System	1.183	1	1.189	6.817	0.014
Error	4.861	28	0.174		

Least squares means

Location	LS Mean	SE	N
Derwent River	0.806	0.108	15
Lake Meadowbank	0.408	0.108	15

North Esk / Lake Trevallyn CPUE (2001/2002)

N:	44
Multiple R:	0.749
Squared multiple R:	0.562

Analysis of Variance

Source	Sum-of-squares	df	Mean-square	F-ratio	P
North Esk / Lake Trevallyn	13.228	1	13.228	53.79	0
Error	10.328	42	0.246		

Least squares means

Location	LS Mean	SE	N
Derwent River	1.371	0.106	22
Lake Meadowbank	0.275	0.106	22

T-Test Results

T-Test: Difference in mean age between the Derwent River and Lake Meadowbank (2000/2001)		
	Derwent River 2000/2001	*Lake Meadowbank 2000/2001*
Mean	25.3776435	21.60137457
Variance	68.62361988	77.10951535
Observations	331	291
Hypothesized Mean Difference	0	
df	599	
t Stat	5.494806978	
P(T<=t) one-tail	2.89549E-08	
t Critical one-tail	1.647401859	
P(T<=t) two-tail	5.79097E-08	
t Critical two-tail	1.963931027	

T-Test: Difference in mean age between the Derwent River and Lake Meadowbank (2001/2002)		
	Derwent River 2001/2002	*Lake Meadowbank 2001/2002*
Mean	13.79259259	17.4893617
Variance	61.16500069	53.58024316
Observations	270	141
Hypothesized Mean Difference	0	
df	301	
t Stat	-4.746713784	
P(T<=t) one-tail	1.60061E-06	
t Critical one-tail	1.649932528	
P(T<=t) two-tail	3.20122E-06	
t Critical two-tail	1.967878234	

T-Test: Inter-annual variation in mean age within the Derwent River (2000/2001)		
	Derwent River 2000/2001	*Derwent River 2001/2002*
Mean	25.3776435	13.79259259
Variance	68.62361988	61.16500069
Observations	331	270
Hypothesized Mean Difference	0	
df	586	
t Stat	17.58828783	
P(T<=t) one-tail	3.21043E-56	
t Critical one-tail	1.647458703	
P(T<=t) two-tail	6.42086E-56	
t Critical two-tail	1.964021976	

T-Test: Inter-annual variation in mean age within Lake Meadowbank (2000/2001)		
	Lake Meadowbank 2000/2001	*Lake Meadowbank 2001/2002*
Mean	21.60137457	17.4893617
Variance	77.10951535	53.58024316
Observations	291	141
Hypothesized Mean Difference	0	
df	327	
t Stat	5.120122746	
P(T<=t) one-tail	2.61171E-07	
t Critical one-tail	1.649527803	
P(T<=t) two-tail	5.22343E-07	
t Critical two-tail	1.967246135	

T-Test: Difference in mean age between the North Esk and Lake Trevallyn (2001/2002		
	North Esk 2001/2002	*Lake Trevallyn 2001/2002*
Mean	18.36128049	16.00714286
Variance	47.75171988	54.03591984
Observations	656	140
Hypothesized Mean Difference	0	
df	195	
t Stat	3.475662551	
P(T<=t) one-tail	0.000314024	
t Critical one-tail	1.652706487	
P(T<=t) two-tail	0.000628048	
t Critical two-tail	1.972202881	