**Title of project:**

Kanakana Harvest Mātauranga: Potential Tools to Monitor Population Trends on the Waikawa River, Southland/Murihiku (A Scoping Project)

**Contract Number: 10-RF-02**

**Principal Investigator Jane Kitson**

**Organisation: Te Ao Mārama Inc.**

**2012**

FINAL TECHNICAL REPORT FOR NGĀ PAE O TE MĀRAMATANGA

Contract number: 10-RF-02

Principal Investigator: Dr Jane Kitson

TE AO MĀRAMA INCORPORATED

# KANAKANA HARVEST MĀTAURANGA: POTENTIAL TOOLS TO MONITOR POPULATION TRENDS ON THE WAIKAWA RIVER, SOUTHLAND/MURIHIKU (A SCOPING PROJECT)

Funded $59,637 | Funding period 1 July 2010 to 30 June 2011

Date: 1 February 2012

# Table of Contents

# Executive Summary

Kanakana/lamprey (*Geotria australis*) is an important traditional Māori fishery, with harvesting still practiced in a number of locations on both North and South islands.

There is no accurate estimate of kanakana/lamprey abundance. However, even with sparse information there is a general perception that kanakana populations have declined. Concern over kanakana numbers caused initiation of monitoring, in the form of visual counts at falls on the Waikawa River, based on harvest mātauranga and performed by an experienced kanakana harvester.

Population monitoring based on traditional ecological knowledge can be a practical and valuable tool for kaitiakitanga. However, we do not know the relationship between the counts at the falls and the actual number of kanakana migrating up the Waikawa River. To assess this relationship we calibrated the nightly counts at The Falls against the actual number of kanakana at a nearby point within the river. To obtain an actual count we used a Dual-Frequency Identification Sonar (DIDSON) acoustic camera, which can enumerate fish in low visibility river conditions and at night with a high degree of accuracy.

The DIDSON has been found to be effective at enumerating migrating adult lamprey abundance. The visual counts of lamprey on rocks correlates with those of the DIDSON. However, more study is required to determine if both methods are effective during higher river flows. Further consideration should be given to stratifying observation periods based on when mātauranga predicts large runs to enable more intensive sampling over a shorter period, and less sampling over periods when mātauranga predicts small runs.

An evaluation of additional kanakana harvest methods was also conducted to investigate additional tools in the monitoring and management of kanakana. The main methods of lamprey harvest are manual collection, nets, weirs, and simple traps. Of these methods the most promising for use as a population monitoring tool would be visual counts (hand picking off rocks ) and use of a hinaki/fyke nets. We therefore suggest further researching the use of nets to determine how effective these traditional methods would be as indices of kanakana abundance.

There is a lack of quantified information on the size of past kanakana runs and abundance. Without this we lack the ability to track population changes and expected interannual variability. Anecdotal and historic information represents the only data sources available to fill these information gaps, therefore social and historical research methods should be used. Mātauranga and historical research would greatly add to the knowledge and management of this poorly understood but culturally important fishery.

Within the Waikawa catchment there is little information on the distribution of the various kanakana life stages, their habitat requirements and the associated threats. This needs to be addressed to assist and prioritise this fishery's management. This is particularly relevant since the occurrence of mass mortalities of migrating adults in Southland in Sept/October 2011.

## Acknowledgements

This project was the combined effort of a number of people, including the researchers: Jane Kitson; Vincent Leith (Wakawa whānau), Dean Whaanga (Te Ao Mārama Inc), Joe Hay and Aaron Quarterman (Cawthron Institute), Steven Ledington (Environment Southland), and Craig Pauling (Te Rūnanga o Ngāi Tahu). The research was also provided support by Aaron Leith (Wakawa whānau), Rachael Webster, Greg Larkin and staff at Environment Southland, Eric Goodwin (Cawthron Institute) and Zane Moss from Fish & Game New Zealand: Southland Region.

We wish to acknowledge the support of the Waikawa whānau and Awarua Rūnanga; and the financial and support in kind from Te Rūnanga o Ngāi Tahu and Environment Southland.

DIDSON training was funded by Envirolink (FRST).

This research was primarily funded by Ngā Pae o Te Māramatanga.

NGĀ PAE O TE MĀRAMATANGA

# Introduction

## Background to Kanakana:

Lampreys along with hagfish are the only surviving members of the most primitive vertebrates, the jawless fish (Agnathans). Lampreys are sometimes called lamprey eels, but it has only a distant relationship with eels, which are part of the jawed, bony fish (class Osteichthyes). Currently the extant lampreys (Petromyzontiformes) are comprised of three families, six genera and 41 species.[1]

New Zealand's only lamprey species is *Geotria australis* and it is also found in western and eastern Australia, Tasmania and southern South America.[2] *Geotria australis* are widely distributed in New Zealand (Figure 1) including the Chatham Islands and Stewart Island.[3]

Kanakana and piharau are the most commonly used names for lamprey in the South Island and North Island, respectively[4]. However it is known by a variety of other names including: pia, pipiharau, pihapiharau, puhikorokoro, korokoro, nganangana[5] and nainai,[6] ute, and waituere.[7] Different life stages are also recognized by different Māori names.[8] Kanakana is the name used in Murihiku, consequently it will be the main name used in this report (except when it is more appropriate to use a different dialect).

Kanakana are anadromous, with the adults migrating from the ocean and into freshwater to spawn, and the juveniles returning to the ocean before repeating the journey. They are harvested at the beginning of this upstream migration. Runs have been noted to coincide with receding floods and possibly the darker phases of the moon[9] and are restricted by large floods.[10] Concentrated migratory movements ('runs') have also been recorded with water temperatures between 12 – 14.5°C, falling rain and extensive cloud cover. [11]

Kanakana have distinct life stages: with a freshwater filter-feeding larvae that metamorphose into miniature adults that return to the sea. In the ocean the adults are parasitic on other fish (and possibly whales) until it reaches a sufficient size before migrating up rivers where it spawns (Figure 2, Figure 3).

Early taxonomists assumed the distinct life stages to be different species.[12]

As the adult kanakana spend time in freshwater they change appearance from brilliant silver/blue with two long turquoise stripes into gunmetal grey and then to drab muddy brown. As the male fish becomes sexually mature it develops a baggy pouch below the head and a bulbous snout (Figure

---

[1] Allen *et al.* (2003)
[2] McDowall (1990); McDowall (2000)
[3] McDowall, (1990); Chadderton (1990)
[4] Beattie (1920)
[5] Best (1929)
[6] Rewi (2009)
[7] Strickland (1990); Best (1929)
[8] Beattie (1920), Strickland (1990)
[9] Jellyman *et al.* 2009
[10] Jellyman *et al.* 2002
[11] Potter *et al.* (1986) cited in James (2008)
[12] Dendy & Olliver (1901); Maskell ( 1929)

3).[13] It takes between 12-15 months for the returning non-feeding pre-reproductive adult to become sexually mature.[14]

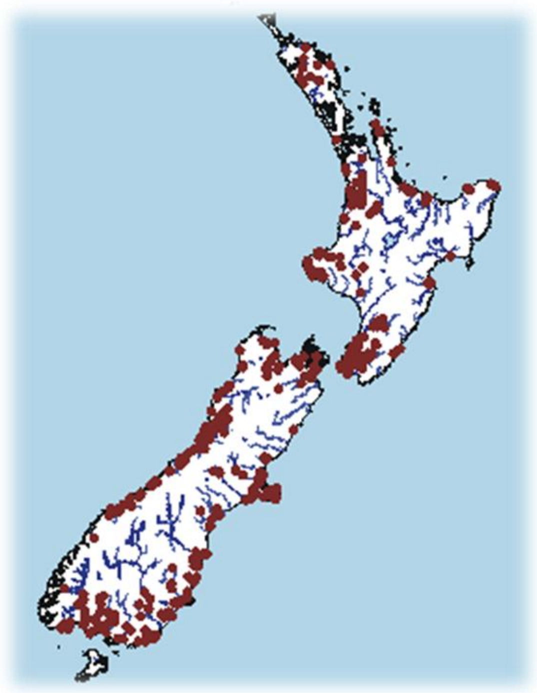


**Figure 1: Distribution of where lamprey captured by fishery scientists in New Zealand. From the NIWA Atlas of NZ Freshwater Fishes[15]**

[13] Glova (1995)
[14] Maskell (1929); Glova (1995)
[15] NIWA website http://www.niwa.co.nz/our-science/freshwater/tools/fishatlas/species/lamprey

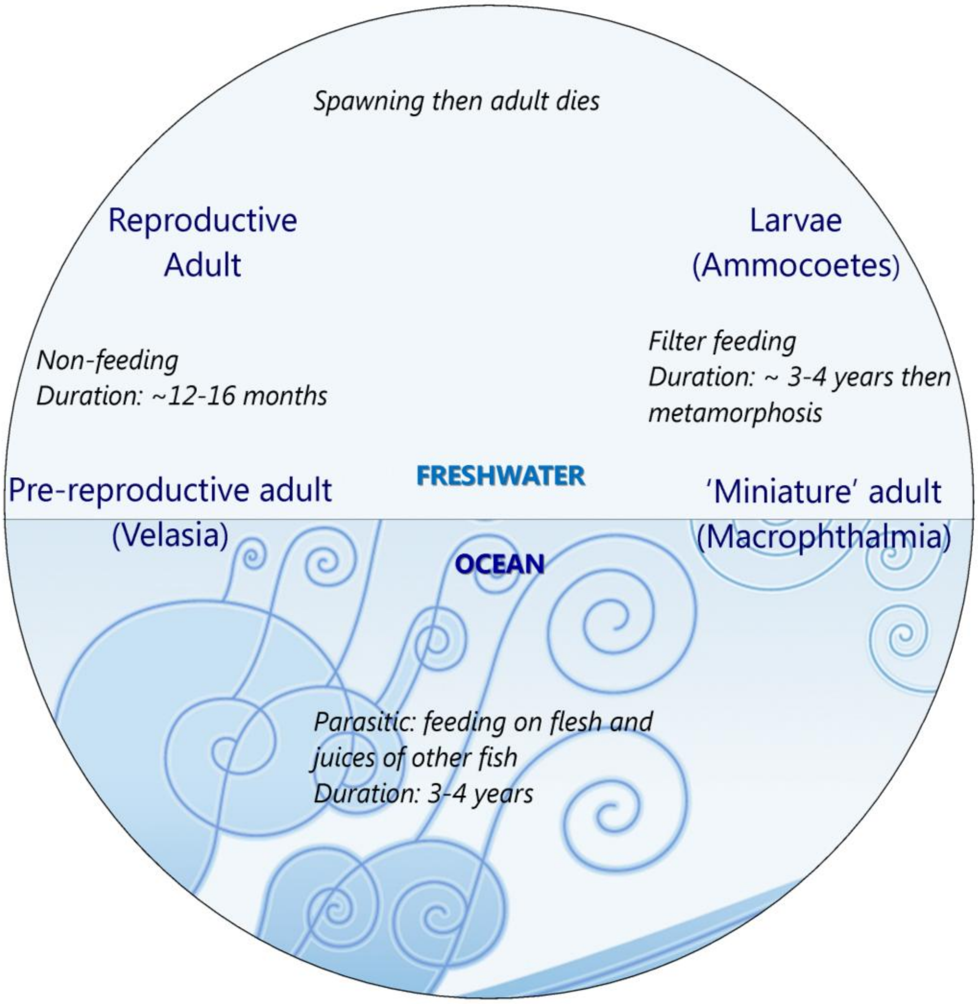
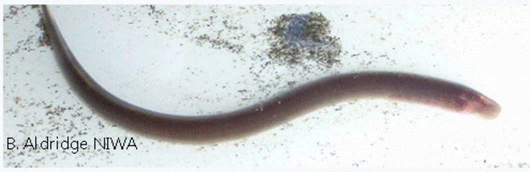
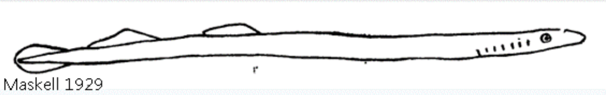



**Figure 2: Lifecycle of *Geotria australis* (Adapted from James 2008)**

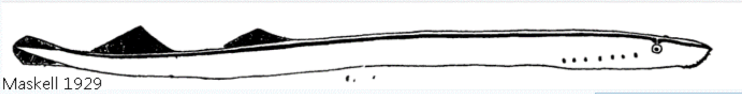




**Life stage:** Larvae (Ammocoetes)
**Size:** <100mm
**Habitat requirements:** Freshwater. Buried in fine sediments (between 3-9 cm) during the day in shady runs. Metamorphosing larvae typically found in downstream reaches with coarser substrates and higher flows.





**Life stage:** 'Miniature' adult (Macropthalmia)
**Size:** 90-100 mm
**Habitat requirements:** migrate to sea between July and August.





**Life stage:** Pre–reproductive adult (Velasia)
**Size:** 450-750 mm
**Habitat requirements:** Enter freshwater as early as April and as late as December . Stage that is harvested.

**Life stage:** Reproductive adult
**Habitat requirements: Take** refuge during the day—under boulders, beneath overhung banks or other instream cover. Spawning: small, shady, hard bottomed streams. Spawning has never been observed.

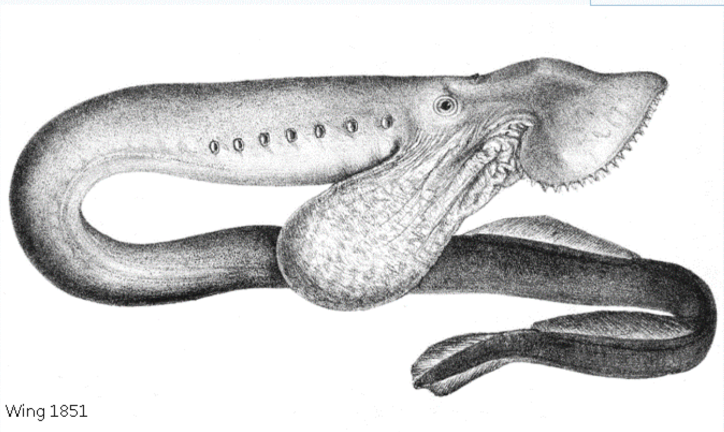




**Figure 3: The different life stages of *Geotria australis* (From James 2008, McDowall 2000, Jellyman and Glova 2002)**

## Kanakana Fishery

Kanakana harvest occurs, or has occurred throughout New Zealand. Fisheries have been recorded in the North Island on the Mōkau, Waitotara, Patea, Waitara, Whanganui, Waipa and Ohinemuri rivers. Harvests occurred across coastal Canterbury (including Ōrari, Ōpihi, Waihao, Temuka and Ohapi rivers and perhaps Waimakariri River), and in Otago and Southland on the Mataura, Clutha/Mata-Au, the upper Taieri, Catlins River, Waikawa, Silverstream, Pomahaka and tributaries of the Waiau River.[16] There are likely to be other places where kanakana have been harvested, but not reported to researchers. Some fishery scientists have noted reluctance by some Māori to discuss their harvest methods and sites to them.[17] Perhaps this signifies the importance of kanakana that kaitaki choose not to share information on their specific fishery to outsiders.

The timing of the kanakana harvest has been documented as starting as early as April and extending as late as December.[18] It appears that the harvest starts earlier in the North Island than the South Island.[19] The main piharau season in the Whanganui River has been recorded as May to July, and sometimes August.[20] Young (1998) noted September being right at the end of the piharau season.

In Southland the main kanakana season extends from August to November.[21]

In Southland the long-term tradition of kanakana harvest still continues at falls on the Mataura River (Te-Au-Nui) and the Waikawa River (Māngai Piri/Niagara Falls and other falls)[22]

This study focuses on the harvests on the Waikawa River. On these falls fish are taken at night by hand off the rocks.

*Keane (2010) recites the following whakatauki - it indicates the timing of the kanakana harvest*

*Ka kitea a Matariki, ka rere te korokoro'*

*(When matariki is seen, the lamprey migrate)*

The manawhenua association with kanakana, Māngai Piri and the wider Waikawa area led to the establishment of a statutory acknowledgement for the Te Ara a Kiwa/Foveaux Strait Coastal Marine Area and a nohoanga site adjacent to the falls, as part of the cultural redress provisions of Ngāi Tahu's historical Treaty Settlement signed with the Crown in 1997. Additionally in October 2008, the Minister of Fisheries established the Waikawa/Tumu Toka mātaitai reserve lodged by Awarua Runanga over four areas within the Waikawa Harbour, Porpoise Bay, Curio Bay and the lower portion of the Waikawa River up to 1 km above the bridge at Māngai Piri and which extends over the 'Top Falls' upstream.

[16] Beattie (1920); Phillipps & Hodgkinson (1922); Best (1929); Maskell (1929); Parrott (1960); Firth (1972); McDowall (1990); Todd (1992); Anderson (1998); McDowall (2011)
[17] Todd (1992); Kelso (1996)
[18] Maskell (1929); Jellyman *et al.* (2009)
[19] Best (1934); Downes (1918); Phillipps & Hodgkinson (1922); Maskell (1929); Coutts (1969); Firth (1972); Anderson (1986); Young (1998)
[20] Downes (1918); Phillipps & Hodgkinson (1922); Firth (1972)
[21] Beattie (1920); Maskell (1929); Parrott (1960); Firth (1972); Dacker (1994)
[22] Beattie (1920); Anderson (1986); Dacker (1990); McDowall (1990); Ngāi Tahu Claims Settlement Act 1998 schedule 42; Todd (1992); Jellyman *et al.* (2009); Tipene & Jellyman (2002); Te Ao Mārama Inc and Waikawa Whānau (2010)

Commercial harvesting of kanakana is prohibited through the Ngāi Tahu Claims Settlement Act 1998.[23]

## Rationale of research

The term Traditional Ecological Knowledge (TEK) describes the adaptive and dynamic body of knowledge that guides customary uses of wildlife. It is acquired through direct experience and observation and is handed down through the generations.[24] The ability of TEK to provide valuable information on species ecology, distribution and management has been recognized.[25]

An Important component of TEK is knowledge about past and current use of the environment and in particular, an understanding of variation in harvest rates and prey abundance.[26]Statistics from harvest levels can be useful for biological research purposes[27] and as a way of monitoring resource abundance and the long-term sustainability of the current harvest. [28]

> *"There used to be kanakana all around here – on all the rivers. They used to block the drains they were so plentiful."*
>
> *Rewi Anglem from Hokonui Runanga quoted in Te Karaka (Rewi, 2009)*

Mahinga kai, the use of foods and resources, gathered from freshwater bodies is a corner stone of Ngāi Tahu culture and identity.[29] Mahinga kai binds whanau, hapū and community together, providing a sense of identity that also serves as the vehicle for the intergenerational transmission of values and knowledge. Kanakana is an important mahinga kai species for Papatipu Rūnanga and whānau in Murihiku.

There is little data on the abundance of this species and nor is there a useful estimate of kanakana/lamprey abundance.[30] This is partly due to the cryptic nocturnal nature of the species, lack of detection of larvae (ammocoetes) and survey limitations of the New Zealand Freshwater Fisheries Database (NZFFD) to detect lamprey.[31]

Threats to kanakana abundance include installation of large barriers to migrations such as hydro-dams, and turbines which might inhibit juvenile's seaward migration.[32] Adults' negotiation of large barriers may also increase the risk of predation by birds and affect the fitness of individuals. Mass mortalities of kanakana occurred in September/October 2011 in Southland with some individuals identified as infected by the presence of a bacterium, *Aeromonas salmonicida* – an unwanted and notifiable organism under the Biosecurity Act 1993 and a new organism under the HSNO Act 1996.

---

[23] Section 306
[24] Stevenson (1996); Huntington (1998); Berkes (1999); Wenzel (1999); Usher (2000)
[25] Freeman (1992); Ferguson & Messier (1997); Ferguson *et al.* (1998); Gunn *et al.* (1998); Wenzel (1999); Moller *et al.* (2004)
[26] Usher (2000)
[27] Usher & Wenzel (1987)
[28] Kitson (2004); (Moller *et al.(* 2004); Kusabs & Quinn (2009)
[29] Tipa (2011)
[30] James (2008); Allibone *et al.*(2010)
[31] James (2008)
[32] James (2008)

Although the bacterium was only identified in 2011 in New Zealand (occurring in kanakana in Murihiku and two rainbow trout in Otago), kanakana harvesters from Southland and South Canterbury commented on seeing the disease's associated lesions for at least 8—9 years on an occasional basis and not necessarily associated with mass mortalities.[33] The mortalities are thought to be associated to increased stress to the population, one possible cause being deteriorating water quality.[34]

Even with sparse information there is a general and firmly-held perception that the abundance of kanakana has declined.[35] Therefore, even with the paucity of data, the New Zealand Threat Classification System classes lamprey as declining.[36] Concern over kanakana numbers initiated monitoring, in the form of visual counts at Māngai Piri/Niagara Falls on the Waikawa River, based on harvest mātauranga and performed by an experienced kanakana harvester.

However, we do not know the relationship between the counts at the falls and the actual number of kanakana swimming up the Waikawa River. To determine this we intend to calibrate the nightly counts at the falls against the actual number of kanakana at a nearby point within the River. In order to do this we used a Dual-frequency Identification Sonar (DIDSON) acoustic camera, which can enumerate fish in low visibility river conditions and at night with a high degree of precision.

The DIDSON has been used elsewhere in New Zealand to enumerate migrating salmon and other fish and behaviors at barriers and flood gates.[37] However, the DIDSON has not been used to enumerate kanakana in New Zealand before but has been used to observe Arctic lamprey (*Lampetra camtschatica*) runs in Alaska.[38] Our research scopes this technology's capability to enumerate kanakana, how well it can distinguish kanakana from tuna/eel, and whether it is capable of distinguishing individual kanakana within a large group and within the bed morphology of the Waikawa River.

This research also aims to identify other traditional harvest methods that could be explored as possible population monitoring tools.

## Objectives of the Research

The over arching objective of this research is to determine effective, practical and reliable kanakana population monitoring methods on the Waikawa River based on mātauranga.

The initial steps to achieve this overall objective are:

1. To apply and test (Dual-Frequency Identification Sonar) DIDSON technology as a new method to determine kanakana abundance in New Zealand rivers.

---

[33] R. Puentener; M. Holmes, V. Leith November 2011 pers. comm.
[34] Van Eyndhoven (2011)
[35] Best (1941); Jellyman & Tipene (2001); Ministry of Fisheries (2007); (Jellyman *et al.* (2009); Rewi (2009); McDowall (2011)
[36] Allibone *et al.* (2010)
[37] Maxwell & Gove (2004); Baumgartner *et al.* (2006); Holmes *et al.* (2006); Doehring *et al.* (2011)
[38] Horne-Brine (2007); Contiz (2011); Luzier *et al.* (2011)

2. To determine the correlation between counts at a kanakana harvest site (a method akin to traditional harvest methods on the Waikawa River) and the counts of kanakana using DIDSON technology over a range of environmental conditions.
3. Document mātauranga to identify other possible traditional harvest methods that could also be explored as possible population monitoring tools.

# Methods

## DIDSON experiment:

The Dual-Frequency Identification Sonar (DIDSON) uses sound to produce near video-quality images of fish at ranges up to 15 m in high-frequency mode (1.8 MHz) and up to 40 m in low-frequency mode (1.2 MHz). The system is operated via a laptop computer to monitor and store images. Data is collected at about 1.5 GB per hour.

The experiment site is about 63 km S73ºE from Invercargill (approximately an 80 km drive) downstream from the Top Falls (Figure 5). The DIDSON was located at a site on the riverbed where bed morphology did not obscure the view of migrating kanakana, and in a place where the whole width of the channel could be monitored. Such a site was determined as close as possible to the falls, so that the number of fish in the water column would most probably correlate with the number of fish counted on the falls.

The only suitable site was 17m wide which meant the DIDSON was run at low definition mode (1.1 MHz) rather than high definition mode (1.8 MHz), and produced a lower quality image. At low definition mode we couldn't distinguish between kanakana and small eels, in a release trial conducted before the main experiment started. However, local knowledge suggested that eels of this size would rarely be seen going upstream in any numbers at this time of year.

The DIDSON was operated from 1509 hrs on the 2nd September 2010 until 0923 hrs on the 13th September 2010, recording at 8 frames per second. Visual counts on the top falls occurred on seven evenings between the 2nd September 2010 and the 10th September 2010, between the hours of 2100 and 0100, by a single observer (see Appendix A).

Water level and water temperature were measured every ten minutes immediately downstream from the DIDSON site using two Tru-track water level and water temperature recorders. Water temperature, turbidity and conductivity were also measured downstream every 20 minutes using a Manta multi-probe logger. However, after analysis the range in both turbidity and conductivity was determined to be insufficient for use in modelling so was discarded. The downstream Tru-track water level and water temperature measurements provided the widest range and best set of measures to model as environmental predictors.

### Data analysis

The relationship between total DIDSON counts per night and those made by the bank-side observer was derived using a simple correlation.

To explore potential relationships between the DIDSON counts and various environmental variables measured during the survey period we initially intended to use Poisson regression. However, prior to fitting a model we explored the data to look for potential relationships between the environmental data and the counts, and between environmental variables (i.e. collinearity). Through this process we reduced the number of potential explanatory variables to five. We then explored the data further using a range of visual techniques, following the protocol described in Zuur *et al.* (2010), to check for outliers and compliance with other potential model assumptions.

Through this data exploration, it became clear that the relationships between kanakana counts and some of the environmental variables were not simple linear relationships. Consequently, we opted to fit a generalised additive model (GAM) to allow for these non-linear relationships. Upon fitting an initial model as a Poisson GAM, we detected an issue with overdispersion, and so corrected for this using a quasi-GAM model where the standard errors were adjusted by a dispersion parameter.

The models were fitted to the night time counts only (1700-0800 hrs), since the vast majority of movement took place at night (only 8 kanakana, from a total of 1230, were counted outside these hours).

We followed an iterative process of fitting models with various combinations of our potential predictor variables (i.e. the environmental variables selected in the data exploration process above), checking for statistical significance and compliance with model assumptions.

The final GAM was fitted with smoother functions of three predictor variables: water level, hours after midnight (i.e. negative for hours before midnight, positive for hours after), and water temperature.

**Figure 4: DIDSON set up at site downstream from the Top Falls (DIDSON in insert). The wire mesh directly downstream from the DIDSON ensures that kanakana swim within the operating field of view.**


**Figure 5: Location of study site, Waikawa River Southland. Marked are Mangai Piri (Red), DIDSON experiment site (Yellow) and Top Falls (Pink).**

## Documentation of other kanakana harvest methods

After discussions with the Waikawa whānau on the most appropriate methodology it was determined the best method was first to conduct a literature review. The methods were categorized by type and where this method was recorded as being used. This information was then sent to be verified and amended by members of the Waikawa whānau.

# Results

## Comparison between DIDSON and observer counts

The total DIDSON counts per night and those made by the observer were strongly correlated (N=7, correlation co-efficient 0.87, Figure 6). One evening of high observer counts on the top falls and the DIDSON strongly influenced this count. However the two types of counts were still shown to correlate when this count was removed (though the relationship was weaker, N=6, correlation co-efficient 0.57).

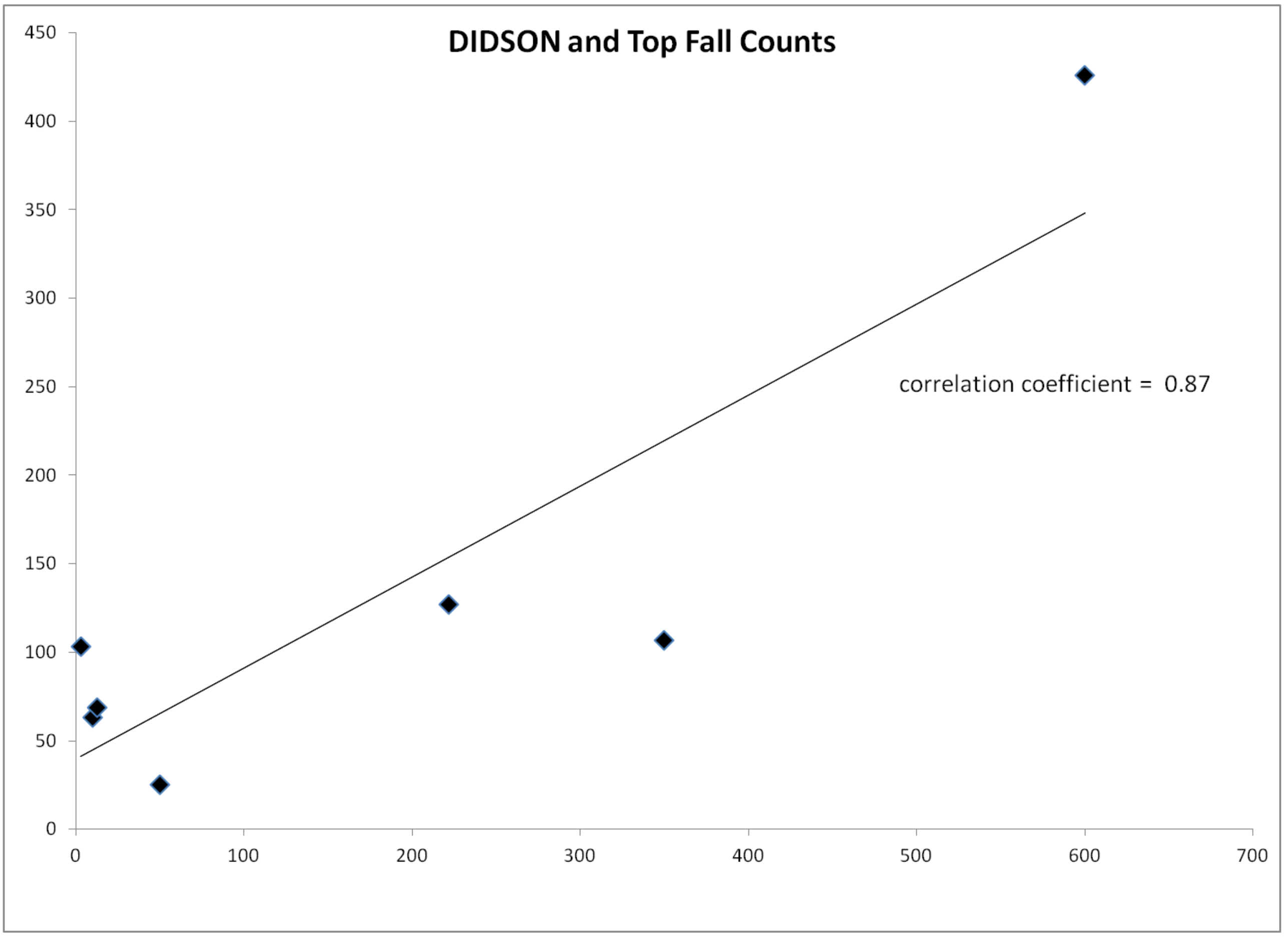



**Figure 6: Relationship between the observer counts and DIDSON counts between 2nd and 10th September 2010.**

Higher river flows two days prior to the DIDSON experiment initiated a kanakana heke. This meant we could not assess the DIDSON capacity to enumerate kanakana at high numbers (i.e. over 600). It is also unknown if the DIDSON counts and visual counts at the top falls would correlate during an event where there are large numbers of kanakana.

The earlier start of the heke meant we had to exclude the first night's visual counts on the top fall because of the likelihood that kanakana had gone past the DIDSON location before it was operating but were still waiting to climb over the top falls (on the 2nd Sept 1,000 kanakana were counted at the top falls but only 260 were recorded by the DIDSON). This limited the sample size available to correlate the two counts.

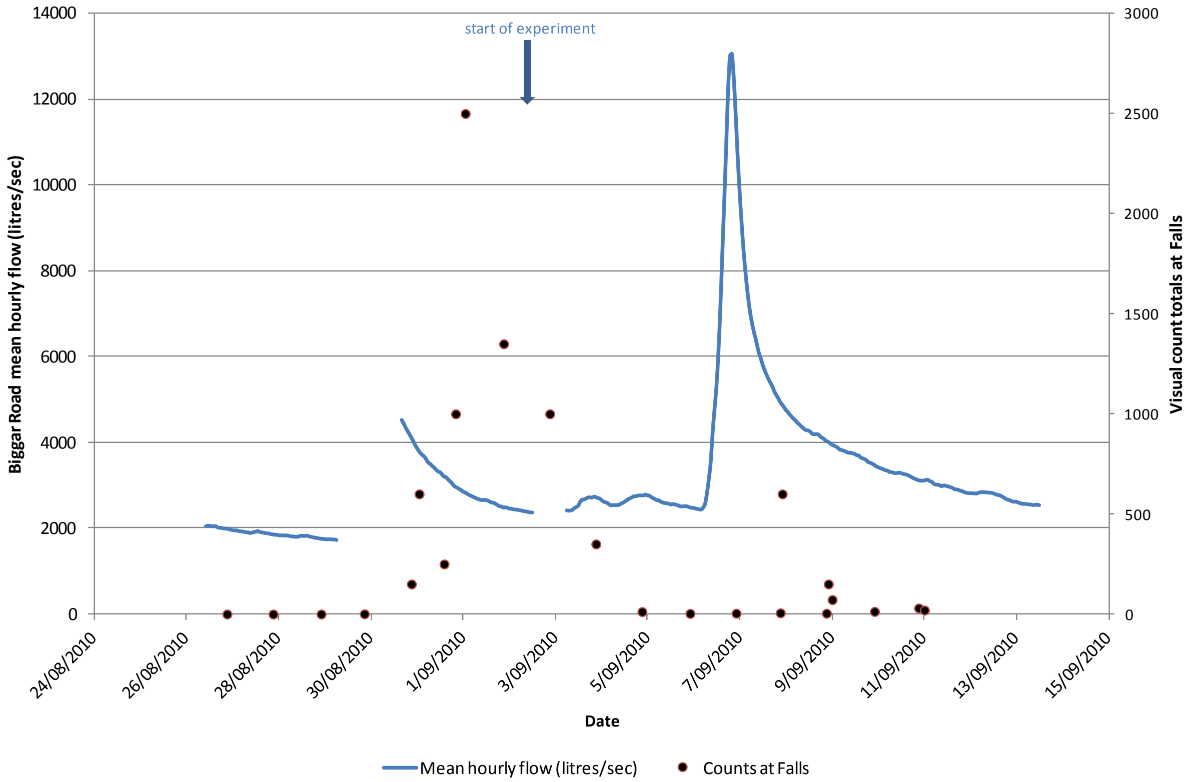



**Figure 7: Mean hourly flow recorded upstream at Biggar Road and visual counts of kanakana at both sets of falls (counts conducted as part of baseline cultural monitoring), before and during the DIDSON experiment.**

## Relationship of DIDSON counts and environmental variables

In the final generalised additive model (GAM) the fit of each model component was significant at an alpha level of 0.001 or higher, and overall the model explained 57.3% of the deviance (Figure 8).

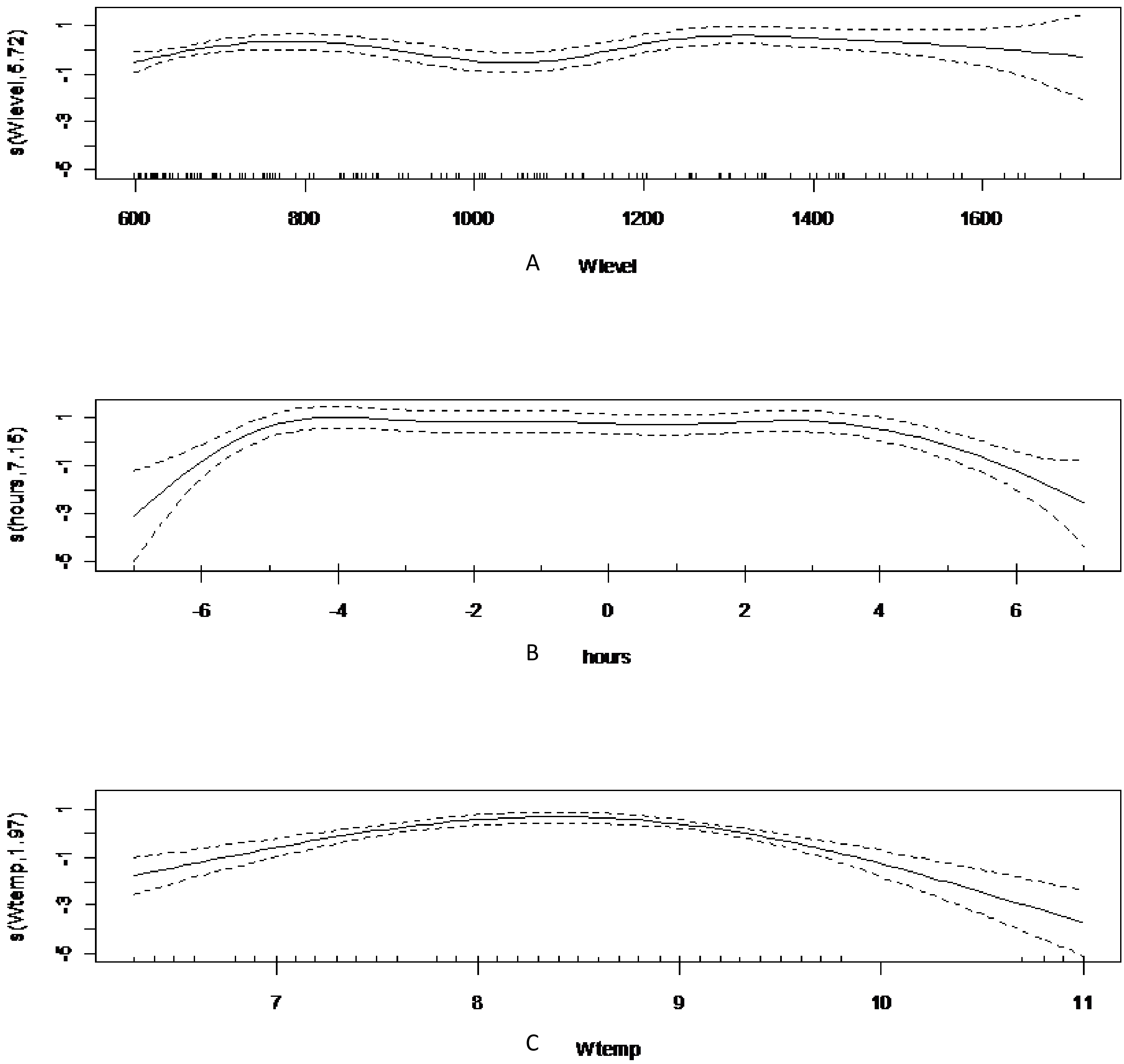



**Figure 8: Partial contribution to the overall Quasi-Poisson GAM model a) Water Level, b) Hours after midnight, c) Water Temperature.**

## Kanakana harvest methods

Four main categories of harvest methods were found in the literature: Manual collection, nets, weirs, and simple traps. Table 1 describes each category and subcategories in more detail.

**Table 1: Lamprey harvest methods in New Zealand.**

| Method | Sites/areas recorded where method used | References | Considerations for lamprey population monitoring |
|---|---|---|---|
| **Manual collection** | | | |
| Hand picking lamprey off falls (rock outcrops) at night using a light. | Waikawa and Mataura Falls and Pomahaka River (Opurere Falls; Southland), Silverstream, Serpentine Area of the upper Taieri, Clutha, Catlins Rivers (Otago), the Waihao River (Canterbury) and in Taranaki. | Downes 1918; Beattie 1920; Beattie 1954 (cited in McDowall 2011); McDowall 1990; Anderson 1998; Jellyman & Tipene 2001; Tipene & Jellyman 2002; Keane 2010; Waikawa whanau November 2011 pers. comm; Taranaki Regional Council nd. | Requires barriers for fish to climb over. Method constricted when flows are too high or too low, because fish can bypass or cannot navigate over rocks. |
| **Hook/Rapu method** - Long sticks with an eel hooks at the end are used to gaff the lamprey out of holes in the river banks and debris. | Waikawa and Mataura Rivers (Southland) and in Temuka (Canterbury). | Southland Times 1972; Hall-Jones, 1992; Tipene & Jellyman, 2002; T. Nicholas Feb 2011 pers. comm; M. Holmes August 2011 pers. comm; D. Ryan and K. Bradshaw October 2011 pers. comm. | Too dangerous to use this method during high flows (when fish are aggregating). |
| Poles placed in holes and crevices in rocks along falls and adjacent to the falls and fishers reach out and remove lamprey which are still attached to the face of the falls. | Mataura Falls (Southland). | Beattie 1920 | Only conducted at certain sites. Same considerations as manually hand-picking of rocks. |
| Technique of lowering a man down over the edge of falls on a rope. The rope held the man, often up to his neck in the fast water, while his feet sought a ledge on the falls. | Mataura Falls (Southland). | Anderson 1986 | As above. Practice does not currently occur. |

| Method | Sites/areas recorded where method used | References | Considerations for lamprey population monitoring |
|---|---|---|---|
| **Nets** | | | |
| Hinaki net used by whānau to determine the strength of a run, whether to go out to harvest and as a means of harvesting kanakana. | Waikawa (Southland) | V. Leith, A. Leith Feb 2010 and November2011 pers. comm. | Already been used has a population monitoring tool by Waikawa harvesters. Used extensively by Taranaki harvesters (S. Tampara pers comm. 2010). Efficiency of method dependant on where net sited (because non-feeding migrating adults cannot be baited). Potential mixed success with this method reported (Kelso 1996). |
| Commercial made nets – similar to eel nets – or long fyke nets stretched out from a river bank. | Ellesmere (Canterbury) and Taranaki and possibly elsewhere. | McDowall 1990; Kelso 1996; Taranaki Regional Council nd. | |
| **Weirs** | | | |
| **Utu piharau/ pa kanakana** - Wooden weirs were built during low flows in summer and autumn. Fences extended from the riverbank straight across the river for a set distance. Nets and lamprey pots anchored between gaps and face upstream. The lampreys migrate at the river edge to avoid swift flows found mid-river. Lamprey moving up the river would find their way blocked, so would swim along the front of the wooden weir to find a way through. Extra current though the gaps in the weir, caused by the blocked-off weir, swept the lamprey downstream into the pots as they tried to swim upstream through the gaps (See Figures 9 and 10). | Pa kanakana – Kaiapo, Temuka (Canterbury); Tuturau on the Mataura River (Southland). Utu piharau –at Hiruharama and Pipiriki on the Whanganui River; Kaimanuka, Waitotara River and Waitara (Taranaki). | Downes 1918; Beattie, 1920; Best 1924; Best 1929 (cited in McDowall, 1990); Best 1934; Best 1941; Kelso, 1996; Anderson 1998; Jellyman & Tipene 2001; Taranaki Regional Council nd | Can only be operated in a certain range of flows (when it is too low the weir is out of the water and when the flows are too high the water flows overtop; Kelso 1996). Application requires ability to drive posts into stream bed and rivers which has low sloping banks that become dry in summer/autumn. |

| Method | Sites/areas recorded where method used | References | Considerations for lamprey population monitoring |
|---|---|---|---|
| **Weirs continued** | | | |
| **Pa Tuna/ V-shaped weir for a small stream** - Fences are built out from both banks at opposite points, running down-stream and gradually converging to a point. Two heavy posts are next driven in down-stream from the mouth of the weir, one opposite each angle, to which they are securely braced, and they are also braced to each other. These carry the *poha*, or leading-net.<br>For this type of weir eels are taken going downstream and lampreys going up. The eels are carried downstream by the full force of the current, without chance of escape, and the lampreys going upstream attempt to enter the current between the posts that hold the leading-net and the angle of the *pa-tuna*, the only possible way, and are immediately swept back into the *poha* net by the force of water (See Figures 11 and 12). | Moumahaki Stream (Taranaki), Matahiwi Rapid of the Whanganui River, Waikaretaheke (Hawkes Bay) | Downes 1918 | In high water flows pa-tuna cannot be operated (Downes 1918). |
| **Stone weir/whakaparu piharau** - A coffin shaped weir constructed of stones and lines with ferns or other material. A mat of flax/fern (or sacks) is placed between the walls and is removed at night (or early morning) and the lampreys cloistered in the mat are removed. | Waikerua Stream a tributary of the Waiau River (Southland) Waitara River, Taranaki Region | Best 1934; McDowall 1990; Hayes *et al.* 1992 (informant: Syd Cormack); Kelso 1996; Keane 2010; Taranaki Regional Council nd. | Perhaps would have limitations at high and low flows. Catches reported in Kelso (1996) are relatively low at 30-40 fish per night (compared withup to 200 per night for fyke nets), therefore methodology may underestimate population abundance. |
| The term whakaparu piharau has also been used to describe rocky groynes with gaps in them are built across the river margins and traps placed in the gaps to catch the lamprey as they move upstream | | McDowall 1990 | |

| Method | Sites/areas recorded where method used | References | Considerations for lamprey population monitoring |
|---|---|---|---|
| **Simple traps and other methods** | | | |
| *Paipai* (barriers) made with small branches placed across low shingle rivers. The incoming kanakana would cling to the branches and be picked off. | | Rewi 2009 (informant Rewi Anglem) | High water flows likely to wash traps away. Likely to under-estimate population abundance. |
| *Whakarau*– A large thick mat was manufactured of bracken laced together with flax. The mat was pegged down in a sheltered spot with either a natural or artificial breakwater. Lamprey would shelter and hide within the provided shelter. To harvest the fish the mat would be rolled up. | Wanganui Region; Waipa River at Falls near Otorohanga (Waikato) | Downes 1918; Keane 2010; McDowall, 1990 | |
| *Whakapua, taruke or pae*- a trap made of a bundle of bracken ferns placed within water and catch lamprey seeking shelter. | | Best 1934, Henare 2009[39] | |
| Mauri – charms used on weirs to lure lamprey into traps | | Downes 1918; Taranaki Regional Council nd. | Needs to be used in conjunction with other methods and by appropriately culturally skilled harvesters. |

[39] Note video footage of placing a *pae* can be viewed on http://www.teara.govt.nz/en/te-mahi-kai-food-production-economics/4/3

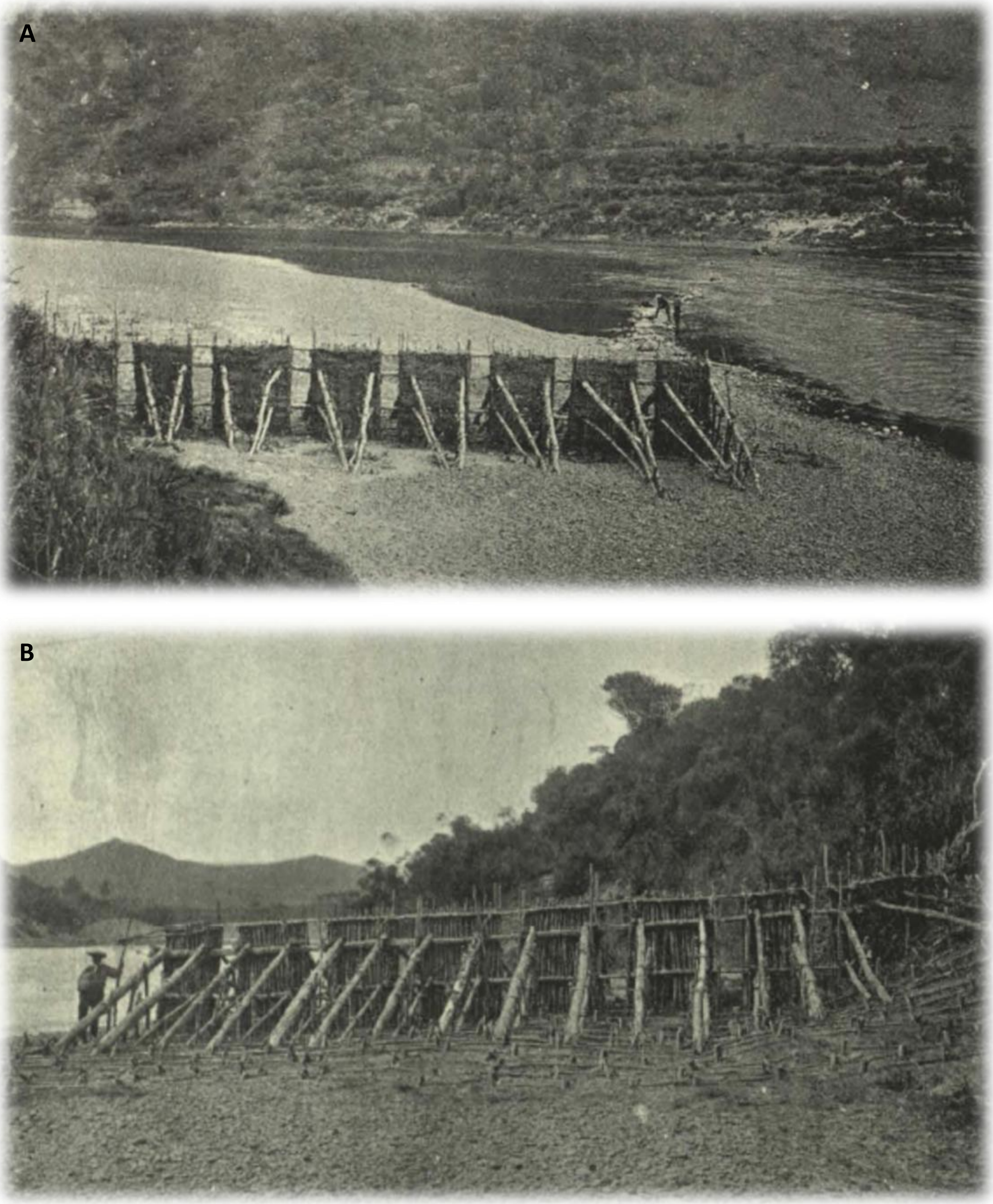



**Figure 9: Utu piharau (lamprey weir) at Parikino, Whanganui River during low water flows A) looking down stream and B) looking upstream (Source Downes 1918, plate XXVII, facing p. 312).**

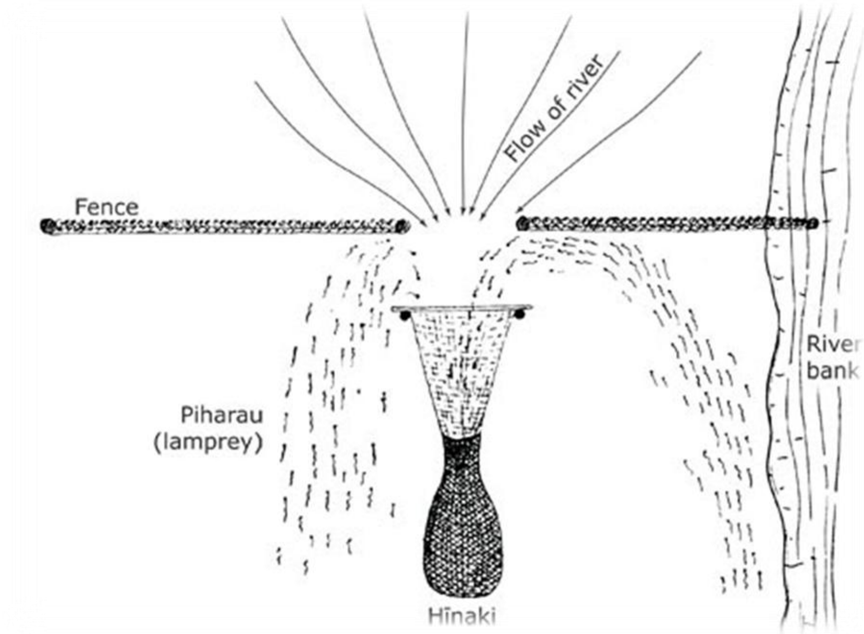



**Figure 10: Utu piharau (Source Best 1929 p. 195).**

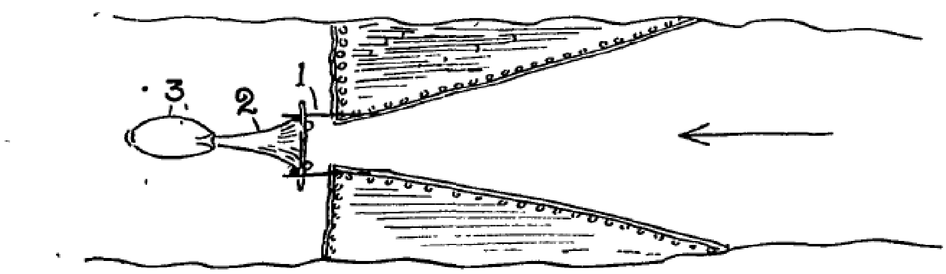



**Figure 11: V-shaped weir. The arrow shows the direction of the current. Shown are the braces (1), poha (2) and hinaki (3). (Source Downes 1918 pg 308)**

**Figure 12: Small pa-tuna V type weir at Ngutuwera, Moumahaki River (Source Downes 1918 plate XIII)**

# Discussion

## DIDSON experiment and visual counts

The DIDSON proved useful to enumerate lamprey numbers over the limited environmental conditions experienced during the experimental period. Other studies (e.g. Moursund *et al.* 2003; Maxwell & Gove 2004; Baumgartner *et al.* 2006; Holmes *et al.* 2006; Han & Uye 2009) have proven the DIDSON is a powerful tool for fish population monitoring. However, for kanakana monitoring, the appropriateness of the DIDSON would be determined by the suitability of the best available site. A suitable site requires bed morphology that would not obscure the view of migrating kanakana and the river bed is sufficiently narrow to ensure all fish are within its range. Use of longer barrier fences to constrict migration within range of the DIDSON could help narrow some sites, however, for larger rivers a complete count would not be possible.

The Waikawa catchment received an elevated flow event after a long period of low flows just days before our experiment, which resulted in a very large run of kanakana. Unfortunately, once we had the DIDSON operating we did not experience a similar large run, therefore, we could not assess the DIDSON capacity to enumerate kanakana at high numbers (i.e. over 600 per night).

However, even with a small sample size the DIDSON and visual counts correlated which indicates the utility of observer counts at the falls as a method of assessing population abundance. Unfortunately, because we were only able to employ use of the DIDSON for a limited period and that did not coincide with a large run, it is unknown if the DIDSON counts and visual counts would correlate during such an event.

The environmental variables, water level, time of evening and water temperature, all had a strong relationship to the counts recorded by the DIDSON. However, the variability of the predictors provides little advice as to when would be the best times to monitor for kanakana, except that it would be best not to count kanakana at dawn or dusk.

## Other lamprey harvest methods as possible population monitoring tools

To provide a relative snapshot of migrating adult lamprey abundance repeated sampling is required to account for seasonal, daily or hourly variations in the timing of the run.[40] The DIDSON could provide this, but is expensive to hire ($500/day) and requires being constantly manned (with associated staff costs) to ensure it is operating correctly in varying flow conditions and to avoid damage or vandalism. It also requires additional time to process the data.

Use of harvest techniques provides practical population monitoring tools that are easy to analyse and support cultural defining activities such as mahinga kai gathering. Such harvest practices have developed over time to occur during optimum environmental conditions and as such could provide overestimates (or underestimates where numbers are too high to count) of actual species abundance.[41]

The main methods of lamprey harvest techniques are manual collection, nets, weirs, and simple traps (Table 1). Of these methods the most promising for use as a population monitoring tools would

[40] Moser *et al.* (2007)
[41] Caughley (1977); Kitson (2004); Moller *et al.* (2004)

be the visual counts (hand picking of rocks method) and use of a hinaki/fyke nets. One of the significant advantages of these two techniques is that they can be used over a range of environmental conditions. As a consequence, they are more likely to sample the full range of run sizes, thus more accurately reflecting the actual population.

In this preliminary study the visual counts ended two nights prior to the DIDSON finishing its recording. The conclusion of the visual counts was due to recorder fatigue (cultural monitoring at the falls had started a month prior to the DIDSON experiment to enable a record of the whole kanakana heke). This also impacted on the sample size available to correlate the two types of counts. This also suggests that the visual count method at the falls does not necessarily meet the overall objective of being practical or even sustainable over the long-term.

The simpler day time methods such as manual collection, nets and simple traps could also be applied for other fishery management needs, such as monitoring fish condition and infections. Measuring fat content (fish health), weight and length would be much simpler during the day – and it would avoid sampler fatigue. Methods such as rapu and simple traps may allow for easier collection of fish when flows are low, which inhibits migration and therefore renders other methods unsuitable. However, these methods are less likely to be useful in determining size of runs.

## Conclusions

The DIDSON has been found to be effective at enumerating migrating adult lamprey abundance at Waikawa River, Southland. The visual counts of lamprey on rocks correlates with those enumerated by the DIDSON. However, more study is required to determine if both methods are effective during higher river flows.

Further work with the DIDSON at Waikawa would benefit from increasing the length of barrier fence to restrict the width of potential kanakana passage, enabling the enumeration of lamprey at high resolution and potentially avoiding any confusion between lamprey and eels.

Due to observer fatigue the visual counts method does not necessarily meet the overall research objective to determine an effective, practical and reliable kanakana population monitoring method on the Waikawa River based on mātauranga. Further consideration should be given to stratifying observation periods based on when mātauranga predicts large runs to enable more intensive sampling over a shorter period, and less sampling over periods when mātauranga predicts small runs.

We also suggest researching further the use of nets to determine how effective these traditional methods would be as indices of kanakana abundance. This research would be required to be conducted over a number of seasons, with varying degrees of strength of heke and varying environmental conditions.

There is a lack of quantified information on the size of past kanakana runs and abundance within the Waikawa catchment. Without this we lack the ability to track population changes and expected interannual variability. Anecdotal and historic information represents the only data sources available to fill these information gaps, and have been used to do so in other harvested species,[42] therefore social and historical research methods should be used.

Kanakana/Piharau are found across the country and it is believed that this species do not return to their natal catchment.[43] Therefore, it is important to consider current and past population abundance and interannual variation across the country. The condition of kanakana has also been noted as varying over years[44] and in different regions.[45] Condition of a species is linked to the desirability to harvest[46] as well as a species' reproductive success.[47] Mātauranga and historical research would greatly add to the knowledge and management of this poorly understood but culturally important fishery.

> *He Manawa piharau*
> *(Having a lamprey's sustained endurance)*
> (Mead & Grove, 2001, p. 94)

Within the Waikawa catchment there is little information on the distribution of the various kanakana life stages, their habitat requirements and the associated threats. This needs to be addressed to assist and prioritise this fishery's management. This is particularly relevant since the occurrence of mass mortalities of migrating adults in Southland in Sept/October 2011 and the potential for the mortalities to occur across cohorts. [48]

---

42 Parsons *et al.* (2009)
43 Glova (1995)
44 Vincent Leith and Tipene O'Regan pers comm.
45 Tipene O'Regan pers comm.
46 Vincent Leith pers. comm.
47 Bromage *et al.* (1992)
48 H. Gill October 2011 pers comm.

# APPENDICES

A. Top Fall visual counts and DIDSON Counts
B. GAM model output
C. Publications and conference papers

# Appendix A

## Top Falls visual counts and DIDSON COUNTS

| Date | Time Start | Time Finish | Top falls visual counts | DIDSON |
|---|---|---|---|---|
| 2/09/2010 | 2100 | 2200 | 1000 | 262 |
| 3/09/2010 | 2145 | 2245 | 350 | 107 |
| 4/09/2010 | 2145 | 2245 | 10 | 63 |
| 5/09/2010 | 2245 | 2305 | 3 | 103 |
| 7/09/2010 | 2200 | 2400 | 600 | 426 |
| 8/09/2010 | 2230 | 2345 | 222 | 127 |
| 9/09/2010 | 2230 | 2330 | 13 | 69 |
| 10/09/2010 | 2145 | 2245 | 50 | 25 |

# Appendix B

## Model output

Model = GAM

Family: quasipoisson

Link function: log

Formula:

count ~ s(Wlevel) + s(hours) + s(Wtemp, k = 3)

Parametric coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 1.2724 0.1566 8.126 2.09e-13 ***

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:

edf Ref.df F p-value

s(Wlevel) 5.719 5.719 4.032 0.00113 **

s(hours) 7.145 7.145 4.927 4.66e-05 ***

s(Wtemp) 1.968 1.968 20.377 2.08e-08 ***

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) = 0.467 Deviance explained = 57.3%

GCV score = 7.1206 Scale est. = 6.3979 n = 156

# Appendix C

## Publications and Conference Papers

**Referred Journal Articles:** None

**Sections in Books:** None

**Conference Papers:** Two

- Kitson J., Leith V., Hay J. and D. Whaanga. 2010. Investigating potential tools to monitor population trends on the Waikawa River, Southland/Murihiku (Scoping project). Nga Pae o Te Maramatanga Critical Issues and Research Symposium: Ki uta Tangaroa, Ki uta Tai: Water Our Future. 15-16 Nov 2010, Christchurch.
- Kitson J., Leith V., Quarterman A., Hay J., Ledington S., Whaanga D. and C. Pauling. 2010. Kanakana/lamprey mātauranga: potential tools to monitor population trends on the Waikawa River, Southland/Murihiku. New Zealand Freshwater Sciences Society Conference 22-26 November Christchurch.

**Community Based Hui:** One

Introduction to the research and site visit for Ngāi Tahu ki Murihiku, Waikawa Community and resource management agencies (ie Department of Conservation, Environment Southland, Southland District Council, Te Taiao Roopu members). Held on the 2nd of September 2010. See attached flier.

**Other:**

Envirosouth (Environment Southland news) Kanakana project links local knowledge with science. Issue 21 (Nov 2010). See attached article.

DIDSON Training hui (2nd September) to introduce and conduct training in the DIDSON technology for staff from Te Ao Marama Inc, Department of Conservation – Southland Conservancy, Environment Southland and runanga members. See attached flier.

Figure 13: Top Falls Waikawa River, Southland.

## 1. Community hui: introduction to research and site visit

TE AO MARAMA INC.

CAWTHRON

environment SOUTHLAND
Te Taiao Tonga

# INVITATION:

### Site visit and introduction to the Waikawa kanakana/lamprey research

***Te Ao Mārama Incorporated, the Waikawa whānau, the Cawthron Institute and Environment Southland invite you to a presentation on the aims of the research we are conducting using cultural monitoring and the Dual-Frequency Identification Sonar (DIDSON). We will visit Māngai Piri/Niagara Falls and see the DIDSON in action.***

**Date: 2 September 2010**

**Time: 3:00pm**

**Venue: Niagara Hall, Waikawa**

**RSVP: By 27th August to Dr Jane Kitson on: jane.kitson@es.govt.nz, 021 1615884, 03 211 5115 (wk), or 03 213 0168 (a/h).**

Please bring sturdy walking shoes.

*Research funded by:*

NGĀ PAE O TE MĀRAMATANGA

*Additional support provided by:*

Te Rūnanga o NGĀI TAHU

**Programme:**

3pm: Meet at Niagara Hall, Waikawa

Mihi whakatau

Walk to falls and where DIDSON set up.

Walk back to Niagara Hall for presentations on the research being conducted.

5:30pm: He whakamutu – closing and light tea.

## 2. Envirosouth Issue 21 (Nov 2010)



# Kanakana project links local knowledge with science

Night after frozen night through the winter last year, Vinnie Leith kept vigil beside the water at Māngai Piri / Niagara Falls. He was counting hundreds upon hundreds of wriggling, writhing kanakana as they waited for the right conditions to allow them to move on upstream.

Vinnie's whānau have been catching kanakana at Māngai Piri / Niagara Falls near Waikawa for generations. He hopes that by taking part in a new study of the migratory fish, he will help ensure that they will still be available for whānau to catch and enjoy 200 years hence.

Kanakana are also known as lamprey and they're often mistaken for eels – their wide, sucking mouth marks them out as a different species but few people get close enough to see that distinguishing feature. They are parasites, sustaining themselves at sea by latching on to whales and large fish and sucking their blood and juices.

From around August to the end of October, kanakana swim up the Waikawa and Mataura rivers, congregating in pools below the falls until rain or high flows enable them to negotiate the rocks and continue their way to the spawning grounds upstream.

Kanakana are an important mahinga kai (source of food) for Ngāi Tahu. Dean Whaanga, Te Ao Mārama Inc's Resource Management Officer, says that historically, Māori trekked to the southern rivers from as far away as Temuka to catch kanakana. Anecdotal reports that kanakana stocks were declining led to the first concerted efforts to monitor their numbers last year.

*Kanakana gathering in a pool at Niagara Falls, waiting for sufficient water to continue their journey upstream. Photo: Steve Ledington*

*Environment Southland water quality scientist Kirsten Meijer with a kanakana.*

This year, Te Ao Mārama Inc, Te Rūnanga o Ngāi Tahu and Environment Southland have brought in help from the Cawthron Institute, whose sophisticated underwater "Didson" sonar camera was used to get an accurate count of numbers, adding to the information gathered by Vinnie Leith and others who were again counting the kanakana in the pools below Māngai Piri over late winter and early spring. This research is funded by Ngā Pae o Te Māramatanga, the New Zealand Māori Centre of Research Excellence.

Environment Southland has been monitoring water quality and conditions in the Waikawa River, compiling information about water levels and temperature, dissolved oxygen, turbidity, salinity, conductivity, temperature and pH levels.

Scientist Jane Kitson, who works for both Environment Southland and Te Ao Mārama, said that other information was also being collected to provide the fullest possible picture of kanakana. That includes oral history to record information from local whānau and fishers, and an assessment of changes in land use to see whether they might be influencing kanakana numbers.

She and Dean Whaanga concur that this is just the beginning of the kanakana research. The interim results will be presented to a hui towards the middle of next year, where the next steps will be agreed.■

## 3. DIDSON training hui

# CAWTHRON DIDSON TRAINING PROGRAMME

*FUNDED BY ENVIROLINK*

FOUNDATION FOR RESEARCH SCIENCE & TECHNOLOGY

Date: 2 September 2010

Time: 10:30am - 2:30pm

Venue: meet at Niagara Hall

1. Introduction to the Dual-Frequency Identification Sonar (DIDSON). How it works and current usage in fishery science and management. (Joe and Aaron Q from Cawthron)
2. Introduction to Waikawa kanakana monitoring (Vincent and Dean)
3. Brief introduction to the DIDSON experiment ( Jane/Steven/Joe)
4. KAI/lunch
5. How to use the DIDSON in the field (at a site on Waikawa River)
    a. Site considerations *(some of us to put on waders to check site).*
    b. DIDSON placement and when it needs to be adjusted
    c. Participants practise placement
6. Field experiment to distinguish kanakana from eels.
7. Wrap-up and considerations for coming experiment.

*Bring gumboots/sturdy shoes (and waders would be useful).*

## Bibliography

Allen, G. R., Midgley, S. H., & Allen, M. (2003). *Field Guide to the Freshwater Fishes of Australia.* Western Australian Museum/CSIRO Publishing.

Allibone, R., Bruno, D., Hitchmough, R., Jellyman, D., Ling, N., Ravenscroft, P., et al. (2010). Conservation status of New Zealand freshwater fish. *New Zealand Journal of Marine and Freshwater Research , 44* (4), 271-287.

Anderson, A. (1986). *Te Puoho's last raid: The battle of Tuturau 1836-37.* Dunedin: Otago Heritage Books.

Anderson, A. (1998). *The Welcome of Strangers.* Dunedin: Otago University Press.

Baumgartner, L. J., Reynoldson, N., Cameron, L., & Stanger, J. (2006). *Assessment of a Dual-frequency Identification Sonar (DIDSON) for application in fish migration studies.* Cronulla: NSW Department of Primary Industries.

Beattie, H. (1920). Nature lore of the Southern Maori. *Transactions and Proceedings of the Royal Society of New Zealand , 52*, pp. 53-77.

Berkes, F. (1999). *Sacred Ecology: Traditional Ecological Knowledge and Resource Management .* Philadelphia: Taylor and Francis.

Best, E. (1941). *The Maori - Volume 2.* Wellington: Polynesian Society.

Best, E. (1934). *The Maori as he was: a brief account of life as it was in pre-european days.* Wellington: Dominion Museum.

Best, E. (1929). *Fishing methods and devices of the Maori. .* Wellington: New Zealand.

Best, E. (1924). The utu piharau, or lamprey weir, as constructed on the Whanangui River. *The New Zealand Journal of Science and Technology* , 25-30.

Bromage, N., Jones, J., Randall, C., Thrush, M., Davies, B., Springate, J., et al. (1992). Broodstock management, fecundity, egg quality and the timing of egg production in the rainbow trout (Oncorhynchus mykiss). *Aquaculture , 100*, 141-166.

Caughley, G. (1977). *Analysis of Vertebrate Populations.* London: Wiley-Interscience.

Chadderton, L. W. (1990). *The ecology of Stewart Island's freshwater communities.* Christchurch, New Zealand: Unpublished MSc thesis, University of Canterbury.

Contiz, J. M. (2011). *A program for improving fisheries management and research in the Arctic-Yukon-Kuskokwin (AYK) Region.* Regional Information Report 3A11-07, Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage.

Coutts, P. (1969). Merger or Takeover. A survey of the effects of contact between European and Maori in the Foveaux Strait Region. *The Journal of the Polynesian Society* , 495-516.

Dacker, B. (1994). *Te Mamae me te Aroha - the pain and the love.* Dunedin: University of Otago Press.

Dacker, B. (1990). *The people of the place: mahinga kai.* Wellington, New Zealand: New Zealand 1990 Commission.

Dendy, A., & Olliver, M. A. (1901). On the New Zealand Lamprey. *Transactions and Proceedings of the New Zealand Institute , 34*, 147-49.

Doehring, K., Young, R. G., & Quarterman, A. J. (2011). Suitability of Dual-frequency Identification Sonar (DIDSON) to monitor juvenile fish movement at floodgates. *New Zealand Journal of Marine and Freshwater Research , 45* (3), 413-422.

Downes, T. W. (1918). Notes on Eels and Eel-Weirs (Tuna and Pa-tuna). *Transactions and Proceedings of the New Zealand Institute* , 296-316.

Ferguson, M. A., & Messier, F. (1997). Collection and analysis of traditional ecological knowledge about a population of Arctic tundra caribou. *Arctic* , 17-28.

Ferguson, M. A., Williamson, R. G., & Messier, F. (1998). Inuit knowledge of long-term changes in a population of Arctic tundra caribou. *Arctic , 51*, 201-219.

Firth, R. (1972). *Economics of the New Zealand Maori.* Wellington: Government Printer.

Freeman, M. M. (1992). The nature and ultility of traditional ecological knowledge. *Northern Perspectives , 20*, 9-12.

Glova, G. (1995). The secret life of the lamprey. *Water and Atmosphere , 3*, 20-21.

Gunn, A., Arlooktoo, G., & Kaomayok, D. (1998). The contribution of the ecological knowledge of Inuit to wildlife management in the Northwestern Territories. In M. M. Freeman, & L. N. Carbyn (Eds.), *Traditional Knowledge and Renewable Resource Management in Northern Regions. Occassional Publication No. 23* (pp. 22-30). Alberta, Edmonton: Boreal Institute for Northern Studies.

Hall-Jones, J. (1992). *John Turnbull Thomson: First Surveyor-General of New Zealand.* Dunedin: McIndoe.

Han, C.-H., & Uye, S.-I. (2009). Quantification of the abundance and distribution of the common jellyfish Aurelia aurita s.l. with a Dual-frequency IDentification SONar (DIDSON). *Journal of Plankton Research , 31*, 805-814.

Hayes, J. W., Davis S. F., Jellyman, D. J., & Jowett, I. G. (1992). Review of Fish Distribution in the Waiau River Catchment, Southland. *New Zealand Freshwater Fisheries Miscellaneous Report No. 109.*

Henare, M. (2009, March 1). *Te mahi kai*. Retrieved Feburary 26, 2010, from Te Ara - the Encyclopedia of New Zealand: http://www.TeAra.govt.nz/en/te-mahi-kai-food-production-economics/4/3

Holmes, J. A., Cronkite, G. M., Enzenhofe, H. J., & Mulligan, T. J. (2006). Accuracy and precision of fish-count data from a "dual-frequency identification sonar" (DIDSON) imaging system. *ICES Journal of Marine Science , 63*, 543-555.

Horne-Brine, M. (2007, Summer). Yukon River Lamprey Fishery. *Oncorhynchus: Newsletter of the Alaska Chapter; American Fisheries Society , XXVII* (3), pp. 1, 3-4.

Huntington, H. P. (1998). Observations on the utility of the semi-directive interviews for documenting Traditional Ecological Knowledge. *Artic , 51*, 237-242.

James, A. (2008). *Ecology of the New Zealand Lamprey (Geotria australis): A literature review.* New Zealand Department of Conservation.

Jellyman, D. J., & Glova, G. J. (2002). Habitat use by juvenile lampreys (Geotria australis) in a large New Zealand river. *New Zealand Journal of Marine and Freshwater Research , 36*, 503-510.

Jellyman, D. J., Glova, G. J., & Sykes, J. R. (2002). Movements and habitats of adult lamprey (Geotria australis) in two New Zealand waterways. *New Zealand Journal of Marine and Freshwater Research , 36*, 53-65.

Jellyman, D., & Tipene, D. (2001). Elusive lamprey in customary fishing study. *Aniwaniwa online* (17).

Jellyman, D., Bonnett, M., Crow, S., & Anglem, R. (2009). *Mahika kai survey of the Mataura River mataitai reserve.* NIWA.

Keane, B. (2010). Part V: Te Mahinga Kai - Te hopu tuna (eeling). In *Te Taiao Maori and the Natural World* , by Te Ara, 162-169. Auckland : David Bateman.

Keane, B. (2009, March 2). *Te hopu tuna - eeling - Catching piharau - lampreys*. Retrieved Feburary 26, 2011, from Te Ara - the Encyclopedia of New Zealand: http:/www.TeAra.govt.nz/en/te-hopu-tuna-eeling/6

Kelso, J. R. (1996). *Methods used to capture lampreys, Geotria australis, in New Zealand. Great Lakes Fishery Commission Report.* Retrieved November 2011, from Great Lakes Fishery Commission: www.glfc.org/research/scr.php

Kitson, J. C. (2004). Harvest rate of sooty shearwaters (Puffinus griseus) by Rakiura Maori: a potential tool to monitor population trends? *Wildlife Research , 31*, 319-325.

Kusabs, I. A., & Quinn, J. M. (2009). Use of traditional Maori harvesting method, the tau koura, for monitoring koura (freshwater crayfish, Paranephrops planifrons) in Lake Rotoiti, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research , 43*, 713-722.

Luzier, C. W., Schaller, H. A., Brostrom, J. K., Cook-Tabor, C., Goodman, D. H., Nelle, R. D., et al. (2011). *Pacific Lamprey (Entosphenus tridentatus) Assessment and Template for Conservation measures.* U.S. Fish and Wildlife Service, Portland, Oregon.

Maskell, F. G. (1929). On the New Zealand Lamprey, Geotria australis Gray. Part 1. - Biology and Life History. *Transactions and proceedings of the New Zealand Institute , 60* (1), 167-201.

Maxwell, S. L., & Gove, N. E. (2004). *The feasibility of estimating migrating salmon passage rates in turbid rivers during a Dual Frequency Identification Sonar (DIDSON) 2002.* Regional Information Report No. 2A04-05, Alaska Department of Fish and Game, Anchorage.

McDowall, R. M. (2011). *Ikawai: Freshwater fisheries in Maori Culture and economy.* Christchurch: Canterbury University Press.

McDowall, R. M. (2000). *The Reed Guide to New Zealand Freshwater Fishes.* Auckland, New Zealand: Reed.

McDowall, R. M. (1990). *New Zealand Freshwater Fishes: A Natural History and Guide.* Auckland, New Zealand: Heinemann Reed.

Mead, H. M., & Grove, N. (2001). *Nga Pepeha a nga Tipuna: The Sayings of the Ancestors.* Wellington: Victoria Uinversity Press.

Ministry of Fisheries. (2007). *FreshwaterSpeciesDraft FishPlan - Current State.* Retrieved from Ministry of Fisheries: http://fs.fish.govt.nz/Page.aspx?pk=22&filST=freshwater

Moller, H., Berkes, F., Lyver, P. O., & Kislalioglu, M. (2004). Combining Science and Traditional Ecological Knowledge: Monitoring Populations for Co-Management. *Ecology and Society , 9* (3), 2 [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art2.

Moser, M. L., Butzerin, J. M., & Dey, D. B. (2007). Capture and collection of lampreys: the state of the science. *Reviews in Fish Biology and Fisheries , 17*, 45-56.

Moursund, R. A., Carlson, T. J., & Peters, R. D. (2003). A fisheries application of a dual-frequency identification sonar acoustic camera. *ICES Journal of Marine Science , 60*, 678–683.

Parrott, A. (1960). *The Queer and Rare Fishes of New Zealand.* London: Hodder and Stoughton.

Phillipps, W. J., & Hodgkinson, E. R. (1922). Further notes on the edible fishes of New Zealand. *The New Zealand Journal of Science and Technology* , 91-97.

Parsons, D. M., Morrison, M. A., MacDiarmid, A. B., Stirling, B., Cleaver, P., Smith, I., et al. (2009). Risks of shifting baselines highlighted by anecdotal accounts of New Zealand's snapper (Pagrus auratus) fishery. *New Zealand Journal of Marine and Freshwater Research , 43*, 965-983.

Rewi, A. (2009). Kanakana kai. *Te Karaka* (42), pp. 33-35.

Southland Times . (1972, October 12). Unique Study a Door of School. *Southland Times* .

Stevenson, M. G. (1996). Indigenous knowledge in environmental assessment. *Arctic , 49*, 278-291.

Strickland, R. R. (1990). *Nga tini a Tangaroa: a Maori-English, English-Maori dictionary of fish names.* Wellington: MAF Fisheries.

Taranaki Regional Council. (no date) Lamprey. *Information.*

Te Ao Mārama Inc and Waikawa Whānau. (2010). *Waikawa Kanakana Research 2009: Monitoring observations and recommendations for future monitoring and research.* Report for Te Putea Whakakaha Mahika Ka.

Tipa, G. (2011). *Cultural Uses in Murihiku. .* Report for Southland Water 2010.

Tipene, D., & Jellyman, D. (2002). *A review of information on Kanakana (Lamprey) in the Mataura Catchment, with suggested management procedures.* Christchurch: Prepared for Hokonui runaka by the National Institute of Water & Atmospheric Research Ltd.

Todd, P. R. (1992). A status report on the New Zealand lamprey. *New Zealand Freshwater Fisheries Miscellaneous Report No. 11* .

Usher, P. J. (2000). Traditional ecological knowledge in environmental assessment and management. *Arctic , 53*, 183-193.

Usher, P. J., & Wenzel, G. (1987). Native harvest surveys and statistics: a critique of their construction and use. *Arctic , 40*, 145-160.

Van Eyndhoven, E. (2011). *Assessment of environmental factors associated with the Aeromonas salmonicida event in kanakana.* Ministry of Agriculture and Forestry. unpublished report 18 October 2011.

Wenzel, G. W. (1999). Traditional ecological knowledge and Inuit: reflections on TEK research and ethics. *Arctic* , 113-124.

Young, D. (1998). *Woven by Water: Histories from the Whanganui River.* Wellington: Huia Publishers.

Zuur, A. F., Ieno, E. N., & Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution , 1*, 3-14.