Estimating the abundance of banded kokopu (*Galaxias fasciatus* Gray) in small streams by nocturnal counts under spotlight illumination

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Abstract

The abundance of banded kokopu (*Galaxias fasciatus* Gray) in small streams has usually been determined by the labour intensive and invasive method of electric fishing. Recently, nocturnal counts under spotlight illumination have been used to determine presence or absence and relative abundance of banded kokopu, but the proportion of the population seen was unknown. We compared 20 spotlight counts of banded kokopu in approximately 20 m reaches in streams in the North Island, New Zealand, to population estimates determined by removal electric fishing in the same reaches. Spotlight counts were related to population estimates over a range of densities, and on average, spotlight counts were 64% of the population estimates. Though we tried to separate age-0 fish from older fish visually in the spotlight counts, the size frequency distribution of the fish caught by electric fishing showed that the visual separation was not reliable. In addition, visual counts were generally inefficient for age-0 fish (40-70 mm total length), as only about 40% were observed.

Banded kokopu were also recorded in streams using time-lapse video recordings with a camera sensitive to low light levels. Diel activity showed two major peaks, one in the early morning from 0400 h to 0900 h, and the other in the afternoon and evening from 1300 h to 1900 h. Fish were less disturbed by the observer's approach after dark than during the day, so we suggest that from dusk to about 2200 h is the best time for visual counts of banded kokopu by spotlight in summer months.

Keywords: banded kokopu - *Galaxias fasciatus* - streams - population estimate - abundance - Galaxiidae - nocturnal observation.

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Introduction

Banded kokopu (*Galaxias fasciatus* Gray: Family Galaxiidae, Order Salmoniformes) are endemic to New Zealand, and occur in small, slow flowing streams at mid to low elevations throughout the mainland and on some offshore islands (McDowall 1990; Jowett *et al.* 1998). Banded kokopu are widely regarded as a nocturnal species (McDowall 1990), although this has not been empirically assessed before, and they are more common in streams with native forest in their riparian margins than in open streams in pasture (Main 1988; Hanchet 1990, Hicks & McCaughan 1997; McCullough 1998). Most current knowledge of banded kokopu distribution has been acquired through electric fishing, which is time-consuming and invasive, and can lead to interruption of growth in some species (Mesa & Schreck 1989). Night time observations using spotlight illumination have been used for the nocturnally active galaxiids such as shortjawed kokopu (Studholme *et al.* 1999), and banded kokopu (McCullough 1998).

The relationship of nocturnal counts of banded kokopu under spotlight illumination to the actual number of fish present have not previously been determined, but the variability of this relationship is crucial to the use of the spotlighting technique for estimating abundance. Removal electric fishing has been used to calculate the relationship between visual counts of salmonids by a diver and independent population estimates (e.g., Hankin & Reeves 1988; Dolloff *et al.* 1993). If the relationship between visual counts and population estimates is sufficiently consistent, then it is possible to correct for any bias associated with the visual observation technique (Hankin & Reeves 1988).

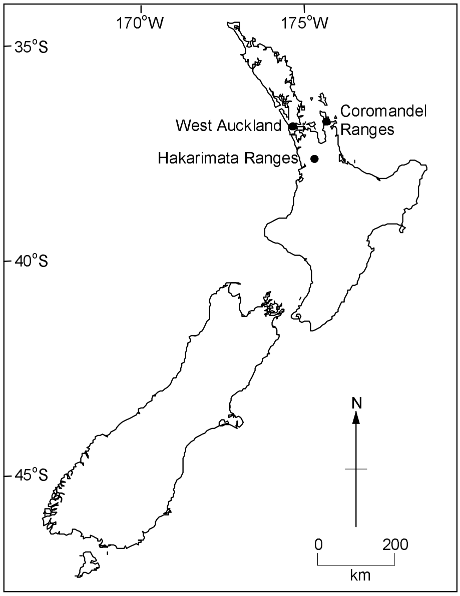

Figure 1. Location of the study streams within the North Island of New Zealand.

In addition, banded kokopu are usually unevenly distributed along stream channels in response to differences in habitat suitability. Banded kokopu are typically found in pools and slow runs, and have a strong preference for in-stream debris (Jowett *et al.* 1998), which frequently results in an uneven longitudinal distribution (Main 1988; McCullough 1998). Relatively short reaches are usually surveyed by electric fishing (e.g., Hicks & McCaughan 1997), whereas a rapid survey technique such as spotlight observation allows fish to be counted in more of the stream. The objectives of this study of banded kokopu were 1) to test the effects of approach noise and spotlight beam colour and intensity, 2) to investigate diel patterns of activity, and 3) to estimate the effectiveness of spotlight counts compared to independent population estimates.

Study sites

The study streams were located in the Waitakere area of west Auckland, on the west coast of the Coromandel Peninsula, and in the Hakarimata Ranges in the Waikato district (Fig. 1). All these streams are in the North Island of New Zealand, and encompass a range of habitat variables. Substrates were variable, ranging from cobbles and bedrock to mud and silt. Native forest or regenerating scrub dominated riparian vegetation at the margins of the study streams (Table 1). Mean water surface widths ranged from 0.53 to 1.28 m (Table 2). Study reaches were chosen to be about 20 m long and included several pools. However, because of the varying lengths of the pools, and the requirement to end a reach at the end rather than in the middle of a pool, reach lengths ranged from 15.1 to 25.3 m. Occurring with banded kokopu in the Coromandel streams were common bullies (*Gobiomorphus cotidianus*) and redfinned bullies (*G. huttoni*). In the Swanson and Waipuna streams there are eels (*Anguilla australis* and *A. dieffenbachii*), and crayfish (*Paranephrops planifrons*).

Methods

To test the reaction of banded kokopu to a person approaching the stream with a spotlight, a camera sensitive to infrared light, illuminated with an infrared-filtered spotlight manufactured by Lightforce Australia Pty Ltd with a 170 mm reflector (model SL170) was suspended above a pool in Swanson Stream. The infrared filter transmitted wavelengths >800 nm. Infrared light is likely to be invisible to most fishes (Lythgoe 1979). The behaviour of banded kokopu in each

Table 1. Substrate and catchment vegetation of the study streams. Map numbers and coordinates refer to the NZMS 260 1:50,000 maps at the approximate location of the study sites.

Region	Stream	Map number	Map coordinates	Substrate	Catchment vegetation
Coromandel	Driving Creek	T10	339 934	Gravel, boulder	Second-growth native forest
Coromandel	Unnamed tributary in Coromandel Golf Course	T10	328 922	Mud, silt, and vegetation	Pasture reverting to scrub
Coromandel	Sawmill Creek	T11	357 871	Gravel, sand	Second-growth native forest
West Auckland	Heale Stream	Q11	532 666	Gravel, cobble	Native forest
West Auckland	Unnamed tributary of Swanson Stream	Q11	495 792	Sandstone bedrock, mud, fine gravel	Second-growth native forest
West Auckland	Unnamed tributary of Swanson Stream	Q11	498 795	Sandstone bedrock, mud, fine gravel	Second-growth native forest
Hakarimata Ranges	Waipuna Stream	S14	973 937	Gravel, cobble	Native forest

Table 2. Dates fished, reach dimensions, and densities of banded kokopu and biomass of all ages for 20 North Island sites sampled in 1997. Densities and biomass were calculated from 2-pass removal estimates derived from electric fishing.

Stream	Reach	Date electric fished	Sun-rise (h)	Sun-set (h)	Population estimate	Length (m)	Mean width (m)	Area (m^2)	Density (fish m^{-2})	Biomass (g m^{-2})
Coromandel										
Driving Creek	1	27 Feb	0704	2003	34.7	23.0	0.67	15.3	2.27	33.0
Driving Creek	2	27 Feb	0704	2003	20.0	17.5	1.13	19.8	1.01	17.2
Golf Course tributary	1	17 Feb	0653	2016	30.2	19.0	0.53	10.0	3.02	104.3
Golf Course tributary	2	17 Feb	0653	2016	29.0	19.5	0.52	10.2	2.84	134.6
Sawmill Creek	1	23 Apr	0653	1745	23.1	25.4	1.00	25.4	0.91	27.5
Sawmill Creek	2	27 Feb	0704	2003	53.5	23.4	0.69	16.1	3.32	107.3
Sawmill Creek	3	23 Apr	0653	1745	25.8	23.0	0.96	22.2	1.16	20.2
Sawmill Creek	4	23 Apr	0653	1745	21.1	21.8	0.83	18.0	1.17	14.6
Waitakere										
Swanson Stream	1	8 Jan	0611	2043	32.8	16.4	0.81	13.2	2.48	28.6
Swanson Stream	2	8 Jan	0611	2043	8.2	15.1	0.85	12.8	0.64	7.4
Swanson Stream	3	8 Jan	0611	2043	16.2	24.6	0.63	15.4	1.05	10.0
Swanson Stream	4	8 Jan	0611	2043	12.8	25.3	1.01	25.6	0.50	1.8
Swanson Stream	5	8 Jan	0611	2043	16.2	20.2	1.09	21.9	0.74	10.4
Swanson Stream	6	8 Jan	0611	2043	2.2	18.5	0.58	10.7	0.20	1.8
Swanson Stream tributary	1	9 Jan	0611	2043	20.0	18.2	1.20	21.9	0.91	2.4
Swanson Stream tributary	2	9 Jan	0611	2043	20.3	21.5	1.09	23.5	0.86	6.3
Swanson Stream tributary	3	9 Jan	0611	2043	15.4	21.7	0.99	21.4	0.72	1.3
Waikato										
Waipuna Stream	1	28 May	0721	1714	36.4	21.9	1.25	27.4	1.33	24.3
Waipuna Stream	2	28 May	0721	1714	18.8	22.4	0.84	18.9	0.99	11.7
Waipuna Stream	3	28 May	0721	1714	14.4	22.3	1.28	28.5	0.51	9.5
Mean									1.33	28.7
95% confidence interval									0.43	18.2

pool was viewed through the camera by means of a monitor positioned approximately 25 m away. An observer with a spotlight approached the stream, firstly with heavy footfalls, and secondly with stealthy steps. For each of these approach types, the spotlight was used on high intensity and low intensity, and for each of these combinations, unfiltered white light, red-filtered light (wavelength >600 nm), and infrared light were used. Between each test, the fish were allowed 30 minutes to resume normal foraging behaviour. During an approach by the observer, movement of a fish away from its foraging position was interpreted as a disturbance.

To determine the patterns of diel activity of banded kokopu, the same camera system was suspended above a pool as for the approach test above, using red-filtered light from the mounted halogen spotlight that was required as a result of the low natural ambient light levels. Activity of banded kokopu over a 24 h period was recorded on videotape. This procedure was repeated three times, once in Swanson Stream, and twice in the Coromandel Golf Course Stream between August and October 1997. After the video recording was complete, the number of fish in the field of view on the video tape was transcribed into counts at 10 minute intervals. The means and standard errors of these counts across all three streams were calculated for each hour of the day.

To estimate the proportion of fish seen in visual counts by spotlight compared to the total population, we selected 20 stream reaches spread across three Coromandel streams, two Waitakere streams, and a Waikato stream. Each 20 m reach was blocked at its upstream and downstream ends with a 3 mm mesh net during daylight. After nightfall on the same day, counts of the banded kokopu were made within the netted-off reach using a red-filtered 100 W halogen spotlight powered by a 12 V battery. During spotlighting, fish were identified as either age 0 (<70 mm in January and February, or <80 mm in April and May) or age 1 or older. Age 1 or older fish were separated into 20 mm size categories on the basis of their visually estimated lengths. In many cases, a ruler could be held within 5 cm of individual adult banded kokopu to give relatively accurate length measurements. Counts were made between 1800 h and 2100 h in two time periods (7 January to 27 February, and 23 April to 21 May), and the total time taken for each spotlight count was recorded. The time of sunrise ranged from 0610 h (6 January) to 0721 h (28 May), and the time of sunset ranged from 2044 h (6 January) to 1714 h (28 May). Water temperatures during the study periods ranged from 12.2 to 17.1°C.

The block nets were left in place overnight, and the next day, removal electric fishing was used to determine the population number in the same reaches as the spotlight counts. A National Institute of Water and Atmosphere (NIWA) Instruments Kainga 300 W backpack electric-fishing machine was used for the fish capture. In most instances, only two passes were required to achieve a reduction of ≥50% between the first and second passes. However, in two reaches (reach 6 of Swanson Stream, and reach 3 of Swanson Stream tributary), three passes were required to reduce the number of fish of all size classes caught to below that of the number of fish caught in the first pass.

The mean reduction between the first and second passes was 65%, so the maximum likelihood method of abundance estimation of Zippin (1958) was the most appropriate model (Cowx 1983). Fish captured in each pass were placed in separate buckets of fresh water, then anaesthetised with benzocaine (ethyl aminobenzoate) prior to length measurement. The time taken for electric fishing was also recorded.

The number of fish in the spotlight counts as a proportion of the population estimate was calculated in two ways. Firstly, an adjustment factor was calculated by dividing the sum of the fish in the 20 population estimates by the sum of the fish seen in the 20 visual counts. This is similar to the sample-based ratio estimator ($\hat{R}$) of Cochran (1977). Secondly, the least-squares linear regression of best fit was calculated from pairs of visual counts and population estimates for the same reach using SYSTAT 10. Both methods were used for all sizes of banded kokopu combined and for age-0 and age-1 fish separately.

To estimate biomass, weights of fish were predicted from the following weight-length regression:

$$\ln(W) = -13.26 + 3.36 \ln(L),$$

where W = weight in g and L = fork length in mm for the length range 78-242 mm (N = 56, r^2 = 0.99). These data were from the Mangakotukutuku Stream (NIWA unpublished data; D. W. West) and Hakarimata Range streams (Hicks unpublished data). The mean fish weight for each site was then applied to the density estimated from removal electric fishing to produce biomass estimates.

Results

Viewed through the remote monitor, banded kokopu moved from their feeding position, usually fleeing to cover, when an observer approached with heavy footfalls. This response was the same regardless of the colour or intensity of the spotlight beam. With a stealthy approach by the observer, fish were still disturbed by the white spotlight, but with a red-filtered spotlight, fish usually moved a short distance from the water column to the streambed, and then resumed immobility almost immediately. Compared to white light, red-filtered light minimised back-scatter in the presence of suspended material such as clay particles, and thus gave a clearer view of the fish.

The presence of the freshwater crayfish (*Paranephrops planifrons*) occasionally interfered with spotlight counts of banded kokopu. When an observer approached the stream, any crayfish present retreated backwards, disturbing any banded kokopu and fine sediment on the streambed.

To determine the times of peak activity, the number of banded kokopu in the video camera's field of view was averaged for each hour within a 24 h period. There were peaks of activity in the early morning (0400-0900 h) and in the afternoon and evening (1300-

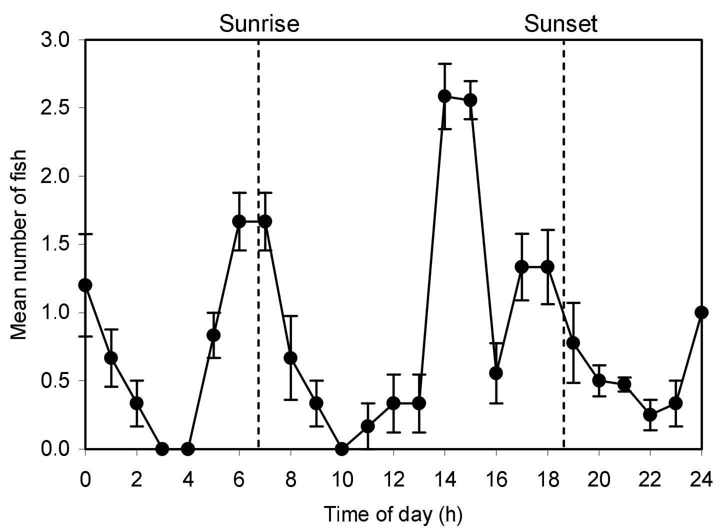

Figure 2. Diel patterns of banded kokopu activity in small streams determined by video observations. The dependent variable is the mean number of fish in the field of view of the video camera counted at 10 minute intervals for three streams. The error bars represent one standard error.

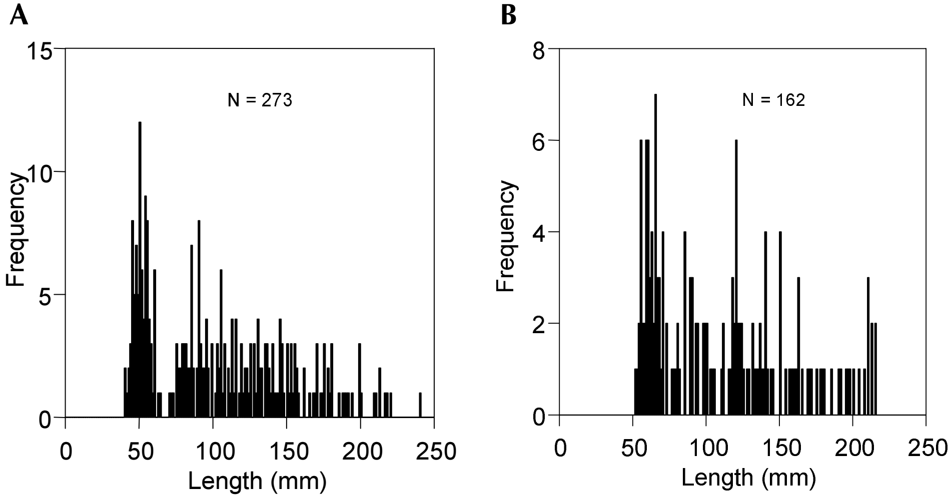

Figure 3. Length frequencies of banded kokopu caught by electric fishing in streams in (A) January-February and (B) April-May 1997.

2100 h; Fig. 2). However, the banded kokopu could not be easily approached or counted during the morning or afternoon periods because they usually fled for cover. During the dim light conditions of the evening, banded kokopu generally showed only a limited response when the observer quietly approached the stream with the red-filtered light that was used to make the spotlight counts.

Age-0 banded kokopu appeared to comprise most of the fish that were active during the daylight hours, typically swimming near the head of a pool. All the mid-afternoon activity seen in the Swanson Stream was attributable to a single age-0 fish. Conversely, most nocturnal activity was attributable to age-1 and older fish.

In January and February, the most numerous size class caught by electric fishing was 41-64 mm FL (Fig. 3A). We assume that these were age 0; the smallest of the next presumed age class was ≥71 mm FL. In April and May, these age 0 fish were about 10 mm longer than in January and February (52-73 mm FL; Fig. 3B), and the next presumed age class was ≥77 mm FL.

Densities of banded kokopu estimated from electric fishing ranged from 0.5 to 3.3 fish m^{-2} (mean = 1.33 fish m^{-2}, 95% confidence interval = 0.43, N = 20; Table 2). Biomasses were highly variable, ranging from 1.3 to 135 g m^{-2} (mean 28.7 ± 18.2 g m^{-2}). Both densities and biomasses were greater in Coromandel streams than in the Waitakere or Waikato streams.

For all fish sizes considered together, multi-pass electric fishing estimated more fish (451 in total; Table 3) than were caught on the first pass by electric fishing (309 fish; Table 4). The first pass in turn caught a greater number of fish than were recorded in spotlighting counts (287 fish; Table 3). The estimated adjustment factor of the visual counts for fish of all ages combined was 1.57, implying that on average 64% of the population was seen by spotlighting at night (Table 3). Estimates of the adjustment factor for

Table 3. Visual counts of banded kokopu made by nocturnal spotlighting compared to population estimates made by removal electric fishing in 1997. The adjustment factor $\hat{R}$ = sum of the population estimates divided by the sum of the visual counts. * = Population estimate was not possible because of insufficient reduction between passes, so the sum of two passes was used instead.

		Number of fish in approximately 20 m reaches					
		All ages		Age 0		Age 1+	
Stream	**Reach**	**Visual count**	**Population estimate**	**Visual count**	**Population estimate**	**Visual count**	**Population estimate**
Coromandel							
Driving Creek	1	22	35	5	12	17	23
Driving Creek	2	16	20	4	9	12	16
Golf Course tributary	1	11	30	0	1	11	29
Golf Course tributary	2	17	29	0	5	17	24
Sawmill Creek	1	7	23	1	*3	6	19
Sawmill Creek	2	48	53	6	*4	42	48
Sawmill Creek	3	16	26	4	4	12	22
Sawmill Creek	4	14	21	5	*3	9	16
Waitakere							
Swanson Stream	1	13	33	7	27	6	13
Swanson Stream	2	6	8	1	1	5	7
Swanson Stream	3	11	16	6	5	5	12
Swanson Stream	4	15	13	1	8	14	5
Swanson Stream	5	12	16	2	5	10	12
Swanson Stream	6	3	2	0	1	3	*1
Swanson Stream tributary	1	8	20	4	12	4	9
Swanson Stream tributary	2	10	20	3	8	7	13
Swanson Stream tributary	3	12	15	5	14	7	1
Waikato							
Waipuna Stream	1	30	36	11	32	19	16
Waipuna Stream	2	5	19	3	14	2	8
Waipuna Stream	3	11	14	6	7	5	7
Sum		287	451	74	175	213	302
Adjustment factor $\hat{R}$		1.57		2.37		1.42	

individual reaches were very variable, ranging between 0.73 and 3.75. About 40% of age-0 fish, and 70% of age-1+ fish, were observed by spotlighting (Table 3). Thus for age-0 fish, the estimated adjustment factor was considerably greater (2.37) than for age-1 and older fish (1.42).

For fish of all ages combined, capture probability ($\hat{p}$) was relatively large and consistent (mean 0.68, range 0.44-0.86; Table 4). For age-0 fish, the mean was lower (0.47) and individual values were more variable. We compared population estimates calculated by the maximum weighted likelihood method of Carle & Strub (1978) to those estimated by the method of Zippin (1958). For population estimates calculated by the method of Zippin (1958), 53% of the population estimates were greater than the two-pass total, and where the total number of fish caught in two passes was ≤10, 48% of population estimates were greater than the two-pass total. However, population estimates made by the method of Carle & Strub (1978) were greater than the sum of two passes in only 28% of cases. Where the total number of fish caught in two passes was ≤10, the population estimate was greater than the sum for two passes in only 7% of cases, even though it is

Table 4. Visual counts of banded kokopu made by nocturnal spotlighting compared to population estimates made by removal electric fishing and their 95% confidence intervals. $\hat{p}$ = capture probability. Where no reduction occurred between successive passes the population estimate failed (= fail).

		Number of fish in each pass											
		All ages				Age 0				Age 1+			
		Pass			$\hat{p}$	Pass			$\hat{p}$	Pass			$\hat{p}$
Stream	**Reach**	**1st**	**2nd**	**3rd**		**1st**	**2nd**	**3rd**		**1st**	**2nd**	**3rd**	
Coromandel													
Driving Creek	1	25	7		0.72	7	3		0.57	18	4		0.78
Driving Creek	2	10	5		0.50	6	2		0.67	4	3		0.25
Golf Course tributary	1	28	2		0.93	1	0		1.00	27	2		0.93
Golf Course tributary	2	28	1		0.96	5	0		1.00	23	1		0.96
Sawmill Creek	1	18	4		0.78	1	2		fail	17	2		0.88
Sawmill Creek	2	38	11		0.71	2	2		fail	36	9		0.75
Sawmill Creek	3	19	5		0.74	2	1		0.50	17	4		0.76
Sawmill Creek	4	13	5		0.62	1	2		fail	12	3		0.75
Waitakere													
Swanson Stream	1	19	8		0.58	9	6		0.33	10	2		0.80
Swanson Stream	2	7	1		0.86	1	0		1.00	6	1		0.83
Swanson Stream	3	9	4		0.56	3	1		0.67	6	3		0.50
Swanson Stream	4	8	3		0.63	4	2		0.50	4	1		0.75
Swanson Stream	5	9	4		0.56	3	1		0.67	6	3		0.50
Swanson Stream	6	1	1	0	0.57	1	0	0	1.00	0	1	0	fail
Swanson Stream tributary	1	10	5		0.50	7	3		0.57	3	2		0.33
Swanson Stream tributary	2	9	5		0.44	4	2		0.50	5	3		0.40
Swanson Stream tributary	3	11	3	1	0.71	10	3	1	0.69	1	0	0	1.00
Waikato													
Waipuna Stream	1	20	9		0.55	8	6		0.25	12	3		0.75
Waipuna Stream	2	15	3		0.80	10	3		0.70	5	2		0.60
Waipuna Stream	3	12	2		0.83	6	1		0.83	6	1		0.83
Sum		309	88			91	40			218	50		
Mean					0.68				0.67				0.70

quite likely that fish remained to be caught in many instances. Thus it seems that for low numbers of fish the method of Carle & Strub (1978) is more likely to underestimate the population size than the method of Zippin (1958).

For all ages combined, 90% of the population estimates were greater than visual counts (Fig. 4A). The regression equation for this relationship was

$$Y = 8.82 + 0.96X,$$

where Y = the population estimate in fish per reach, and X = the visual count in fish per reach (r^2 = 0.70, N = 20, $P < 0.001$). For the age 0 fish, 75% of the population estimates were greater than visual counts, and in three instances, age 0 fish caught by electric fishing were not seen by spotlighting (Fig. 4B). The regression equation for this relationship was

$$Y = 0.91 + 2.13X,$$

for which r^2 = 0.53, N = 20, and $P < 0.001$. When only age 1 and older fish were considered, 80% of the population estimates were greater than visual counts, and the regression equation for the relationship was

$$Y = 4.42 + 1.00X,$$

for which r^2 = 0.67, N = 20, and

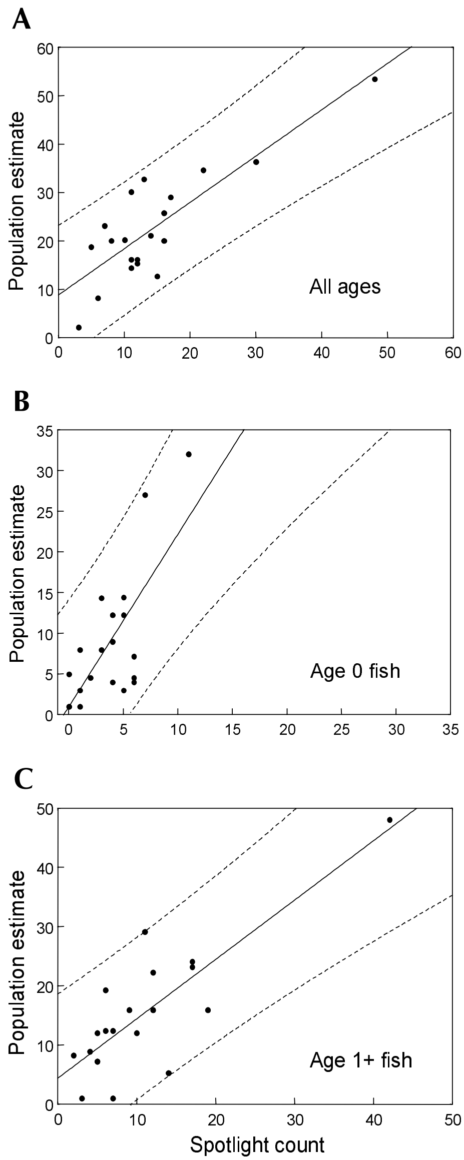

Figure 4. Relationship of uncorrected visual counts of banded kokopu made by spotlighting at night to population estimates made by removal electric fishing in 15-25 m long streams reaches. (A) All ages, (B) age 0 fish, and (C) age 1 and older fish (N = 20 in each case). Regression lines (solid lines) and their 95% prediction intervals (dashed lines) are shown. P-values for all regression models < 0.001.

$P < 0.001$ (Fig. 4C). In all cases, residuals of regressions were normally distributed ($P < 0.01$). Confusion of age-0 fish with older fish was evident in reaches 3 and 4 of Swanson Stream when we determined regression relationships between the population estimates and the visual counts.

Spotlighting was much more time-efficient than electric fishing, taking 12 ± 1.7 minutes for each approximately 20 m reach (mean ± 95% confidence interval), or 0.71 ± 0.20 minutes m^{-2}. The electric fishing required to produce a removal population estimate took an average of 73 ± 11 minutes per 20 m reach, or 4.4 ± 1.2 minutes m^{-2}. No other species of galaxiids (i.e., those fishes that could possibly be confused with banded kokopu) were collected the following day during electric fishing. Streams with high abundances of banded kokopu had few other fish species except for occasional common (*Gobiomorphus cotidianus*) and redfinned bullies (*Gobiomorphus huttoni*) (unpublished data).

Discussion

Nocturnal counts by spotlight illumination of banded kokopu in six small streams were related to population estimates. Our estimate of the mean proportion of banded kokopu counted by spotlighting (64%) was the same as the first pass of removal electric-fishing (mean 68% for banded kokopu in our study). For juvenile trout, 61-74% were caught in the first pass of removal electric-fishing (Hayes & Baird 1994). Banded kokopu seemed to be less disturbed by red-filtered light than by white light, and were more approachable after dark, though this did not coincide with peak activity of banded kokopu.

Banded kokopu appear to be crepuscular, displaying peaks of activity during early morning and late twilight (Fig. 2). However, the mid-afternoon peak in activity was surprising. A previous study showed that total stomach contents of banded kokopu were significantly heavier in the morning than late in the evening (Halstead 1994), implying that the majority of feeding occurred overnight.

Other galaxiid species, for instance giant kokopu (*Galaxias argenteus*) and koaro (*Galaxias brevipinnis*), can occur in the same stream as banded kokopu (Chadderton & Allibone 2000). Although some habitat segregation is usual (Chadderton & Allibone 2000), these fish appear superficially similar at similar sizes, and it is unlikely that the species could be reliably separated during spotlight counts. Thus spotlight counts are probably appropriate only where banded kokopu are the single galaxiid present in a stream reach. Electric fishing revealed that banded kokopu were the only galaxiid present in the stream reaches that we surveyed.

We considered the maximum likelihood model of Zippin (1958) the most appropriate to calculate population estimates from two-pass removal electric fishing. Cowx (1983) recommended the maximum weighted likelihood method of Carle & Strub (1978), but we found that with small numbers of fish, the predicted population size was almost always the same as the sum of the fish caught in two passes, which seemed unrealistic in many cases with low capture probabilities.

Sites were chosen for this study on the basis of their range of densities of banded kokopu; without this range, determining the linear relationship of visual counts to population estimates would not have been possible. Banded kokopu densities in our study (1.33 ± 0.43 fish m^{-2}; mean ± 95% confidence interval) were similar to Ship Creek in south Westland (mean 0.9 fish m^{-2}; Taylor & Main 1987), and Whanganui Inlet, northwest Nelson (mean 0.61 fish m^{-2}; Eldon & Ward 1991). These densities are considerably greater than the mean for streams in the Kahurangi National Park, northwest Nelson (0.037 ± 0.022 fish m^{-2}; Jowett *et al.* 1998), in native forest streams on the east coast of the North Island (0.06 ± 0.04 fish m^{-2}; Rowe *et al.* 1999), or in other Waikato sites (0.010 - 0.039 fish m^{-2}, Hicks & McCaughan 1997). These differences are probably related to stream size, as density on an areal basis tends to be inflated in narrow streams because banded kokopu show a strong preference for bank side cover (McCullough 1998). Proximity of some of our sites to the coast may also have contributed to the high densities of banded kokopu that we saw, as banded kokopu are most commonly found in small, clear streams <150 km from the coast (Jowett *et al* 1998; Rowe *et al.* 2000). The high densities of banded kokopu in our study were reflected in high biomasses (mean 28.7 ± 18.2 g m^{-2}) compared to other Waikato sites (biomass range 0.07 - 3.12 g m^{-2}; Hicks & McCaughan 1997).

We suggest that two approaches are suitable for correcting visual counts of banded kokopu to the number of fish likely to be present. Firstly, spotlight counts can be multiplied by an adjustment factor appropriate for the age group (similar to the ratio estimator method of Cochran 1977). However, given the questionable reliability of the separate age groups in the spotlight counts, it is probably better not to attempt separation, but instead to multiply the spotlight count of all ages combined by the adjustment factor of 1.57, obtaining an estimate of the total number of fish present (Table 3). This technique would work for low densities as well as high densities, but would not produce an estimate of the error. Secondly, to produce a population estimate with an estimate of the error, the regression line and its 95% prediction intervals can be used (Fig. 4A). For instance, if 20 banded kokopu were counted in a 20 m reach, then the population estimate and its 95% prediction interval would be 28 ± 14 fish. At low densities (say less than about 3 fish in a 20 m reach) this technique would be unreliable, since for a visual count of zero the regression line predicts a population estimate of 9 fish.

The use of regression is appropriate in this context because although the spotlight counts are only estimates of the actual number of fish, when used as a predictor of population size the spotlight counts are known without error. Thus we use the regression equation to predict population size from a single invariant, independent value, i.e., the spotlight count for a given stream reach.

There are many advantages to spotlighting compared to electric fishing in evaluating the abundance of banded kokopu in small streams. It allows more stream to be sampled with the same given effort than does electric fishing. Because fish densities in streams vary longitudinally, the precision of individual point estimates is probably much less important in estimating fish populations than is sampling a sufficient length of stream (e.g., Hankin & Reeves 1988). In this study, twofold to tenfold differences in densities determined by electric fishing were observed within a single stream (Table 2). A limited number of sampling reaches can thus misrepresent the true variability in fish densities. With a rapid sampling technique such as calibrated spotlighting, a large number of sampling reaches can reveal differences in longitudinal distribution of banded kokopu.

Since others may want to correct visual counts of banded kokopu in streams where independent population estimates have not been made, we can speculate about the problems in doing so. We sampled a range of stream types in different localities, and thus our results should be relatively robust for a wide range of small streams. However, it is very likely that different observers will see different proportions of the banded kokopu that are present. It is worthwhile for the spotlighters to familiarise themselves during daylight with the stream reach to be surveyed, because this makes spotlight counting at night easier and safer. Counting should also be made from downstream to upstream to leave disturbed and turbid water behind when entering an unsurveyed section. Also, spotlight counts will be compromised by any conditions that obscure fish from the viewer. Thus spotlighting is most appropriate for streams ≤2.0 m wide that are mostly pool habitat with clear water, where the water surface is not obscured by surface turbulence, floating leaves, or overhanging vegetation. The technique may be applicable to other nocturnal fish species for which abundance can be independently estimated.

We conclude that even under ideal conditions spotlight counts provide only crude estimates of the abundance of banded kokopu, especially where fish densities are low. However, spotlight counts have advantages over other sampling techniques. Spotlighting is rapid and has low impact on the fish; by contrast, electric fishing takes about six times longer, and requires expensive equipment, extensive training, and more personnel. Thus despite their lack of precision, spotlight counts are useful for rapid, preliminary population estimates over long sections of stream, especially where the fish density is likely to be quite variable between reaches.

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