The National Inanga Spawning Database: trends and implications for spawning site management

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ABSTRACT

New Zealand whitebait comprises the migratory juveniles of five species of native *Galaxias*. The most abundant of these is inanga, *Galaxias maculatus*. In 1987, the Department of Conservation (DOC) commissioned nationwide field surveys to identify (with the aim of protecting) inanga spawning sites, with data to be collated into a database administered by the National Institute of Water and Atmospheric Research Ltd (NIWA). The database currently holds 562 records from a total of 194 inanga spawning sites. Spawning sites have been located in every coastal DOC conservancy except Auckland. Further work to identify spawning sites is required, particularly in Northland, Auckland, Waikato, Wellington and Southland Conservancies. At least some protection work has been carried out in every conservancy where spawning has been located.

Inanga spawning usually occurs on autumnal spring tides, with the nationwide peak spawning activity taking place 2 or 3 days after the new or full moon; however, some spawning may also occur in spring. Preferred spawning sites appear to be the banks of tidally-influenced flow-stable waterways, and tributaries and small creeks in very large catchments, often where there are embayments and confluences. Inanga spawn gregariously amongst inundated bankside vegetation. Consequently, spawning sites and eggs are prone to damage by cattle trampling or grazing.

Exotic vegetation commonly associated with inanga spawning includes a number of grass and herb communities, often dominated by tall fescue (*Festuca arundinacea*). A wide variety of native plants are also associated with inanga spawning. These include New Zealand rush (wiwi, *Juncus gregiflorus*), bull rush (raupo, *Typha orientalis*), flax (harakeke, *Phormium tenax*) and toetoe (*Cortaderia richardii*). The spread of reed sweet grass (*Glyceria maxima*) and other exotic grass species unfavourable for fish spawning into spawning areas is of concern.

Keywords: Inanga, *Galaxias maculatus*, whitebait, spawning, habitat production.

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1. Introduction

In New Zealand, whitebait are the migratory juveniles of five species of *Galaxias* (McDowall 1990), the most abundant of which is inanga (*Galaxias maculatus* Jenyns). This fish has an annual life cycle. Adults usually spawn gregariously amongst tidally-inundated riparian vegetation in late summer or autumn. Inanga are highly selective about where they spawn and, assuming other factors remain unchanged, utilise approximately the same spawning area over many years. The small (approximately 1 mm diameter) eggs develop amongst the humid litter-layer near the water's edge for a period of 2–4 weeks, depending on ambient temperature. Eggs hatch when fully developed and re-inundated by high, usually tidally-influenced, water levels. Hatched inanga fry swim out of the riparian vegetation, and are washed out to sea on the ebbing tide. The fry remain at sea for 6 months, feeding on plankton. The juveniles, now recognisable as whitebait, migrate back into rivers during spring. Assuming they evade capture by whitebaiters, whitebait grow and mature over the summer months in lowland waterways and lakes.

Thus, for half of their life, inanga are affected by factors associated with marine ecosystems, and for the other half, those associated with freshwater ecosystems.

The factors affecting inanga survival at sea are poorly understood and, probably, unmanageable. They include:

- Natural mortality, including predation.
- Variations in food source determined by water temperature, currents, light, trophic levels and, possibly, the state of the Southern Oscillation.

Inanga survival in rivers, lakes and streams is also affected by natural mortality and variations in climate and habitat. However, they also have to contend with detrimental impacts associated with human activity. These include:

- Whitebait fishing pressure.
- Damage to rearing habitat.
- Damage to spawning habitat.

2. Background

The West Coast of the South Island accounts for the majority of the national whitebait catch, and the extensive areas of suitable habitat provide an environment for a significant inanga population. It is also the only region in New Zealand with reasonably consistent whitebait catch records over a long timeframe (1927 to 1973, McDowall & Eldon 1980). The high annual variability of the whitebait catches prevented these authors reaching a conclusion about whether the West Coast whitebait fishery was in a state of decline over this period. Characteristically, a series of bad annual catches were often followed by years when catches were very high. This natural variability in the main fishery means that it is not surprising that early reports of the detrimental effect of stock trampling and grazing on inanga spawning sites (Hefford 1930) were largely ignored, although the clear demise of the North Island whitebait fishery had been known and discussed for many years (McDowall 1968).

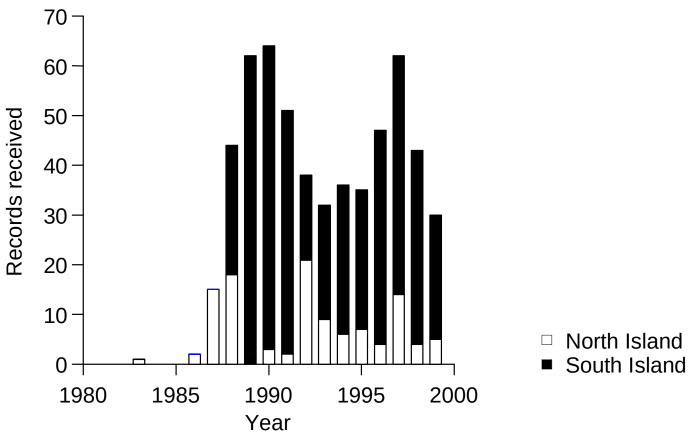
However, after several poor whitebaiting seasons in the 1980s, concern resurfaced about the decline in the national whitebait fishery. Consequently, DOC commissioned the Fisheries Research Division of Ministry of Agriculture and Fisheries (MAF) to undertake field surveys to locate inanga spawning grounds and, subsequently, to provide guidelines to enable DOC staff to continue the surveys. Trained MAF personnel visited conservancies to train DOC staff, and assist in locating inanga spawning grounds in their respective areas. Significant outputs from this programme included:

- A review of South Island spawning sites up to the end of 1991 (Taylor et al. 1992).
- Reports on the whitebait spawning sites in the Bay of Plenty (Mitchell 1990a), and the Waikato River (Mitchell 1990b).
- Research on spawning site management with respect to the detrimental and beneficial effects of grazing in the North Island (Mitchell 1991), and the identification of larval fish to locate spawning sites (Mitchell 1992).
- The production of a waterproof field manual detailing how to locate and manage inanga spawning sites (Mitchell & Eldon 1990). This was distributed to every DOC conservancy.

The South Island review led to the development of a waterproof data form for use in the field (Appendix 1), and a recommendation that a national database of known inanga spawning grounds be established (Taylor et al. 1992). These were to ensure data integrity, to facilitate transfer of data to regional authorities, and to facilitate research on inanga spawning behaviour.

The database was originally set up in Dbase IV® (Ashton-Tate), and administered by NIWA in Christchurch. Graphic modules of SYSTAT® were interfaced to the database for data presentation (Taylor 1993), and subject to daily (incremental) and weekly (full backup) procedures. All verified records of inanga spawning since 1983 were then added to the database, with field-forms completed and backdated for records pre-dating the form's development. Completed field-forms from DOC conservancies have been added to the database annually since 1993, usually over the period between February and the end of the NIWA financial year (June 30) (Fig. 1). The database was transferred to Microsoft Access® in 1997.

Figure 1. Inanga Spawning Database records 1983–99.



At the end of the 1999 season, the database held 562 records from a total of 194 spawning sites (Fig. 2a, b). Some of the major spawning sites are monitored annually or biennially. Each spawning site is assigned a NZMS 260 map reference; however, two spawning locations can be as much as 71 m apart, yet still associated with one grid reference in the database.

3. Objectives

The objectives of this report are:
- To examine trends and patterns arising from collated ecological information within the inanga spawning database (and other relevant data sets), and to discuss their implications for spawning enhancement and management.
- To identify deficiencies in the nationwide distribution of spawning sites, or their subsequent protection.
- To provide recommendations on how further inanga spawning sites can be successfully identified and/or managed.

4. Results

4.1 MAJOR SPAWNING AREAS

The following discussion provides a brief historical summary of the major known spawning sites in each DOC conservancy, and their level of protection from deleterious factors (e.g. stock grazing and trampling, pollution, siltation, flooding).

4.2 NORTH ISLAND

Rivers and their respective estimated spawning areas from North Island conservancies are listed in Table 1.

4.2.1 Northland

Inanga spawning in Northland was first identified in 1997 in the Otaika River which flows into Whangarei Harbour. Although the recorded area is very large (215 m^2, Table 1), egg density was reported to be low and patchy. During that year, the largest site was trampled by stock during the spawning season. While some of the smaller spawning sites were fenced by landowners in 1999, the largest spawning site is still subject to grazing, and its integrity is dependent on the goodwill of the landowners to restrict stock movement.

TABLE 1. ESTIMATED AREAS OF KNOWN SPAWNING SITES FOR THE NORTH ISLAND.

REGION	CATCHMENT	TOTAL AREA (m^2)
Northland	Otaika	215
Waikato	Oparau	18
	Raglan harbour	-
	Waikato	-
Wanganui	Kai Iwi	10
	Kaupokonui	20
	Manawatu	180
	Mokau	8
	Onaero	65
	Rangitikei	32
	Turakina	30
	Unnamed	-
	Waingongoro	-
	Waitara	-
	Waiwhakaiho	-
Wellington	Hutt	45
East Coast/Hawke's Bay	Awatere	
	Haparapara	-
	Karakatuwhere	-
	Waiokaha	-
	Waipoa	20
	Whangaparoa	-
	Wharekahika	-
	Clive	48
	Esk	2
	Tukituki	125
	Tutaekuri	-
Bay of Plenty	Kaituna	-
	Nukuhou	-
	Ohiwa	-
	Otara	150
	Rangitaiki	-
	Uretara	4
	Waiau	4
	Waiaua	-
	Waihi Estuary	-
	Waioeka	-
	Waiotahi	-
	Wairoa	-
	Whakatane	-

- = area not recorded on the database.

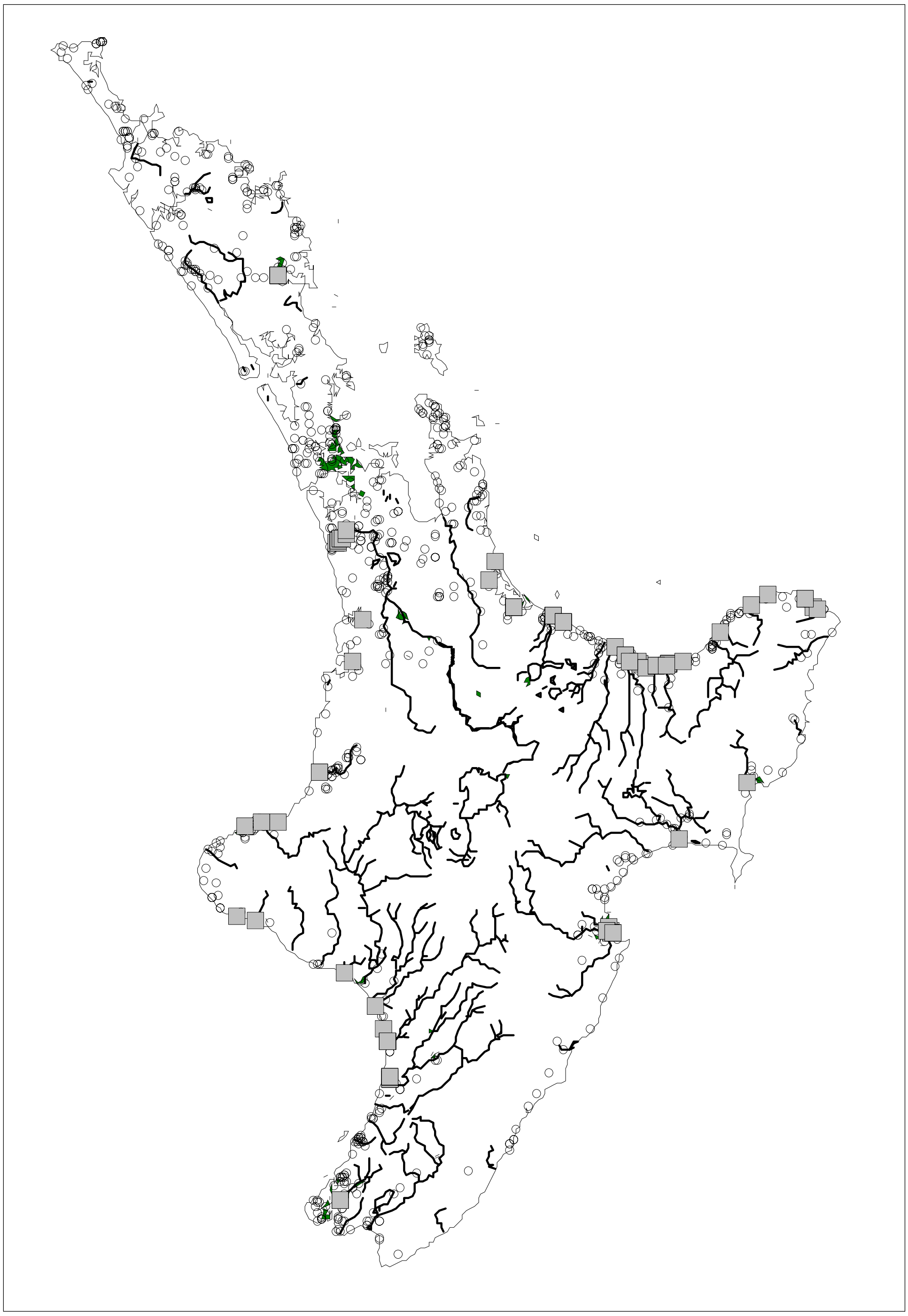


Figure 2a. Known locations of inanga spawning sites in the North Island from 1983 to 1999 (squares), against sites from which inanga have been identified (circles).

Figure 2b. Known locations of inanga spawning sites in the South Island recorded from 1983 to 1999 (squares), against sites from which inanga have been identified (circles).

4.2.2 Auckland

No survey work, or known inanga spawning sites have been recorded from the Auckland conservancy.

4.2.3 Waikato

The lower Waikato River was subject to intensive MAF Fisheries inanga spawning surveys over the period 1983–87 (Mitchell 1990b). Consequently, 11 spawning sites, 10 on the true left bank, were identified along the lower river. One major site discovered in 1983 was duly abandoned by spawning fish after it was trampled by cattle during the study period. In 1987, many of the other known spawning sites were under threat from grazing and immediate steps were recommended to protect them (Mitchell 1990b). At the time of writing, the status and ecological integrity of the lower Waikato spawning sites is unknown, although a recently discovered (1999) site on the Oparau River has been fenced by the landowners.

4.2.4 Bay of Plenty

A large number of spawning sites were identified by MAF Fisheries staff in the Bay of Plenty during the summer of 1987/88, including those found during surveys of the Waiaua, Waioeka and Waiotahi Rivers (Mitchell 1990a). In 1992, further spawning sites (in the Waiau and Uretara Rivers) were identified by DOC, and the known spawning grounds were resurveyed.

While the area of the Waioeka (Otara River) site at Opotiki has not been accurately determined, it was estimated to be approximately 150 m^2, and considered to be the largest known spawning site in the Bay of Plenty. It was utilised by spawning fish each year from 1988 to 1992, before being damaged by grazing stock. A restricted out-of-season grazing regime was recommended for this site, as the technique had been successfully deployed further downstream where spawning is located on a river island.

The size of spawning sites, or spawning intensities have not been estimated for many of the Bay of the Plenty sites, despite sketch plans and comments on the datasheets indicating that they are substantial. No further updates on the spawning sites in the Bay of Plenty have been received since the 1992 field surveys.

4.2.5 East Coast/Hawke's Bay

A number of small and widespread spawning sites were located in the East Coast Conservancy from 1992 to 1994. Again, while the sizes of the spawning sites were not estimated, it is clear that some were substantial. For example, in the Whangaparoa catchment, both banks of two parallel streams were heavily utilised for spawning over a distance of 25 m. Unfortunately, the spawning site and stream banks, including eggs, were heavily trampled by stock. In fact, unrestricted stock grazing appeared to be an undesirable feature of all the East Coast spawning sites, including an additional site identified in 1997. Watercress gatherers may have reduced the value of this particular site, as eggs were found attached to the stems and leaves of this plant.

Some of the best examples of the benefits of habitat restoration work are found in Hawke's Bay Conservancy. Inanga spawning was first recorded on the Clive River (along an 80 m length) in April 1991. This site and adjacent areas upstream and downstream were fenced so that grazing stock were excluded from 160 m of river bank. The length of river bank used for spawning had increased significantly when the site was monitored during the 1992 season, and by the end of the 1993 season, inanga spawning on the Clive River extended over the full extent of the fenced area. The fenced area was again extended by a further 100 m after the 1993 spawning season in an effort to further augment inanga spawning (H. Rook, pers. comm.). Similarly, the Tutaekuri River spawning site was first identified in April 1991 and extended over a length of approximately 70 m. While fenced from grazing stock, and utilised again for spawning in 1992, the 1993 spawning season was poor. An oil-contaminated boom found downstream of the site indicated that the site had probably been polluted during the season.

One of the largest spawning sites recorded was found in the Tukituki River in May 1993. Spawning extended over 250 m of riverbank, and was very intensive, reaching levels 5 and 6 on the database spawning activity index (Table 2). This site was fenced by Hawke's Bay Regional Council and DOC, with an additional 50 m of riverbank fenced upstream in an effort to extend spawning further along the reach. By the end of 1994, an estimated 1.7 km of fencing had been erected on three rivers in the Hawke's Bay Conservancy. These sites continued to be used during the autumnal tides, but also in spring (October), when significant numbers of inanga were observed spawning at the Tukituki site in 1996. Spawning by another inanga year-class took place on the Tukituki site during the following autumn (May 1997), and also on the Clive River.

TABLE 2. SPAWNING ACTIVITY INDEX USED ON DATABASE SURVEY FORM (SEE APPENDIX 1b).

1.	Pre-spawning shoaling. Tight shoals of ripe strippable fish swimming parallel to the bank. These fish often intrude into very shallow water, often (but not always) at locations where they spawn on subsequent tides. Pre-spawning shoaling takes place usually when the tide is rising or at its peak. Spawning cues (milt production, or splashing) are not associated with shoaling behaviour.
2.	Just detectable spawning involving less than 200 fish. No milt detectable in the water, and spawning barely audible.
3.	Spawning associated with 200–1000 fish, slight water discolouration by milt. Spawning audible between 5 and 10 metres away.
4.	Spawning audible from about 10 m away, with definite water discolouration in the shallows, but no discolouration in flowing water. Large shoals (1000–3000) of spent fish may be seen leaving the area.
5.	Intense spawning activity involving 3000 to 10 000 fish, audible from some distance, with strong discolouration of both standing and flowing water.
6.	Shoals of 10 000s of spent fish observed leaving area. Conspicuous, intense, noisy spawning causing extensive water discolouration by milt downstream of the spawning site.

4.2.6 Wanganui

Major spawning sites in the Wanganui Conservancy include those on the Manawatu River (180 m^2) and the Onaero River (65 m^2). The large Manawatu site has been protected by temporary electric fencing since the 1995 season, and the Onaero site has been both fenced and planted in flax, as have a number of other spawning sites in the Conservancy (Waitara, Mokau). At the time of writing, an uncooperative landowner prevented protection of the Rangitikei River spawning site.

4.2.7 Wellington

Currently, there is little inanga spawning data for Wellington Conservancy. This is partly due to the steep coastal topography over much of the conservancy that limits the freshwater habitat suitable for inanga recruitment, rearing and, thus, spawning potential; and partly to staff changes in Wellington conservancy during the late 1990s that have affected data transfer to NIWA.

A spawning site with an area of 25 m^2 was identified on the Hutt River (at Sladden Park, Lower Hutt) in April 1996, and was considered to be vulnerable because the grass was regularly mown to the water's edge, and because of oil pollution from a nearby boat ramp. Another site was identified on Black Creek on the opposite side of the Hutt River channel. In 1998, DOC raised management options for the site with Hutt City Council, but no response from the Council has been received (P. Griffen, DOC, pers. comm.). A recent spawning site survey commissioned by the Wellington Regional Council allowed the author to visit the site in April 2000, and it was clear that riparian management had not changed since the 1996 survey, and no eggs were found there.

4.3 SOUTH ISLAND

Rivers and their respective estimated spawning areas from South Island conservancies are listed in Table 3.

4.3.1 Nelson/Marlborough

Inanga spawning sites have been identified in Nelson/Marlborough Conservancy since the 1993 spawning season. To the end of 1999, spawning had been identified from six catchments, including an unnamed catchment comprising a spring-fed stream rising on the Motueka River delta, but flowing directly into the sea (Table 3). This waterway had a relatively large spawning area compared with its catchment area.

Inanga spawning has been reported from several locations within the Wairau Catchment, including Roses Overflow, the Opawa River, and the Pukaka Drain areas. The Roses Overflow spawning site has been monitored since 1993, and landowners had agreed in 1997 to co-operate with fencing the river margin. Inanga spawning was identified over a reasonable area from Pearl Creek on the Waimea River in 1994 (Table 3), but unfortunately some of the area is subject to grazing.

TABLE 3. ESTIMATED AREAS OF KNOWN SPAWNING SITES FROM SOUTH ISLAND RIVERS.

CONSERVANCY	CATCHMENT	TOTAL AREA (m^2)
Canterbury	Ashley	58
	Avon	50
	Ellesmere	13
	Heathcote	21
	Opihi	-
	Orari	1
	Pareora	3
	Rakaia	-
	Rangitata	1
	Waihao	-
	Waimakariri	8
	Washdyke Ck	1
Otago	Catlins	7
	Kakanui	121
	Otago Harbour	3
	Purakaunui	2
	Shag	36.1
	Taeri	10
	Taieri	29.5
	Waianakarua	6
	Waikouaiti	57.5
	Waitaiti	1
	Waitaki	1
	Waitati	9
Southland	Aparima	-
	Mataura	2
West Coast	Buller	36
	Granite	100
	Grey	119
	Jones	15
	Karamea	-
	Mahinapua	-
	Makawhio	3
	Manakaiaua	1
	Moeraki	3
	Okari	2
	Oparara	17
	Orowaiti	23
	Poerua	-
	Taramakau	-
	Turnbull	2
	Waimangaroa	12
	Waita	1
	Waitaha	3
	Waitangitaona	3
	Wall	2
	Wanganui	-
	Whareatea	10
Nelson	Marahau	-
	Otuwhero	38
	Riwaka	-
	Unnamed	100
	Waimea	60
	Wairau	76

-= area not recorded on the database.

4.3.2 West Coast

The West Coast of the South Island is considered to still comprise the most substantial whitebait fishery in New Zealand (McDowall 1990). Therefore, it is hardly surprising that West Coast Conservancy has the largest number and extent of inanga spawning sites recorded in the South Island (352 m^2). This total represents spawning sites distributed over 22 catchments, from the Oparara River in the north to the Turnbull River in the south. The recorded spawning sites on the Granite and Grey Rivers comprise two-thirds of the Conservancy's known spawning area (Table 3). Electric fencing was erected by DOC in 1995 at the Granite Creek site, as the spawning habitat was already subject to stock trampling and grazing. In this ecologically compromised state, egg density was reported as low.

Inanga spawning was recorded from Cobden Island on the main stem of the Grey River in 1990. The major threats to this spawning site were encroaching landfill and leachate from the adjacent Greymouth rubbish dump. The region was resurveyed in 1991, but there has been no Grey River input into the database since then. Three new spawning sites were found on the Orowaiti, Waimangaroa, and Whareatea Rivers in north Westland in 1994, but there has since been little database input from the West Coast. However, the author has had verbal assurances that many of the inanga spawning sites are monitored, fenced, or otherwise excluded from stock damage during the spawning season (P. Gerbeaux pers. comm).

4.3.3 Canterbury

Inanga spawning has been identified in 11 Canterbury catchments, from the Ashley River in the north to the Waihao River in the south. A tributary of the Ashley River (with the colloquial name of 'Benzies Creek') has proved to be a productive and consistent spawning habitat. However, this site (on private land) is occasionally subject to stock damage. Interestingly, one of the largest spawning sites is on the Avon River in suburban Christchurch, where the City Council has desisted from mowing bankside grasses to the water's edge. This site has been monitored by NIWA and DOC since 1989, and spawning has gradually extended more than 250 m upstream (Taylor 1999). Over this same period, the aquatic rearing habitat for inanga in the lower river has also markedly improved, with wetland restoration programmes and intensive riparian plantings contributing to the improvement. Inanga spawning on the Heathcote River has also benefited from regrading and replanting of a favoured riparian area. Inanga spawning has since extended downstream from the restored area.

4.3.4 Otago

Approximately 283 m^2 of spawning area have been recorded from 13 catchments in Otago Conservancy. These extend from the Waitaki River in the north to the Purakaunui River in the south. The Waiareka Creek spawning sites in the Kakanui River catchment are, collectively, the largest and most important in the region. These sites were identified in 1997, and resurveyed in April 1998, when large numbers of eggs were found. The Orbells Crossing spawning sites on the Waikouaiti River were identified in 1996 and, with an area of 50 m^2, represent an important spawning area in Otago. Both the Waikouaiti and Waiareka spawning sites are now completely fenced, and willow trees have been removed from the Waiareka site. Willow trees tend to shade underlying vegetation, reducing its luxuriance and suitability for spawning. Inanga spawning has also been identified in the vicinity of the outlets of Lakes Waihola and Waipori (on the Taieri River system), and eggs may be laid over a large area at these sites. While stock do not have access to these sites, willow trees tend to encroach on the Lake Waipori sites. A small spawning site near the Waitaki River mouth was identified in 1999, but after a rise in water level the eggs were washed away.

4.3.5 Southland

After considerable survey work in Southland Conservancy over a number of years, one spawning site was found in 1996 on the Mataura River, and this site was fenced later that year. In the same year, a large concentration of ripe inanga was observed in a backwater of the Aparima River, a stretch of river where the banks are grazed by cattle. In 1998, the local Whitebaiters Association reported 'massive whitebait shoals' 'moving into the grassy areas' near the suspected site (W. Cooper, DOC, pers. comm.), and this suspected spawning site is also understood to be fenced.

5. Physical factors and their relationship with inanga spawning activity

5.1 SEASONALITY OF INANGA SPAWNING

The database indicated that spawning activity was most frequently recorded during March (Autumn), but some spring spawning was recorded (Fig. 3) during the few occasions when surveys were conducted at this time of year. In fact, there were only 4 months of the year (June–September) when spawning was not recorded. In 1993 an intensive spring spawning event occurred over a significant area of known and established spawning sites in Hawke's Bay. Spring spawning may also take place in other areas of New Zealand, but will only be detected if surveys are conducted at that time.

5.2 GEOGRAPHICAL VARIATION IN ONSET OF SPAWNING

The records show a trend for the main inanga spawning event that occurs from summer through autumn (January to May) to occur later in the season in more northerly locations (Fig. 4). There was a statistically significant correlation between Julian day of spawning records and each record's northing coordinate

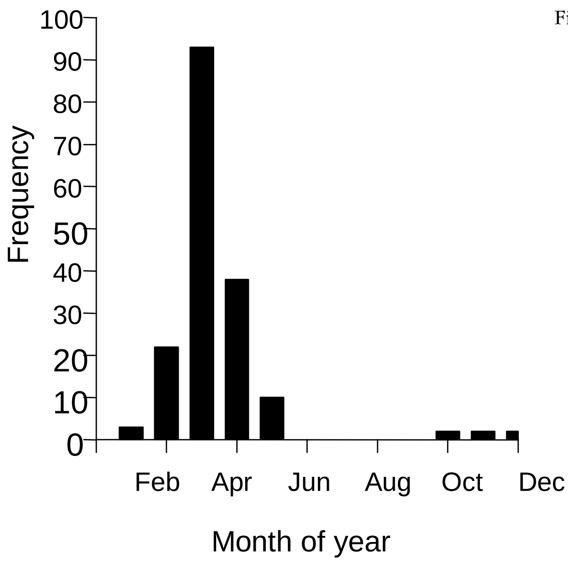


Figure 3. Spawning records by month.

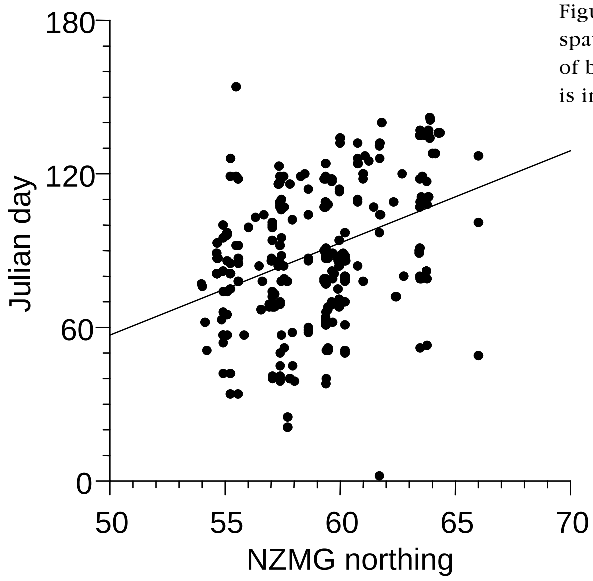


Figure 4. A trend towards later inanga spawning in northern locations. The line of best fit for the untransformed variates is indicated.

($t = 4.8$, $p < 0.05$). However, as there are few records of spawning sites in Southland and a general lack of survey effort from Auckland and Northland, it is not possible to validate this trend. Also, in the North Island, sampling was generally undertaken slightly (but significantly) later in autumn, which complicates the analysis of this relationship. However, spawning does appear to start later with decreasing latitude.

5.3 STREAM ORDER AND SPAWNING ACTIVITY

An index of stream 'order' was derived for each spawning record. For the purposes of this study, and because spawning is largely confined to coastal waterways, the conventional stream ordering protocol is reversed, with numbering beginning from the river mouth (Table 4). This ordering sequence is easier to derive for waterways close to the sea than conventional stream order (which commences in the headwaters), and is more appropriate for a species

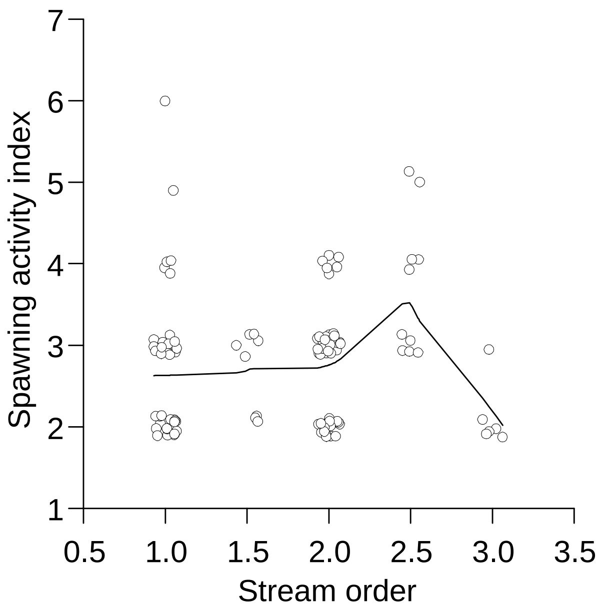
TABLE 4. THE CODING OF STREAM ORDER FOR COASTAL WATERWAYS IN WHICH INANGA SPAWNING WAS RECORDED.

STREAM ORDER	DESCRIPTION
1.0	Main channels discharging directly into the sea.
1.5	Confluence of main channel with any tributary flowing into it.
2.0	Tributary flowing into main channel.
2.5	Confluence of feeders and a tributary flowing into the main channel.
3.0	A feeder flowing into a tributary.
3.5	Confluence of a feeder and a contributing waterway.

that rarely dwell in habitats greater than 30 m a.s.l. In addition, confluences of waterways are specifically coded as there is strong anecdotal evidence that these areas are favoured by spawning inanga.

Recorded peak spawning activity took place in a wide variety of waterways of differing stream order (main channels, and contributing tributaries), with significant differences in activity levels across stream 'orders' (Kruskal Wallis $K = 15.7$, $p < 0.05$, Fig. 5). Peak spawning activity was significantly higher (Mann Whitney $U = 542.5$, $p < 0.05$) at the confluences of waterways than along straight-flowing reaches, and largely due to the high level of spawning activity associated with the confluence of feeders that joined tributaries flowing into the main channel (i.e. order 2.5).

Figure 5. A jittered dot plot indicating a possible elevation of spawning activity in mainstem tributaries. Line = moving average (i.e. lowess smoothing).



An examination of stream order and catchment area revealed that with increasing catchment area, spawning in the tributaries predominated over spawning in the mainstem (Fig. 6). This shift in spawning location, from mainstem locations to tributaries, was statistically significant (Kruskal-Wallis $K = 27.7$, $p < 0.05$). The few data from very large catchments has been omitted because of the difficulties in establishing the relative extent of spawning in large tidal systems.

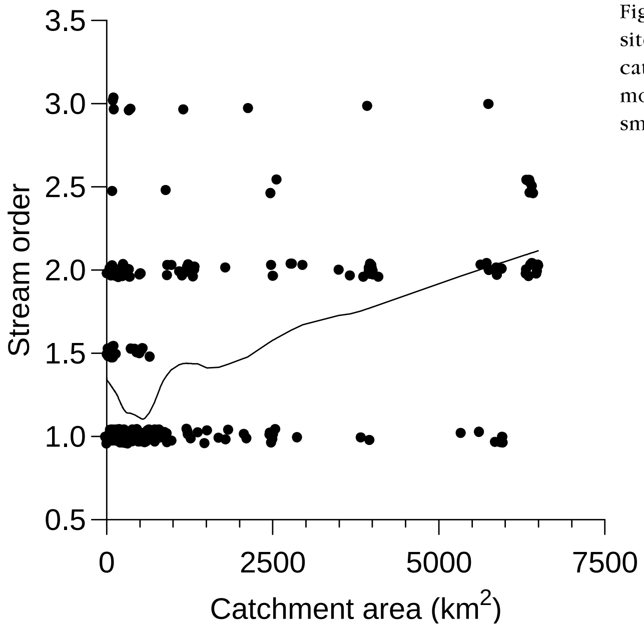


Figure 6. Increasing spawning-site stream order with total catchment area (km^2). Line = moving average (i.e. lowess smoothing).

There was no apparent relationship between overall catchment area and spawning activity levels (as opposed to spawning extent), or between catchment area and the spawning area utilised.

5.4 LUNAR PERIOD

Occasionally, good staffing levels allowed the simultaneous monitoring of inanga spawning from adjacent catchments on the same day. However, on those occasions recorded spawning activity still varied widely between catchments; probably due to differences in inanga population size and maturation rates. Most of the maximum levels of spawning activity were observed several days after the new moon or full moon tide, although most of the surveying effort also took place at that time (Fig. 7). It was occasionally noted on database records that spawning activity peaked when the highest of spring tides had occurred a few days before.

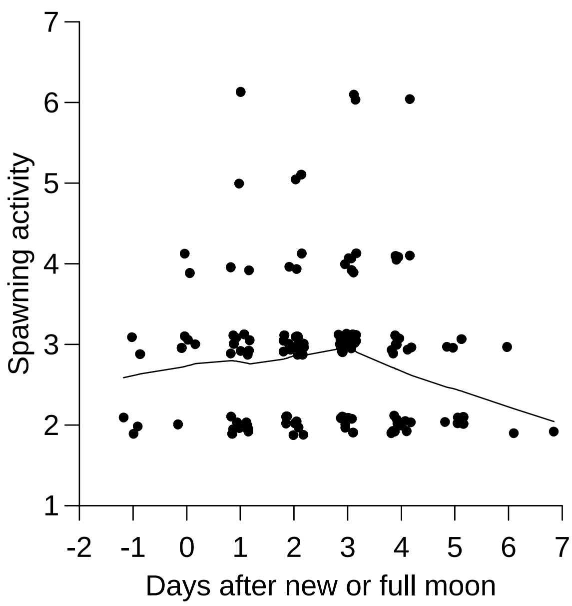
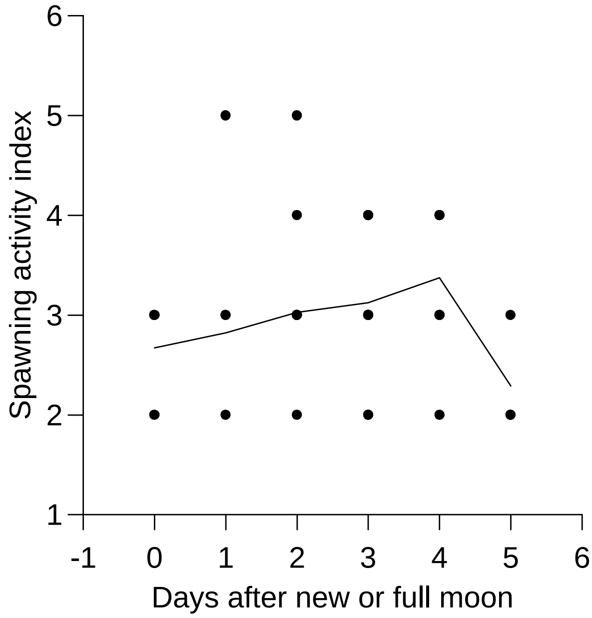


Figure 7. Variation in spawning activity with lunar cycle. Line indicates moving average (lowess smoothing).

While many lowland rivers in New Zealand experience two spring-tides a month, associated with both the new moon or full moon phases, some areas (e.g. the east coast of the South Island) experience only 1 spring-tide a month, associated with either the new or full moon. Inanga spawning is similarly affected, and spawning may occur twice a month in some conservancies (e.g. West Coast), but only once a month in others (e.g. Canterbury).

Clearer patterns of spawning activity emerge where observations are made on successive days on a relatively small number of catchments. The database records four instances from Westland Rivers (Karamea, Buller, Grey, Orowaiti) where spawning activity was monitored consecutively over a sequence of several days on monthly spawning events. These show a clearer relationship with the lunar cycle (Fig. 8).

Figure 8. Variation in spawning activity level in four West Coast catchments. Line = moving average (i.e. lowess smoothing). Some points are superimposed.



5.5 SPAWNING LOCATION IN RELATION TO TIDE HEIGHT AND SALTWATER WEDGE

There were insufficient actual (as opposed to forecasted) tide-height data available from the database to review national trends; however, there were a number of observations in Westland which indicated that on sequential daily falling spring tides, inanga spawned closer to the sea. On the Karamea River, over 2 days, inanga spawned further downstream with a fall in spring tide height of approximately 0.3 m. Similarly, on the Turnbull River tidal amplitude fell by 0.2 m, with a consequent downstream movement of most spawning activity of approximately 200 m.

In practice, it is quite difficult to accurately determine the saltwater limit at the time of peak tide, and usually requires a boat and a conductivity meter. Of the data available, spawning sites were distributed fairly evenly around the termination of the saltwater wedge, with some located well downstream or upstream of the salt limit (Fig. 9). The median distance between spawning sites and the saltwater limit was 107 m (n = 84). Outliers from the trend include a

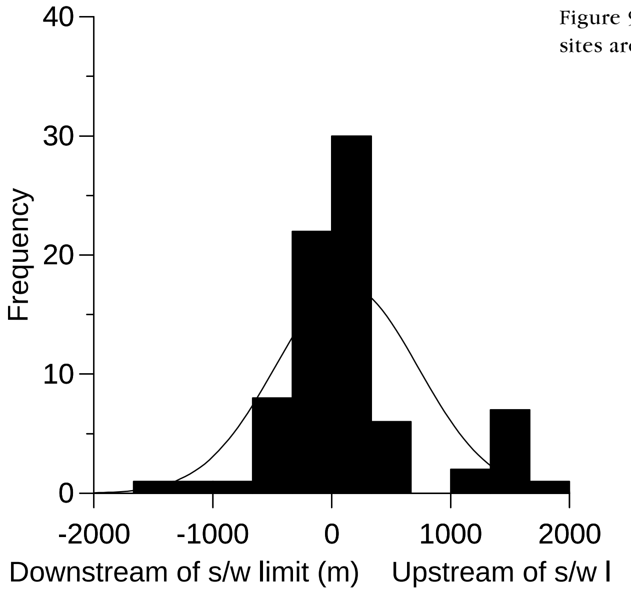


Figure 9. The distribution of spawning sites around the saltwater limit.

spawning site (now abandoned by inanga) on the Heathcote River in Christchurch, located approximately 1.5 km upstream of the existing saltwater wedge. With the decommissioning of a major instream structure, and restoration of the original river course, inanga spawning now takes place much closer to the saltwater limit.

An outlier in the other direction (i.e. spawning well downstream of the saltwater limit) was recorded from the Mokau River on the west coast of the North Island, where spawning was located 12 km downstream of the saltwater limit. The river, however, was under the influence of a 3.6 m tide at the time (for clarity this record is omitted from Fig. 9).

5.6 TIDE-GATES AND CULVERTS

The effect of instream obstructions on inanga spawning was neither well understood nor documented when the inanga spawning database was established. Consequently, a field on the database form allowed users to indicate whether a culvert or tide-gate impeded inanga passage at high-water (Appendix 1).

While spawning was normally only recorded on systems where tide-gates were absent, there are records where limited spawning occurred upstream of faulty gates. For example, inanga spawning was recorded upstream of a faulty gate on the Buller River (West Coast) estuary prior to its repair by local Council staff. After repair, inanga were observed schooling upstream of the obstruction but not spawning. After the gate was jammed open on the next low tide, spawning resumed on the following high tide at the previously established site (J. Green, DOC, pers. comm.). In addition, the author located a single nest of eggs upstream of a flap-valve gate in a tributary draining into the Avon/Heathcote Estuary (Taylor 1999), and spawning was recorded just upstream of flood gates on a tributary of the Wairau River by the Conservation Corps in Marlborough in 1999. In all cases where spawning has been recorded upstream of tide-gates, activity or eggs have been restricted to a small area adjacent to the gates, implying a behavioural response to saltwater leakage through the structure.

Currently, only one small inanga spawning site has been recorded upstream of a culvert, but the extent to which the culvert inhibited saltwater intrusion (or inanga colonisation) was unknown. There are records of spawning downstream of flap-valve tide-gates and, in one instance, this involving spawning over quite an extensive area.

5.7 THE TIMING OF SPAWNING WITH RESPECT TO THE TIDAL CYCLE

The median duration of spawning was 44 minutes (range 10–60 minutes, s.d. = 14 minutes, n = 22), and the median time delay between high tide and the onset of spawning was 55 minutes, although this was highly variable (60 minutes before high tide to a maximum of 142 minutes afterwards, n = 61). This variability may represent inconsistencies in determining the precise time of high tide, but is also likely to reflect the distance between sea and the spawning site, and fish behavioural preferences. For example, the observation of spawning taking place 1 hour before the high tide was at a location well upstream of the saltwater wedge. Inanga have also been recorded spawning on freshes rather than tidally-influenced water-level fluctuations.

6. Biotic factors and their associations with inanga spawning

6.1 RIPARIAN VEGETATION AND SITE SELECTION

Most riparian zones in New Zealand are now dominated by exotic grasses, and the same is true of the majority of spawning sites recorded in the database. Several exotic grasses frequently present in mixed-species communities at spawning sites commonly had inanga eggs attached to them. These were tall fescue *(Festuca arundinacea*), creeping bent (*Agrostis stolonifera*), and Yorkshire fog (*Holcus lanatus*) (Fig. 10). Within these communities, tall fescue was almost always the dominant species, with creeping bent and Yorkshire fog comprising lesser proportions respectively. Tall fescue appeared to dominate grassed riparian zones generally, even those where spawning didn't occur (Raw data, National Inanga Spawning Database).

Exotic herbs favoured at spawning sites included clover (*Trifolium* spp.) and musk, the latter herb usually monkey musk (*Mimulus guttatus*). Although inanga eggs were frequently attached to them, rarely did these plants dominate the riparian plant community. Eggs also adhered to or were trapped on the stems of lotus (*Lotus pendunculatus*), water cress (*Rorippa* spp.), cow parsley (*Anthriscus sylvestris*), and buttercup (*Rununculus* sp.). On one occasion, inanga eggs were found within a moss bed (unidentified sp.).

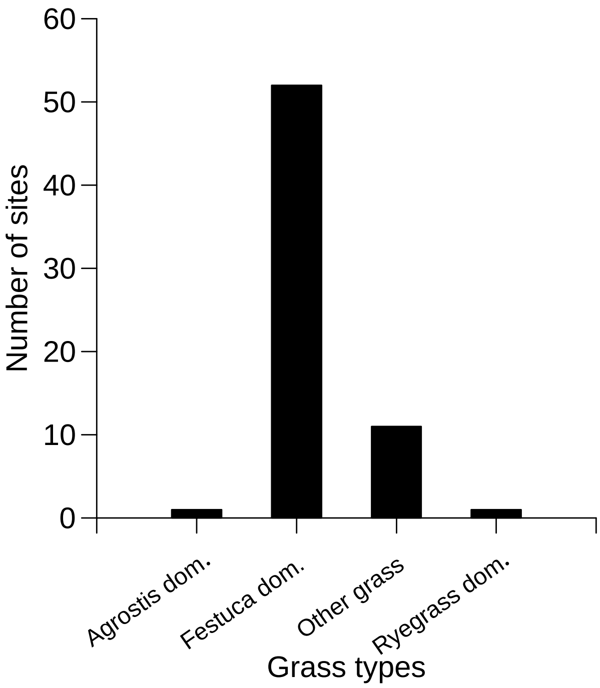


Figure 10. Frequency of occurrence of grass, herb, and native spawning vegetation from known spawning sites (dom. = dominated).

Native vegetation was uncommon in the tidally-influenced riparian zone of many waterways surveyed, and rarely featured at spawning sites. On only three occasions did native vegetation dominate the plants used for spawning. At the locations of these spawning events, eggs were identified on a wide variety of vegetation including flax (*Phormium tenax*), toetoe (*Cortaderia richardii*), raupo (*Typha orientalis*), wiwi (*Juncus gregiflorus*) and, on one occasion, punga. Surrounding associated vegetation included *hebe* sp., *coprosma* sp., and kowhai (*Sophora* sp.).

Invasion of exotic grasses unsuitable for spawning fish is a potential problem in some parts of the country. Species of concern at present are reed sweet grass (*Glyceria maxima*) (Bay of Plenty, Mitchell 1993; Wellington, Taylor 2001; lower Clutha, pers. obs.) and reed canary grass (*Phalaris arundinacea*). Reed canary grass was introduced approximately 30 years ago, reportedly for cattle feed. It is invading the wetlands around Lake Wainono and the Waihao River (south Canterbury), and is proving to be unsuitable for spawning fish (S. Harraway, DOC, pers. comm.).

7. Discussion

7.1 REGIONAL VARIATIONS IN INANGA HABITAT AND SPAWNING SITE KNOWLEDGE AND PROTECTION

Some conservancies have surveyed their administrative region extensively, and have succeeded in identifying and protecting many spawning sites. West Coast conservancy has, from the outset of the programme in 1988, attempted to distribute expertise and surveying effort over the conservancy's long coastline.

A high standard of reporting at both the field centre and conservancy level has facilitated the monitoring of inanga spawning sites, despite high staff turnover and several departmental restructurings.

However, a comparison between the national distribution of inanga and known spawning sites (Tables 1 & 3; Figs. 2a & b) indicates areas where surveys are required to identify further spawning sites. These include Northland, Auckland, Waikato, Wellington and Southland Conservancies, and specific geographic areas in other conservancies, e.g. Coromandel Peninsula in Waikato Conservancy, Kaikoura Peninsula and Golden Bay in Nelson/Marlborough Conservancy, Banks Peninsula in Canterbury Conservancy and parts of Hawke's Bay Conservancy. In the case of Hawke's Bay, the spawning sites that have been identified are substantial and are now well protected from wandering stock. Also, there are relatively few rivers that support inanga in this conservancy—particularly in the southern Hawke's Bay–northern Wairarapa area (McDowall 1984).

It would appear that identifying and protecting inanga habitat is not a priority in Northland and Auckland conservancies, which is not unexpected, given that the whitebait fishery in these areas is small (McDowall 1984). In contrast, in the southern part of the North Island, there are many records of inanga a number of streams and rivers around and to the northwest of Wellington with good whitebait runs (e.g. Horokiwi, Makara, and Pauatahanui Streams) for which spawning sites have yet to be identified. Fortunately, rivers in the Wellington province are currently being surveyed for inanga spawning sites in a joint programme between the Wellington Regional Council and NIWA (Taylor 2001).

The identification of inanga spawning sites reportedly appears on the business plans of many conservancies early in the financial year, but excessive workloads and changes in priorities within conservancies frequently result in the work being deferred. In conservancies where sites have previously been identified and protected, deferment of monitoring-type work for a year is unlikely to lead to major problems. However, the postponing of fencing or other protection works at spawning sites vulnerable to routine grazing or other threats is of concern. In this category are the many identified spawning areas along the lower Waikato River which are known to be vulnerable to stock grazing (Mitchell 1990b); although some protection work is now underway (C. Annandale, DOC, pers. comm.).

Steep coastal areas (with the exception of East Cape) are generally poorly surveyed, not only because of access difficulties, but also because areas of suitable habitat and resident populations of inanga tend to be small, meaning that inanga spawning sites are also likely to be small and hard to find. Further, the protection of a number of small spawning sites is relatively expensive compared with protection of a smaller number of larger spawning sites. For this reason, the specific priority in some conservancies (e.g. West Coast) has been to identify spawning sites in rivers with known or suspected large inanga populations.

The flood-plains of major rivers in the southern half of the South Island are extensively drained, pastoralised, and protected with tide-gates. Consequently, the availability of areas suitable for spawning may be low in comparison to the amount of adult and rearing habitat available. Examples of this situation include the lower river margins in Southland (especially the Mataura River), and the Clutha River. A recent inanga spawning survey of the latter catchment indicated that while the river possessed a good whitebait run, the availability of unmodified and ungrazed spawning habitat without tide-gates (which have been demonstrated to inhibit inanga spawning) was surprisingly small (NIWA data).

There are some coastal areas of the New Zealand where few inanga are present and, by extension, little inanga spawning is expected. These include most of Fiordland, where the topography is too steep for inanga (McDowall 1981), and the east coast of the lower North Island (Cape Palliser to Hawke's Bay), which is both steep and dry.

7.2 SEASONALITY OF INANGA SPAWNING

While the whitebait run is primarily a springtime event, it is known that fresh whitebait can be caught in rivers at all times of the year (McDowall & Eldon 1980). Because inanga rarely live for more than one year, it implies that some inanga spawn at low levels during seasons other than autumn. In support of this precept are historical anecdotal accounts of significant 'out-of-season' spawning (R. McDowall, NIWA, pers. comm.) and spring inanga spawning is known to occur in Chile (Peredo 1994).

There were no recent records of significant spring spawning in New Zealand until the database record of intense spawning activity in October 1993. This spring spawning event occurred at a known spawning site on the Tukituki River (Hawke's Bay Conservancy). This area had been subject to heavy grazing pressure in the past, but after being fenced from stock for 4 years, it had re-vegetated with a luxuriant sward of exotic grasses. The intensity and magnitude of the spawning activity (level 5 out of 6, see Table 2) implied a significant population of 'out-of-season' inanga, which may reflect good habitat conditions for inanga generally, both at sea and in rivers and streams. There are ecological advantages to 'out-of-season' breeding. Whitebait returning to rivers in autumn would not be subject to fishing pressure from whitebaiters, and predation from trout (post-spawning) is likely to be lower than at other times. Eel predation may also be lower during the winter when water temperatures drop below 10°C (Jellyman & Todd 1982).

Some fenced spawning sites are deliberately grazed by cattle during the spring to prevent the displacement of vegetation suitable for spawning with noxious weeds and woody plants. However, 'out-of-season' inanga spawning could present a problem for this management regime, and 'spot checks' should be conducted to ensure inanga are not attempting to spawn during the period in which stock are present.

7.3 STREAM ORDER AND SPAWNING ACTIVITY

The relationship between stream order and spawning activity must be interpreted in conjunction with the relationship between stream order and catchment area. It is becoming increasingly clear that inanga (at least nowadays) prefer to spawn in smaller waters, with smaller upstream catchment areas, and a lower risk of flooding. On the Waikato River, most recorded spawning was associated with the confluence of tributaries which enter the main river, and confluences or bank embayments appear to feature in many spawning sites throughout New Zealand. It would appear that spawning fish are seeking locations with low water velocities, and low risk of flooding and egg loss. Nationally, these results indicate spawning activity is often high at the confluence of mainstem tributaries and their feeders, similar to the results obtained from the database in 1993 (Taylor 1993). Lower laminar flows, or even eddies, may also increase the probability of egg fertilisation, as milt will be retained over the eggs for a longer time period. In summary, there is fairly clear evidence from the database that spawning inanga prefer confluences, embayments, back eddies, or other areas isolated from a strong laminar water current.

7.4 LUNAR PERIOD

The lunar and tidal periodicity of inanga spawning migrations has been well described in previous research work (Burnet 1965), and spawning activity appears to be related to lunar phase (Benzie 1968). How ripe inanga co-ordinate the downstream spawning migrations when well upstream of the tidal influence remains a mystery (McDowall 1969). The database results indicate that maximal spawning activity takes place 2 or 3 days after the new or full moon (Fig. 7), which is often when tidal waters are at or just past their peak. The variation in spawning activity with lunar phase probably reflects the variation in spawning populations between rivers, and that spawning is more directly related to tidal patterns and water level changes than lunar phase.

There is circumstantial evidence that inanga spawning (as opposed to migration) is triggered by water level changes rather than lunar phase. For example, spawning has been observed during a fresh on Papakeri Creek and Makawhio River in West Coast Conservancy. This event occurred a day before the new moon. The database also records inanga spawning during the peak of a wind-induced level change on Lake Ellesmere, a shallow coastal windswept lake in Canterbury.

Hatching of inanga eggs depends on their being re-immersed in water, so the water level must rise to at least the level it was when the eggs were laid. The risk of fully-developed embryos dying before another rise in water level is reduced by the eggs having yolk reserves that are sufficient to sustain embryos for several weeks after full development, particularly if temperatures are low (Benzie 1968). Under normal conditions this period should include several tides or freshes potentially high enough to re-immerse them.

7.5 GEOGRAPHICAL VARIATION IN THE ONSET OF SPAWNING

The database shows a statistically significant trend for inanga spawning to be recorded later in the autumn in the North Island. However, northern locations were also surveyed significantly later in the season, which prevents definitive conclusions on the influence of latitude on inanga spawning (possibly mediated by the influence of water temperatures and photoperiod). The temporal shift in spawning records appears stronger than the surveying bias, and as further data is gathered from Northland, especially early in the season from established spawning sites, then a statistical assessment of geographical trends may become possible, perhaps with a parametric 'analysis of covariance' approach.

Certainly, throughout New Zealand, inanga spawning is likely to take place at any time from February to April, but eggs have been found as early as January in Westland, and as late as June on the Waikanae River on the Kapiti Coast north of Wellington (McDowall 1968). It is probable that egg nests deposited in June in the South Island, especially in Canterbury, Otago, or Southland, would be exposed to frosts and, to my knowledge, no live inanga eggs have been observed under such conditions.

7.6 EMBRYONIC DEVELOPMENT WITH TEMPERATURE

The embryonic development and temperature regime of an isolated egg nest (in tall fescue grass) has been monitored at an inanga spawning site in Christchurch during May (Taylor 1998). In this simple field experiment, a small temperature logger recorded the temperature of the egg nest *in situ* at hourly intervals for a period of 23 days. While spawning probably took place on a spring-tide event, the nest was deposited well below the maximum water level, and was regularly inundated by tides of only moderate amplitude. This was verified by direct observation, and from the temperature record, which showed sharp changes in temperature as the nest was submerged. As a consequence of the repeated nest flooding, many viable eggs from the nest were dispersed up and down the bank as they developed, presumably under the agitating action of the rising and falling tides. Whether the increased submergence time would increase their exposure to ingestion by other fish is unknown. After approximately 3 weeks, the initial egg mass had diffused amongst the surrounding grasses to such an extent that it was difficult to locate sufficient eggs to evaluate embryo development stage.

In this field trial, egg nest temperatures varied between 3.4°C and 14.7°C (mean 9.8°C), although temperatures 'spiked' when the eggs were flooded on the incoming tide. Development rates based on the collected eggs and the mean temperature were consistent with the results of Benzie (1968).

The normal development time of inanga eggs is given by the following formula:

$D = 38 - 1.68 \times T$ (Taylor 1998)

where D = development time in days, and T is the mean temperature (°C).

7.7 SPAWNING VEGETATION

The quality of spawning vegetation is critical for successful egg development. There are many examples of this throughout New Zealand. In Hawke's Bay, the quality of grass vegetation used for spawning was improved over several years by extending the area fenced from grazing stock (H. Rook, DOC, pers. comm.). Similarly, in Christchurch City, the area used by spawning inanga has been extended by not mowing bank-side grass over the late summer and autumn period.

Spawning occurs amongst a variety of exotic and indigenous plant species, all of which provide a sheltered humid environment for egg development. The manner in which the humid micro-habitat is maintained varies among plants. A number of exotic grasses are well suited to maintaining a viable inanga egg micro-climate. For example, the tall fescue grass (*Festuca arundinacea*) is commonly associated with inanga spawning. It grows in clumps, and produces an encircling mat of decomposing grass blades in the late summer and autumn, which are often used as substrate for inanga eggs. The shallow-rooted grass develops a fine root mat near the soil surface that traps inanga eggs close to the soil surface (Taylor et. al 1992). Under these conditions a microhabitat of almost 100% humidity can be maintained, even under very dry (8% Relative Humidity) open-air conditions (Taylor 1995). Yorkshire fog (*Holcus lanatus*) has a similar habit, except that it is the downy leaf blades and stems (that provide excellent adherence) where eggs are found. Eggs adhere to the horizontal root runners of creeping bent (*Agrostis stolonifera*), which overlie the soil surface. Creeping bent can also tolerate long periods of root submergence, and will grow out into the waterway, providing refuge for spawning fish.

At least one exotic grass introduced in relatively recent times has caused major problems for whitebait spawning in the lower reaches of some rivers. North Island trials have shown that reed sweet grass (*Glyceria maxima*) is avoided by spawning inanga (Mitchell 1993). This grass, which originally had a Eurasian distribution, is also a problem weed in the USA. While stock grazing may prevent *Glyceria* from dominating grass communities, the plant is known to be cyanogenic and has caused deaths in grazing cattle (Barton 1983). In the past, intermittent stock grazing regimes have been used to prevent suitable exotic grass plant assemblages from being succeeded by unsuitable woody plant communities, but this may not be possible if *Glyceria* becomes the dominant grass.

The herb monkey musk (*Mimulus guttatus*) has a growth habit similar to creeping bent. It grows out from the stream margins and across the water surface, as both its stems and leaves are buoyant. This foliage forms a thick floating canopy, obscuring the shoals of inanga from predators. In a similar manner to Yorkshire fog, the monkey musk stems are slightly pubescent, and eggs are often found on the underside of the stems and leaves. Lotus (*Lotus pedunculatus*), and watercress (*Nasturtim* spp.) may also trap many inanga eggs. Watercress is sometimes harvested, particularly by Maori, and runanga may have to be made aware of its importance to inanga if it is used locally as a spawning substrate.

7.8 NATIVE VEGETATION

In recent times, more aggressive exotic riparian flora have largely supplanted native vegetation on coastal river reaches. However, while most indigenous flora is now gone, the remnants provide sufficient information to assess what these areas used to be like. For example, Meurk (undated) has provided the following description:

'The unmodified, tidally influenced riparian vegetation of Westland must have comprised tall overarching forest and scrub: kowhai, pate, manatu, kahikatea, NZ broom, ti kouka, tree tutu, putaputaweta and other forest trees, and tall tussock species—notably harakeke, tussock sedge, mikimiki, koromiko, wiwi, oioi, and kiokio. (N.B. oioi or jointed rush is typically a species of brackish water, however it is occasionally found in freshwater swamps so its zonal position is somewhat blurry).

This cover sheltered and shaded the banks and trapped leaves and twigs, and supported a loose growth of soft turfy sedges (purei), spike sedge, and various herbs such as *Leptinella, Pratia, Hydrocotyle, Rununculus, Potentilla* and mosses. It was within the roots and decaying leaf litter among the sedges and herbs, under the taller vegetation, that the inanga must have spawned.... '

The few database records of native spawning vegetation are consistent with this floral description, although it is now known that beds of emergent raupo are also utilised. Raupo and flax beds have proved to be very difficult to inspect for inanga eggs, because the tall strong vegetation prevents easy access. However, the author has heard inanga spawning within raupo beds in Lake Ellesmere and has found the eggs adhering to their decomposing leaves after tidal waters have receded (Taylor et al. 1992). Schools of inanga have also been observed concentrating spawning activity in the centre of emergent raupo beds (S. Harraway, DOC Otago, pers. comm.). This behaviour may represent an adaptation to minimise predation by wading birds or eels.

7.9 SPAWNING LOCATION IN RELATION TO TIDE HEIGHT AND SALTWATER WEDGE

While the majority of spawning sites recorded on the database are located near the termination of the saltwater wedge, many are still significant distances upstream or downstream (Fig. 9). There are still considerable differences of opinion regarding the importance of the saltwater wedge to inanga spawning, and the problem is compounded by the technical difficulty of conclusively establishing the longitudinal distribution of eggs, except in the most minor of waterways. It is the author's view that migrating inanga use the saltwater/freshwater interface as a cue to trigger spawning, and that the spawning location relative to the interface, whether upstream or downstream, is dependant on the availability of appropriate vegetation. Evidence for this is provided by the clear progression of spawning locations downstream on falling sequential spring tides within one catchment. However, this only occurs if spawning vegetation is suitable over a generally wide area.

The lack of access to a saltwater wedge appears to inhibit spawning behaviour and, importantly, if access to salt is re-established, spawning will resume. For this reason, there is some justification for experimenting with the partial opening, or controlled leaking, of tidegates in an effort to trigger spawning. The quantities of saltwater required may be very small, easily controlled, and therefore present little or no risk of flooding.

8. Implications for spawning ground management

Examination of the data collated on the Inanga Spawning Database suggests the following must be addressed in the locating and management of spawning sites:

- When searching for spawning sites, small tributaries must be checked as well as mainstem sites, particularly in large catchments. In large catchments, the confluences of waterways feeding into major tributaries are worth particular attention.
- Spring (October–November) spawning may be taking place in many areas. In places where grazing animals are used to suppress woody-plant adventives, an effort should be made to ensure that possible springtime spawning doesn't coincide with stock grazing.
- Extensive flax and raupo beds may play an important role in spawning. Many of these areas have been disregarded because spawning had not been observed on their periphery. However, there is now evidence that significant spawning may take place in the centre of these beds.
- There are early indications that some spawning habitats may be under threat from introduced grasses unsuitable for fish spawning, especially reed sweet grass (*Glyceria maxima*) and and reed canary grass (*Phalaris arundinacea*). Field staff are reminded to be vigilant for these grasses, and support their eradication.

9. Future of the Inanga Spawning Database

The Inanga Spawning Database has been administered by MAF and, latterly, NIWA since the database was conceived in 1990. There have been a number of tangible benefits of having the database administered at a national level. A national overview has facilitated spawning site identification over a wide geographical area, and the protection of a number of sites in nearly every DOC conservancy has allowed most conservancies to contribute to both the regional and national whitebait fishery. Survey expertise has also been dispersed throughout the country, which reduces the risk of knowledge loss through staff turnover. National consistency in data format and data integrity has facilitated analysis, and has allowed the replacement of conservancy paper records on several occasions. Further, the ecological progress of each spawning site can be tracked, and those conservancies contributing little data, or those with threatened or important spawning sites, can be easily identified and encouraged to contribute.

In the course of surveying and managing inanga spawning sites, DOC has developed positive relationships with voluntary conservation and/or environmental groups, trusts, schools, farmers, and Maori. The issues associated with spawning site management are now being handled effectively at a local level, in different ways appropriate to each conservancy. While a national perspective has been useful to encourage the initial identification of spawning sites, the subsequent local-level response to management issues will, ultimately, determine the fate of the whitebait fishery resource. It would therefore appear appropriate for the inanga spawning database to continue, but with administration by DOC.

10. Recommendations

In addition to the points raised in the Section 8, the author makes the following recommendations:

- As the administrative body most directly responsible for managing inanga and inanga spawning sites, it would be appropriate for the Department of Conservation to take over administrative control and responsibility for the Inanga Spawning Database.
- More data on spawning sites are needed particularly from Northland, Auckland, Wellington and Southland Conservancies, and protection works along the Waikato River catchment should be encouraged.
- GPS (Global Positioning System) position fixes on spawning sites should be made and transferred to a computer database, or stored in a GIS (Geographic Information System) format. Most of the positional errors in GPS have now been removed, and this allows accurate determination (< 10 m) of position (in NZMG) and in real time without the use of supplementary radio signal information. GPS fixing would facilitate the relocation of sites by inexperienced staff, but would also be useful in GIS mapping, land management and protection work when the data is shared between DOC and local or regional authorities.

12. Acknowledgements

This report originated from work carried out under Department of Conservation research investigation 3230.

My gratitude is extended to the Department of Conservation for financially supporting not only this review, but the identification of inanga spawning sites, and their subsequent protection over many years. The Christchurch City Council is acknowledged for allowing the use of microhabitat temperature and humidity data which was collated under their commission.

Locating inanga spawning sites is not easy. Searching for tiny eggs or spawning activity in bankside vegetation is often wet, dirty, tedious work; hard on the back, and the spirit. The nature of this activity, and the fact that many people willingly sacrificed many hours of their own time attests to the quality and character of the people involved. I thank all the personnel from DOC, Regional Councils, District Councils, NIWA, cultural and school groups who have assisted in identifying and protecting inanga spawning sites. Some, but not all, of these people are listed below:

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Wanganui: D.A. Smith, Norm Marsh, Matt Cook, Tom Rouse, Bryan Williams.

Wellington: Marcus Simons, Roger Elliott, Bruce Dix.

West Coast: Martin Abel, Alan Buckland, Ted Breenan, Bill Cain, Kevin Casey, Maria Cole, Colligan family, Barry Chalmers, Mr. Cunningham, Shane Cross, David Eastwood, Tony Eldon, Alice Gilsenan, Philippe Gerbeaux, John Green, Barry Hanson, Steve Herring, Greg Kelly, Geoff Kitchin, Barry Hanson, Mal Hansen, Craig Miller, Chris Pugsley, George from the Karamea Field Centre, Charlie Mitchell, Ian McLennan, Stephen O'Dea, John Reid, Norm Stopforth, Joe Syron, and Chris Woolmore.

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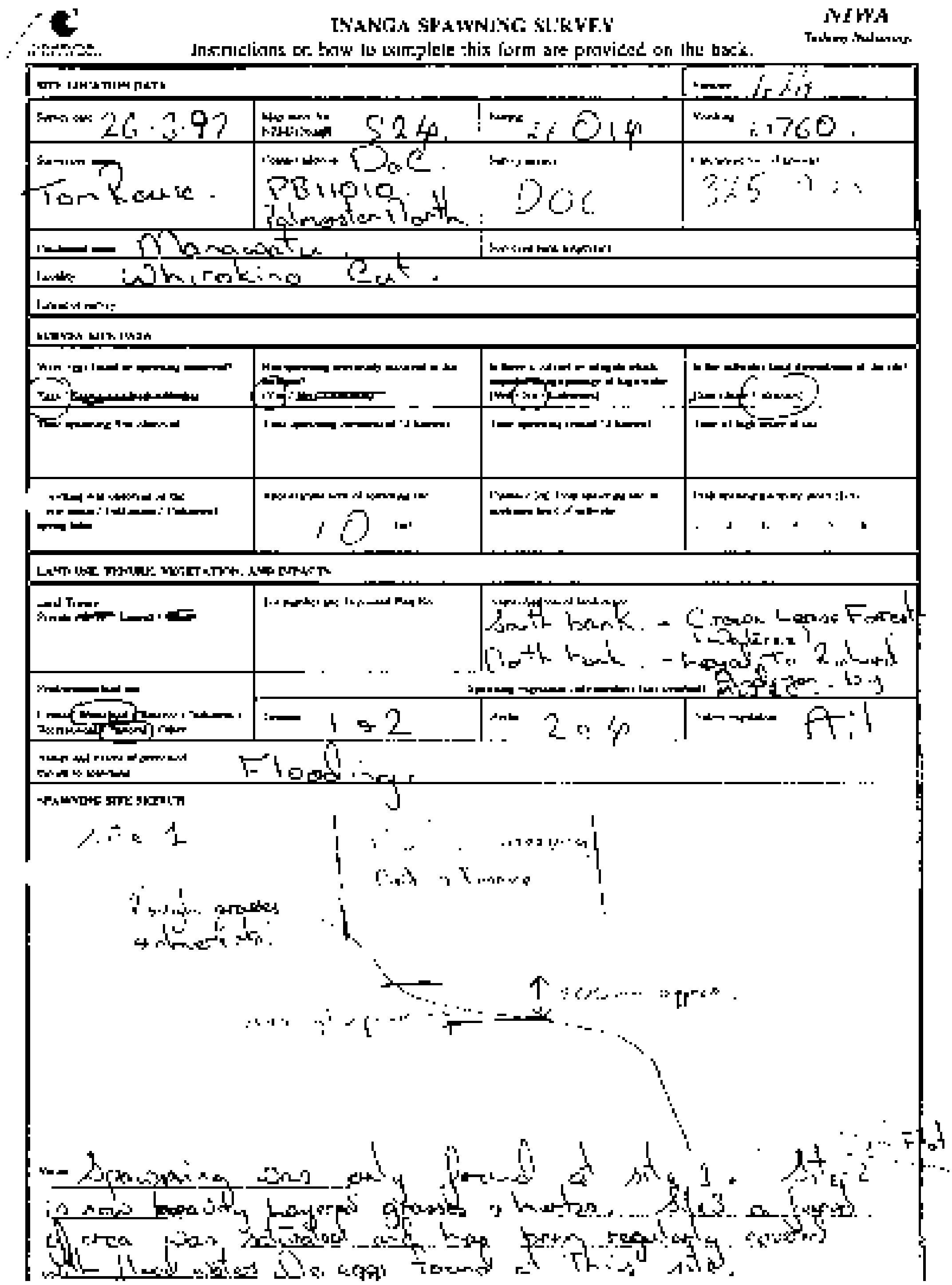
APPENDIX 1a

Sample inanga spawning database form.


INANGA SPAWNING SURVEY

Instructions on how to complete this form are provided on the back.

NIWA

26·3·97

S24

014

760

Tom Rowe

DoC PB11010 Palmerston North

DOC

Manawatu

Whirokino Cut

10

South bank - Crown Lease Forest

1 & 2

2 & 4

Flooding

Site 1

APPENDIX 1b

Instructions and code explanations for the inanga spawning database form.

GUIDELINES FOR COMPLETING THE INANGA SPAWNING SURVEY FORM

It's not expected for everyone to have the knowledge or experience to completely fill in the survey form, but your best effort is certainly appreciated. On this precept, if you are not sure about filling in a section, please don't guess. Leave the appropriate section blank, and jot your thoughts down in the notes section at the base of the form. The waterproof field guide "How to locate and protect whitebait spawning grounds", published by MAF Fisheries, is an invaluable aid for locating and evaluating spawning grounds.

Number: A space for entering your own classification code or record number.

Map sheet Number: Cross out either the old inch to the mile map series (NZMS 1) or the metric 1:50000 (NZMS 260) series. Please give the full grid reference.

Catchment number: As published in Catchments of New Zealand, issued by the Soil Conservation and Rivers Control Council.

Surveyed bank length: The length of river course systematically surveyed.

Extent of survey: A brief description of the extent of the area surveyed. Eg. From main road bridge to estuary mouth.

Time spawning commenced: The time spawning actually started, which is not necessarily the time spawning was first observed.

Spawning Activity Index: Enter the most applicable level of spawning activity when spawning is at its peak.

1. Prespawning shoaling. Tight shoals of ripe strippable fish swimming parallel to the bank. These fish often intrude into very shallow water, often (but not always) at locations where they spawn on subsequent tides. Prespawning shoaling takes place usually when the tide is rising or at its peak. Spawning cues (milt production, or splashing) are not associated with prespawning shoaling behaviour.

2. Just detectable spawning involving less than 200 fish. No milt detectable in the water, and spawning barely audible.

3. Spawning associated with 200-1000 fish, slight water discolouration by milt. Spawning audible between 5-10 metres away.

4. Spawning audible from about 10 m away, with definite water discolouration in the shallows, but no discolouration in flowing water. Large shoals (1000-3000) of spent fish may be seen leaving the area.

5. Intense spawning activity involving 3000 to 10000 fish, audible from some distance, with strong discolouration of both standing and flowing water.

6. Shoals of 10,000's of spent fish observed leaving area. Conspicuous, intense, noisy spawning causing extensive water discolouration by milt downstream of the spawning site.

Spawning vegetation code numbers:

List, in order of predominance, plants in the vicinity where spawning occurred. The codes which pertain to the most prevalent vegetation should be underlined, and a ring should be drawn around the code numbers representing vegetation upon which inanga eggs were directly attached. For example, if eggs were found on the grass Yorkshire fog in a community dominated by tall fescue, with some carex, buttercup, and clover, then this would be coded:
Grasses 1, 4 Herbs 4,2 Native Vege 2. If you are unsure of the identity of a plant, code it as 'unknown' in the meantime. You may wish to take a sample from the site to get it identified by an expert. If you are confident that there is spawning site plant other than those listed present, then state its identity in the notes.

Vegetation codes:

Grasses:	1.	Tall fescue	Herbs:	1.	Lotus
	2.	Creeping bent		2.	Clover
	3.	Chewings fescue		3.	Musk
	4.	Yorkshire fog		4.	Buttercup
	5.	Mercer grass		5.	Plantain
	6.	Perennial ryegrass		6.	Water celery
	7.	Swamp millet		7.	Moss
	8.	Other, specify		8.	Creeping Jenny
	9.	Unknown		9.	Mint
				10.	Selfheal
Native Vegetation:	1.	Toetoe (Toitoi)		11.	Yarrow
	2.	Cutty grass (carex)		12.	Wandering Jew
	3.	Niggerhead		13.	Cow parsley
	4.	Wiwi (NZ rush)		14.	Twitch
	5.	Jointed rush		15.	Other, specify
	6.	Oioi (jointed wire rush)		16.	Unknown
	7.	Spike Rush			
	8.	Umbrella sedge			
	9.	Raupo			
	10.	Flax			
	11.	Other, specify			
	12.	Unknown			

Nature and extent of perceived threats to spawning:

A brief note on actual or impending damage to the spawning site. Eg. stock grazing and/or trampling, pollution, flooding, grass mowing etc.

Spawning site sketch:

A quick sketch of the spawning site(s) or area surveyed in relation to the water course, and possibly a 'side-on' drawing of the bank profile, depicting the relationship between the eggs, the surrounding vegetation, and the slope of the stream bank to the waters edge.

Photographs:

If you like, you can paste photographs on this side of the form.