Lamprey pheromones in the Tasman Region, 2019-2020

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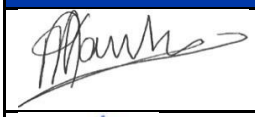	Reviewed by:	Paul Franklin
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Executive summary

From September 2020, New Zealand has new national policies (Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (NESFW) & National Policy Statement for Freshwater Management (NPSFM) 2020) that will significantly enhance the management of threatened freshwater fish species in New Zealand. These new policies require every regional council to identify and protect the habitats of threatened species. In the Tasman Region, lamprey (kanakana/piharau) is one freshwater fish species whose habitats require protection under the new legislation as they are classified as "Threatened - Nationally Vulnerable" in the New Zealand Threat Classification. For Tasman District Council to protect lamprey populations, an understanding of their distribution in the region is fundamental. To assist in locating lamprey populations, NIWA has developed Polar Organic Chemical Integrative Samplers (POCIS). POCIS are deployed in streams for several weeks, where they accumulate the pheromone petromyzonol sulphate (PS) that is released by upstream resident larval lamprey. The amount of PS taken up by the sampler can be used to calculate average concentrations of PS in the stream water and this can be related back to larvae populations upstream of the sampling point. Detection of larval populations helps identify important spawning and larval rearing streams, as the pheromone signature of larvae is used by migratory adults to select spawning streams.

In 2019 and 2020, POCIS were utilised to examine the distribution of larval lamprey at 48 sites in the Tasman Region. Results indicate that the Aorere, Waimea, Paturau and Motueka river catchments have a higher abundance of larval lamprey relative to the other sites sampled. These river systems entering the Tasman and Golden Bays could, therefore, be important spawning and larval rearing habitats. Of importance is that Waimea Water Limited are in the process of building a water supply dam on the Lee River, which is a key tributary of the Waimea River catchment containing a strong lamprey signature. Presently, the proposed fish pass at Waimea Dam is designed to enable fish species capable of climbing passage upstream of the dam, namely koaro and longfin eels. However, lamprey is not included in the target fish species and lamprey require a very different passage structure to other native fish. POCIS results suggest that lamprey spawning and rearing habitat will be impacted by the pending Waimea Dam and as they are a threatened fish species this is in breach of Section 26ZJ of the Conservation Amendment Act 2019.

Identification of larval populations using the POCIS methodology creates a baseline for further investigations to help pinpoint areas of catchments where lamprey are resident and determine what parts of the catchment are key habitat for lamprey. Based on the POCIS data, catchments should be prioritised for surveys of lamprey and their habitat to ground truth results and to determine the extent of habitats present for both spawning and larval rearing. Identification of these critical life-stage habitats will enable Tasman District Council to meet their requirements under the NPSFM (2020) and devise management strategies for the protection of lamprey populations.

1 Introduction

Pouched lamprey (kanakana/piharau; *Geotria australis*) have an anadromous life cycle with three key life stages. Larvae, or ammocoetes, begin their life as blind filter feeders in freshwater. After several years in freshwater, juvenile lamprey metamorphose (change colour and form) into macrophthalmia and migrate to the sea. In the ocean they are parasitic and feed on other fish. After 3-5 years in the ocean, adult lamprey re-enter freshwaters between autumn and spring and travel upstream to their spawning areas. It is thought that adults select spawning streams by detecting the scent (or pheromones) released by larvae resident upstream. The adults do not feed once in freshwater and they will spend up to 18 months maturing before they spawn and die.

Lamprey can be regarded as a "living fossil" and aside from their intrinsic value for native biodiversity, historically, lamprey were a very important mahinga kai for Maori communities. However, populations are in decline and, presently, lamprey are classified as "Threatened - Nationally Vulnerable" in the New Zealand Threat Classification (Dunn et al. 2018). In September 2020, new national policies take effect; the National Policy Statement for Freshwater Management (NPSFM) 2020 and the National Environmental Standards for Freshwater (NESFW). These new policies require every regional council to identify and protect the habitats of threatened species. For Tasman District Council to meet their legislative requirements and protect threatened lamprey populations, an understanding of their distribution in the region is fundamental. However, suitable habitats are often in remote headwater streams, electric fishing is often ineffective at sampling juvenile lamprey, and although adults spend over a year in freshwater before spawning, they are cryptic and cannot be captured in nets or through electric fishing outside of their upriver migration.

1.1 Polar Organic Chemical Integrative Sampler (POCIS)

Pheromone samplers, recently developed by NIWA, can be used as an alternative monitoring technique to overcome sampling limitations (Stewart et al. 2011; Stewart and Baker 2012). Pheromones are chemicals that pass between members of the same species that have inherent meaning. In the case of fish, pheromones are water-soluble and found in low concentrations. As such, sensitive and selective methods are needed to separate and analyse these pheromones from an environmental matrix that may contain many other chemicals (Stewart et al. 2013). NIWA researchers have found that pouched lamprey is the only New Zealand species to release the pheromone, petromyzonol sulphate (PS; Figure 1-1), which is thought to form one of the pheromone cues used by adult lamprey to select spawning streams during their upriver migrations.

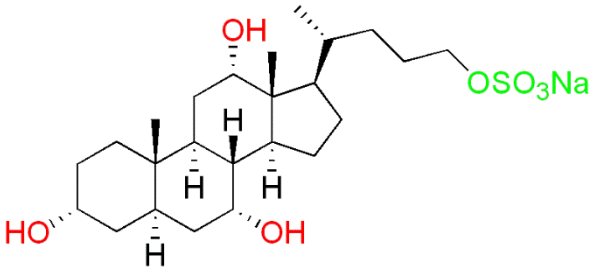

Figure 1-1: Chemical structure of petromyzonol sulphate.

NIWA developed Polar Organic Chemical Integrative Samplers (POCIS) in 2008 and have since used them to estimate the abundance of stream resident lamprey larvae at sites across New Zealand.

POCIS are deployed in streams for a set length of time (usually between one to three weeks) where they accumulate the pheromone petromyzonol sulphate from the water (Figure 1-2). Advanced mass spectrometry analysis is used to measure the amount of PS accumulated by each sampler (Stewart et al. 2011). By incorporating POCIS uptake kinetics and stream flow, the amount of PS in each sampler is then related back to an average PS water concentration over the deployment period. Due to the low abundance of lamprey larvae in New Zealand, stream concentrations of PS are extremely low. As such, traditional grab water sampling has proven ineffective for detecting PS in a study catchment, whereas POCIS returned positive results for most sites (Stewart and Baker 2012).

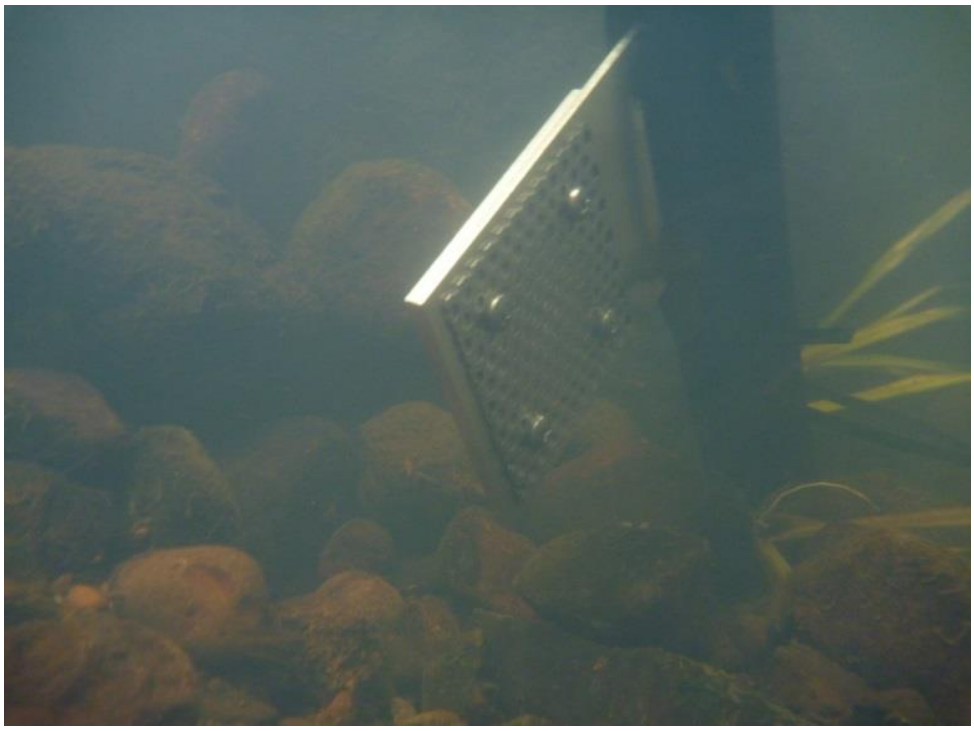

Figure 1-2: Typical POCIS deployment in streams.

As POCIS accumulate PS over time, they can be used to provide a crude estimate of larval lamprey abundance upstream of the sampling point. The use of the pheromone samplers also enables the monitoring of a much larger area than would be possible with manual sampling, as each sampler effectively samples the entire volume of water upstream of its location. To electric fish or set nets over an equivalent area is logistically challenging due to the time and labour required. In addition, because adult lamprey are thought to select spawning streams based on the presence and abundance of larval lamprey, the identification of streams containing high densities of larvae can be used to infer the importance of these areas for adult spawning.

In 2019 and 2020, Tasman District Council (TDC) utilised the pheromone samplers to examine the distribution of larval lamprey in their region. This report presents the results of the POCIS deployment across both years.

2 Methods

2.1 Sampling sites

POCIS were deployed and successfully retrieved at 27 sites in the Tasman Region in 2019 (Table 2-1) and at 20 sites in the Tasman Region in 2020 (Table 2-2). Each sampler was attached to a warratah installed adjacent to the main flow of the stream or river. In periods of high rainfall (flood events) or in fast water velocities, the membrane that retains the POCIS sorbent can tear, releasing the sorbent into the water and causing the sampler to fail. It is postulated that this is through hydraulic shear stress. During the 2019 sampling, 25 of 27 Tasman Region POCIS were retrieved with their membranes intact. One additional POCIS from the Tasman Region located in the Buller River (Site 28) was stolen/lost and could not be retrieved. During the 2020 survey, all 20 POCIS were retrieved with their membranes intact.

Table 2-1: Sample sites and time of POCIS deployment for the 28 sites in the Tasman Region catchment in 2019.

Site Number	Sample	Stream	Deployed	Retrieved	Days Deployed	NZTM Northing	NZTM Easting
1	TDC1	Wairoa River @ SH6	11/02/2019	27/02/2019	16	1610000	5419545
2	TDC2	Wai-iti River @ Waimea West Rd	11/02/2019	27/02/2019	16	1608240	5420465
3	TDC3	Dove River 355 m US Motueka	11/02/2019	27/02/2019	16	1585232	5432000
4	TDC4	Motueka Upstream Motupiko	11/02/2019	27/02/2019	16	1586230	5411125
5	TDC5	Motupiko 6200 m US Motueka	11/02/2019	27/02/2019	16	1583525	5406760
6	TDC6	Wangapeka 375 m US Motueka	11/02/2019	Removed from H_2O	16	1581795	5424582
7	TDC7	Pearse 80 m US Motueka River	11/02/2019	27/02/2019	16	1584278	5435455
8	TDC8	Graham Stream at 50 m DS Motueka West Bank Rd	11/02/2019	27/02/2019	16	1586145	5437590
9	TDC9	Motueka DS Graham TR	11/02/2019	27/02/2019	16	1586372	5437505
10	TDC10	Rocky River at Motueka West Bank Rd	11/02/2019	27/02/2019	16	1593374	5443832
11	TDC11	Shaggery River at Motueka West Bank Rd	11/02/2019	27/02/2019	16	1595746	5448457
12	TDC12	Brooklyn Stream at Motueka West Bank Rd	11/02/2019	27/02/2019	16	1597275	5450515
13	TDC13	Takaka River @ Kotinga	11/02/2019	27/02/2019	Membrane torn	1584026	5475930
14	TDC14	Anatimo Creek @ McShane Rd	11/02/2019	28/02/2019	17	1595423	5480260

Site Number	Sample	Stream	Deployed	Retrieved	Days Deployed	NZTM Northing	NZTM Easting
15	TDC15	Basin Creek @ Quartz Range Rd	12/02/2019	28/02/2019	16	1557455	5480235
16	TDC16	Kaituna @ Solly Road	12/02/2019	28/02/2019	16	1567397	5492740
17	TDC17	Aorere ~100 m DS Rockville Bridge	12/02/2019	28/02/2019	16	1568648	5491340
18	TDC18	Aorere @ Le Comte	12/02/2019	28/02/2019	16	1569540	5498150
19	TDC19	Parapara 2300 m US SH60	12/02/2019	27/02/2019	15	1572434	5490062
20	TDC20	Onekaka at Shambala	12/02/2019	27/02/2019	15	1575145	5488025
21	TDC21	Parawhakaoho at SH60	12/02/2019	27/02/2019	15	1577931	5484035
22	TDC22	Bell Creek (Waikoropupu River) 230 m US Springs River	12/02/2019	27/02/2019	15	1580662	5478665
23	TDC23	Anatoki River	12/02/2019	27/02/2019	15	1583128	5475747
24	TDC24	Mangles @ 5km US Buller	14/02/2019	27/02/2019	Membrane torn	1549275	5370635
25	TDC25	Matakitaki @ SH6 (100 m d-s)	14/02/2019	27/02/2019	13	1543415	5372340
26	TDC26	Maruia @ US Buller	14/02/2019	27/02/2019	13	1534770	5372875
27	TDC27	Owen @ 275 m US SH6	14/02/2019	27/02/2019	13	1554520	5385155
28	N/A	Buller @ US Ariki	14/02/2019	Lost/stolen		1532653	5374780

Table 2-2: Sample sites and time of POCIS deployment for the 20 sites in the Tasman Region catchment in 2020.

Site Number	Sample	Stream	Deployed	Retrieved	Days Deployed	NZTM Northing	NZTM Easting
1	TDC1	Lee Rv 370 m US Roding	19/2/2020	2/03/2020	12	5416285	1612730
2	TDC2	Roding Rv 300 m US Lee	19/2/2020	2/03/2020	12	5416610	1612575
3	TDC3	Wairoa Rv 575m US Lee	19/2/2020	2/03/2020	12	5415815	1610590
4	TDC4	Webb Stm 280m US Anatori	19/2/2020	2/03/2020	12	5493195	1546280
5	TDC5	Anatori 240m US Webb	19/2/2020	2/03/2020	12	5493200	1546165
6	TDC6	Patarau Rv 3km US Dry Rd Br	19/2/2020	2/03/2020	12	5499515	1554170
7	TDC7	Bonny Doon 500m DS Parakeet Ck	19/2/2020	2/03/2020	12	5489900	1563835
8	TDC8	Kaituna Rv 930m US BonnyDoon	19/2/2020	2/03/2020	12	5492350	1564575
9	TDC9	Wainui Rv 30m US Totaranui Rd	20/2/2020	3/03/2020	12	5479420	1594725
10	TDC10	Waingaro Rv 30m US Takaka	20/2/2020	3/03/2020	12	5474310	1583955

Site Number	Sample	Stream	Deployed	Retrieved	Days Deployed	NZTM Northing	NZTM Easting
11	TDC11	Takaka Rv 5m US Lindsay Br	20/2/2020	3/03/2020	12	5462605	1584790
12	TDC12	Riuwaka N Brch 80m US S Brch	20/2/2020	3/03/2020	12	5455855	1593575
13	TDC13	Riuwaka S Brch 30m US N Brch	20/2/2020	3/03/2020	12	5455865	1593645
14	TDC14	Riuwaka Rv at SH60	20/2/2020	3/03/2020	12	5453985	1598735
15	TDC15	Baton 420m US Motueka	20/2/2020	3/03/2020	12	5430560	1583470
16	TDC16	Dart 70m US Wangapeka Rd	20/2/2020	3/03/2020	12	5414470	1570680
17	TDC17	Wangapeka Rv 50m US Dart	20/2/2020	3/03/2020	12	5414760	1570785
18	TDC18	Sherry at Blue Rock	20/2/2020	3/03/2020	12	5419370	1578050
19	TDC19	Wai-iti at Wai-iti Vly Rd Belgrove	20/2/2020	3/03/2020	12	5410630	1596430
20	TDC20	Moutere at Chings Rd	21/2/2020	3/03/2020	11	5443150	1599415

2.2 Methodology for calculation of PS water concentrations from POCIS

POCIS is very effective in estimating time weighted average (TWA) water concentrations of PS at extremely low concentrations with detection limits around 12 fmol (12×10^{-15} M).[1] In contrast, using the same mass spectrometry technique, traditional grab water sampling affords detection limits of 2.5×10^{-14} M, which is considerably higher than those provided by POCIS (Stewart & Baker 2012).

Time weighted average (TWA) water concentrations of PS were calculated from equation (1), where C_w is the TWA concentration of the analyte in the water (ng/L), C_s is the concentration of the analyte in the sorbent (ng/g) at time t (days), M_s is the mass of sorbent in the POCIS (g) and R_s is the sampling rate (L/day).

$$(1)\ C_w = \frac{C_S M_s}{R_s t}$$

An indicative sampling rate (R_s) for PS was established as 0.4 L/day by laboratory loading experiments (Stewart and Baker 2012). However, variables such as flow, temperature, biofouling and pH can all affect sampling rates under field conditions (Harman et al. 2012). The effect that each variable has is still not widely known. However, these variables have been controlled as much as practical by:

1. Placing the samplers in the main flow of streams.
2. Minimising temperature effects by deploying samplers at sites within reasonable proximity to each other and at the same time.
3. Deploying samplers for similar time periods to standardise the amount of fouling.

[1] Detection limits are determined to a large extent by the time of deployment, which is why they can vary. We attempt to deploy POCIS for the same length of time to provide a consistent detection limit.

R_s remains a significant source of uncertainty in the calculation of water concentrations and could only be accurately calculated by a series of experiments to assess the effects of variables stated above (flow, temperature, biofouling and pH) on PS uptake kinetics on POCIS.

There is a reasonable relationship between R_s and log D (essentially the 'water solubility' of a chemical) as shown in Figure 2-1. Log D for PS was calculated as 3.14 (www.chemaxon.com) and from the formula in Figure 2-1, R_s of 0.235 was calculated for PS.

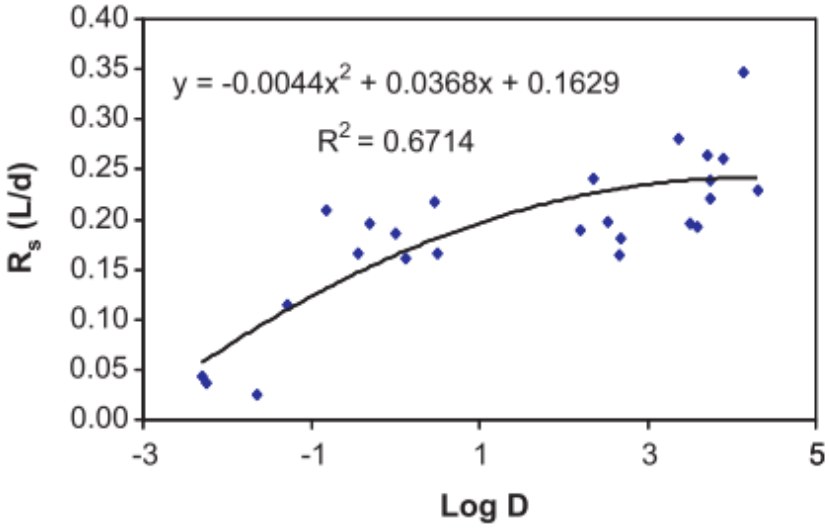

Figure 2-1: Relationship between sampling rate (Rs) and log D for trace organic chemicals. From Morin et al. (2013).

2.3 Extraction and analysis of POCIS

POCIS were retrieved from each stream, packed on ice and frozen at -20 °C until transported on ice to NIWA Hamilton. POCIS were extracted in batches of two, each following the same protocol. After allowing sufficient time to thaw (approximately 5 minutes), loose debris was washed off the outside of each membrane with NanoPure™ water. POCIS housings were clamped to ensure the sorbent was kept intact and fastenings removed. Membranes were carefully pulled apart with tweezers and the sampler placed into a glass funnel over a sintered glass funnel (Figure 2-2).

The POCIS sorbent was subsequently washed into the sintered glass funnel with methanol (ca. 10 mL) and extracted, under vacuum, into a 100 mL glass round bottom flask. Further methanol (10 mL) was added to the sintered glass funnel and evacuated under vacuum into the round bottom glass. This process was repeated 3 times to give exhaustive extraction of PS from the sorbent and a final volume of 50 mL.

Methanol was removed under rotary evaporation and residual water by high vacuum. Methanol (1 mL) was added to the flask and sonicated to ensure dissolution of PS. This was passed through a 0.2 µm nylon syringe filter into an amber 2 mL glass vial. This process was carried out twice. Methanol (2 mL) was removed under a stream of N_2 gas, the vial capped and kept frozen until mass spectrometry analysis by Analytica Laboratories Ltd (Hamilton) using the method described in Stewart et al. (2011).

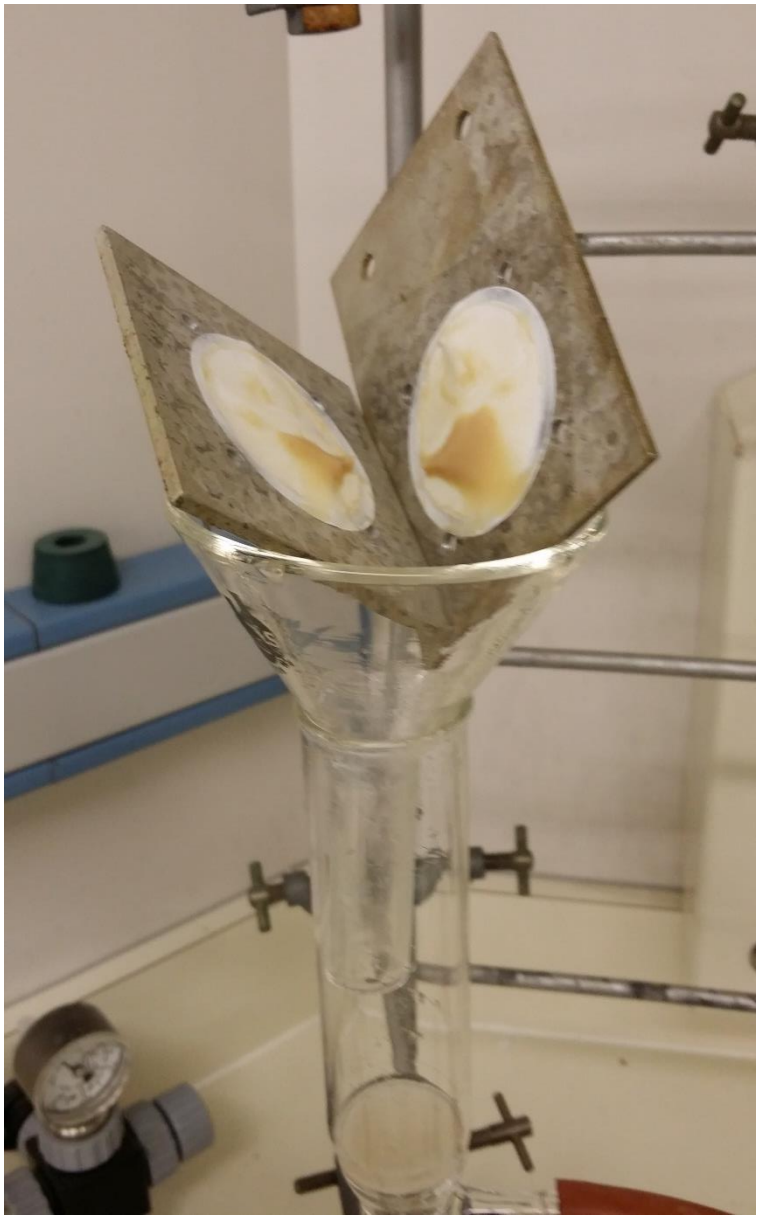

Figure 2-2: POCIS sampler being prepared for extraction. Note the brown paste is the POCIS sorbent and the white circular patches are the two membranes.

2.4 Caveats

It is acknowledged that there is inherent variability and error in the estimates used to create a measure of larval abundance upstream of each POCIS sampling point. Briefly, the main errors arise from:

1. The uptake rate of PS by POCIS has been calculated under laboratory conditions (Stewart and Baker, 2012), but not under field conditions. However, field calculations are not practical as water temperature, fouling, pH and flow can all influence the uptake of PS. To account for this, variability has been minimised as best as is practical and an uptake rate of PS has been derived based on the relationship between its physico-chemical properties and published literature uptake values for a series of chemicals (Morin et al. 2013).

2. Earlier studies have shown that PS degrades rapidly in stream water due to microbial breakdown, with a half-life of 1.5 days (Polkinghorne et al. 2001). With POCIS deployment typically around 2 weeks it is necessary to protect PS from microbial breakdown while the sampler is in the stream. Polyether sulfone (PES) membranes are the most effective for long term use in integrative samplers (Alvarez et al. 2004) and, with a pore size of 0.1 µm, will prevent microbial infiltration of the sorbent and the associated breakdown of PS.

3. The true flow rate through each sampler over the deployment period cannot be accurately measured and only a crude estimate can be derived from databases and hydrological monitoring stations.

With inherent sources of uncertainty, the relative abundance estimates calculated from the POCIS samplers are considered very crude semi-quantitative estimates. In this regard they can be used to infer streams that are likely to contain high and low larval densities relative to other sites sampled in the catchment over the same monitoring period. Because of the spatial and temporal variability inherent in all factors used to develop the abundance estimates, the figures should never be used to compare POCIS data between catchments or POCIS data in the same catchment over a different time period.

It is important to note that if sites failed to detect the larval pheromone, it does not mean that lamprey are necessarily absent. Instead it indicates that the concentration of the larval pheromone is below the detection threshold and, therefore, lamprey are either absent or in low abundances in those areas. This suggests that such waterways, even if low densities of lamprey exist, are not key spawning and rearing areas relative to sites where the pheromone is detected in high concentrations.

3 Results & discussion

3.1 Water concentrations

Time weighted average (TWA) water concentrations were calculated for each site over the deployment period (Figure 3-1 & Figure 3-2). The larval lamprey pheromone PS was detected at 12 sites in 2019 and 5 sites in 2020.

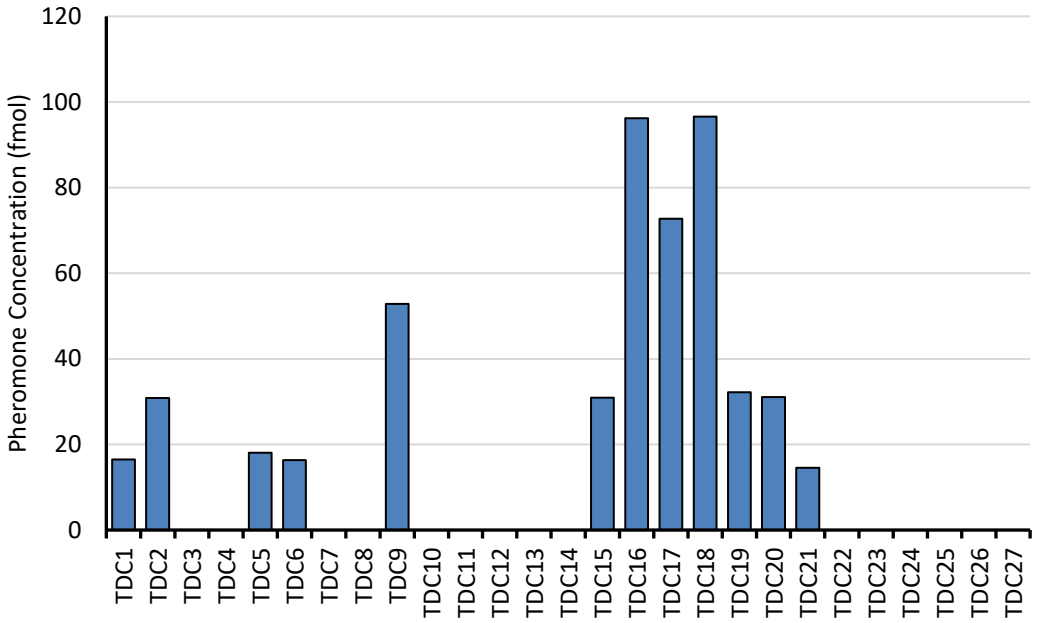

Figure 3-1: Calculated time averaged water concentrations (fmol) of petromyzonol sulphate (PS) for the sites sampled with POCIS in the Tasman Region catchment in 2019. Note: fmol is 10^{-15} M.

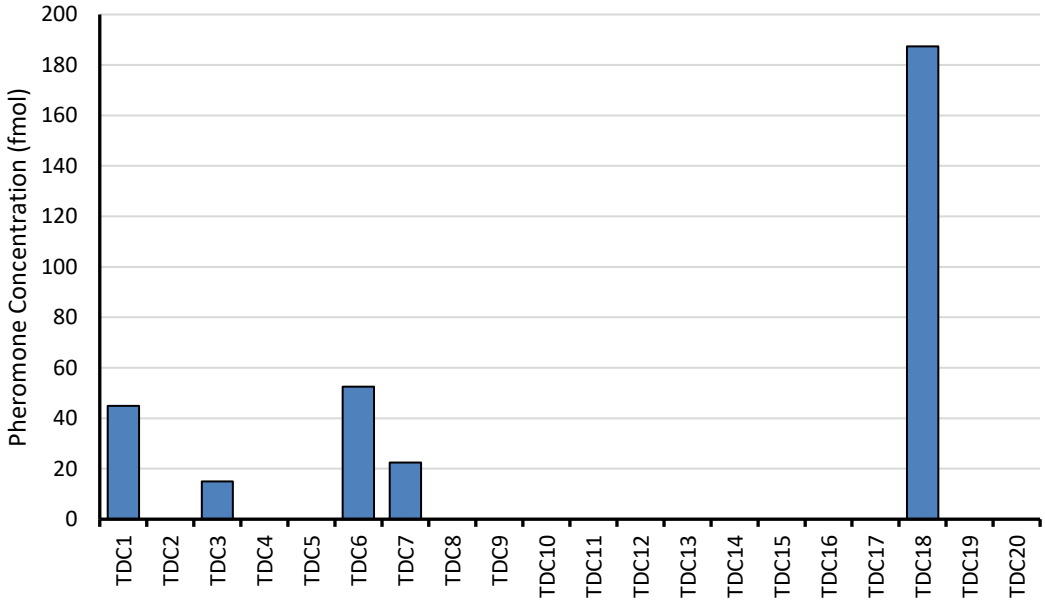

Figure 3-2: Calculated time average water concentrations (fmol) of petromyzonol sulphate (PS) for the sites sampled with POCIS in the Tasman Region catchment in 2020. Note: fmol is 10^{-15} M.

The sample sites with larval pheromone (PS) detections were mostly located on the mainstem of rivers in both years, with the compound not detected in many tributaries sampled (Figure 3-3 – Figure 3-5). As the river catchments sampled contain a large number of tributary streams, data indicates that lamprey are residing in select tributaries rather than dispersed widely through the catchments.

Within the Golden Bay area, the strongest detections for the lamprey pheromone were found in the Aorere River catchment (Sites 15-18 in 2019 & Site 7 in 2020), the Parapara River, Onekaka River and Parawhakaoho River (Sites 19-21 in 2019; Figure 3-3). Of these sites, the New Zealand Freshwater Fish Database (NZFFD) only has records for lamprey from the Onekaka River. All four sample sites within the Aorere River catchment detected the lamprey pheromone at high levels in 2019, which included two mainstem sites of the Aorere River itself and the Kaituna River, a large tributary. Of the two sites sampled in 2020, a tributary stream feeding into the Kaituna River detected the lamprey pheromone, supporting the 2019 observations (Site 7). However, the furthest upstream site in the Kaituna River did not detect the lamprey pheromone (Site 8; Figure 3-3). These data suggest lamprey are well distributed and in high abundance within the Aorere catchment. Additional investigation is required to further identify key tributaries lamprey reside in and gain an understanding of their distribution in the upper Aorere catchment.

Sites in the Takaka River failed to detect the lamprey cue in both years (Figure 3-3). Records of lamprey from the NZFFD have observations of a single individual in the lower reaches of the mainstem of the Takaka River and the Go Ahead Creek tributary of the Anatoki River, which wasn't sampled using POCIS in the current survey. Therefore, the low number of observations and lack of detection with the POCIS samplers suggest that if lamprey are present in the Takaka River catchment they are likely in low abundance or are present in areas we have not currently sampled. Other survey sites feeding into the eastern side of Golden Bay; the Anatimo Creek site (Site 14 in 2019) and the Wainui River site (Site 9 in 2020) also failed to detect the lamprey pheromone (Figure 3-3). Overall, within Golden Bay, data indicate that rivers and streams feeding into the western and central part of the bay may be more productive for lamprey than rivers and streams feeding into the eastern side of the bay.

There were moderate levels of lamprey pheromone detected in the lower section of the Paturau River in 2020 (Site 6; Figure 3-3). The lamprey pheromone was not detected at either site in the lower Anatori River in 2020 (Site 4-5; Figure 3-3). Presently, the NZFFD holds no records of lamprey in either catchment but moderate levels of pheromone recorded in the lower Paturau River warrants further investigation to both identify the key areas of the catchment utilised by lamprey and if other west coast streams not currently sampled also contain lamprey.

Within the Tasman Bay area, the strongest detections of the lamprey pheromone were found in the Motueka River catchment (Sites 5, 6, 9, in 2019 and Site 18 in 2020; Figure 3-4). Across both years, pheromone was detected in the mainstem of the Motueka River (Site 9) as well as two large tributaries; the Motupiko River (Site 5) and the Wangapeka River (Site 6) in 2019, and further upstream in the Wangapeka River in 2020 (Site 18; Figure 3-4). It should be noted that the pheromone concentration recorded at Site 18 in 2020 may not be accurate due to interference from other organic compounds and the concentration of PS was estimated based on the qualifier ion used in all analyses. Seven smaller tributary streams sampled across 2019 and 2020 failed to detect the lamprey cue, as well as two sites in the upper Wangapeka River in 2020 (Figure 3-4). Samplers set north of Motueka in the Riuwaka River catchment (Sites 12-14) and south of the Motueka River in the Moutere River catchment (Site 20) failed to detect lamprey pheromone in 2020. Overall, data indicates that lamprey may be patchily distributed in rivers surrounding Motueka and within the Motueka River itself.

Samplers set in two main tributaries of the Waimea River in 2019, the Wairoa River (Site 1) and the Wai-iti River (Site 2) detected the lamprey pheromone (Figure 3-4). Two additional sites sampled in 2020 also detected the pheromone; in the Lee River (Site 1) and higher in the Wairoa River (Site 3). The Roding River (Site 2) as well as an upstream site in the Wai-iti River (Site 19) were also sampled in 2020 with no detections at either site (Figure 3-4). The Waimea River catchment is large and, therefore, further investigation is needed to determine what parts of the catchment are key habitat for lamprey. Presently, the NZFFD hold no records of lamprey in the Waimea River catchment but does have a record for lamprey in a small unnamed stream in the Waimea Inlet. In particular, Waimea Water Limited are in the process of building a water supply dam on the Lee River, which is a key tributary of the Waimea River catchment containing a strong lamprey signature. Presently, the proposed fish pass at Waimea Dam is designed to enable fish species capable of climbing passage upstream of the dam, namely koaro and longfin eels. However, lamprey is not included in the target fish species and lamprey require a very different passage structure to other native fish. POCIS results suggest that lamprey spawning and rearing habitat will be impacted by the pending Waimea Dam and as they are a threatened fish species this is in breach of Section 26ZJ of the Conservation Amendment Act 2019.

The lamprey pheromone was not detected at any of the four tributary sites within the Buller River catchment in 2019 (Sites 24-27; Figure 3-5). Unfortunately, the sampler set in the mainstem of the Buller River (Site 28) was lost or stolen and this would have been a key site for determining if lamprey were present higher in the catchment. The NZFFD does, however, hold records for lamprey in two tributary streams close to the mouth of the Buller River. Therefore, further investigation of this catchment is warranted.

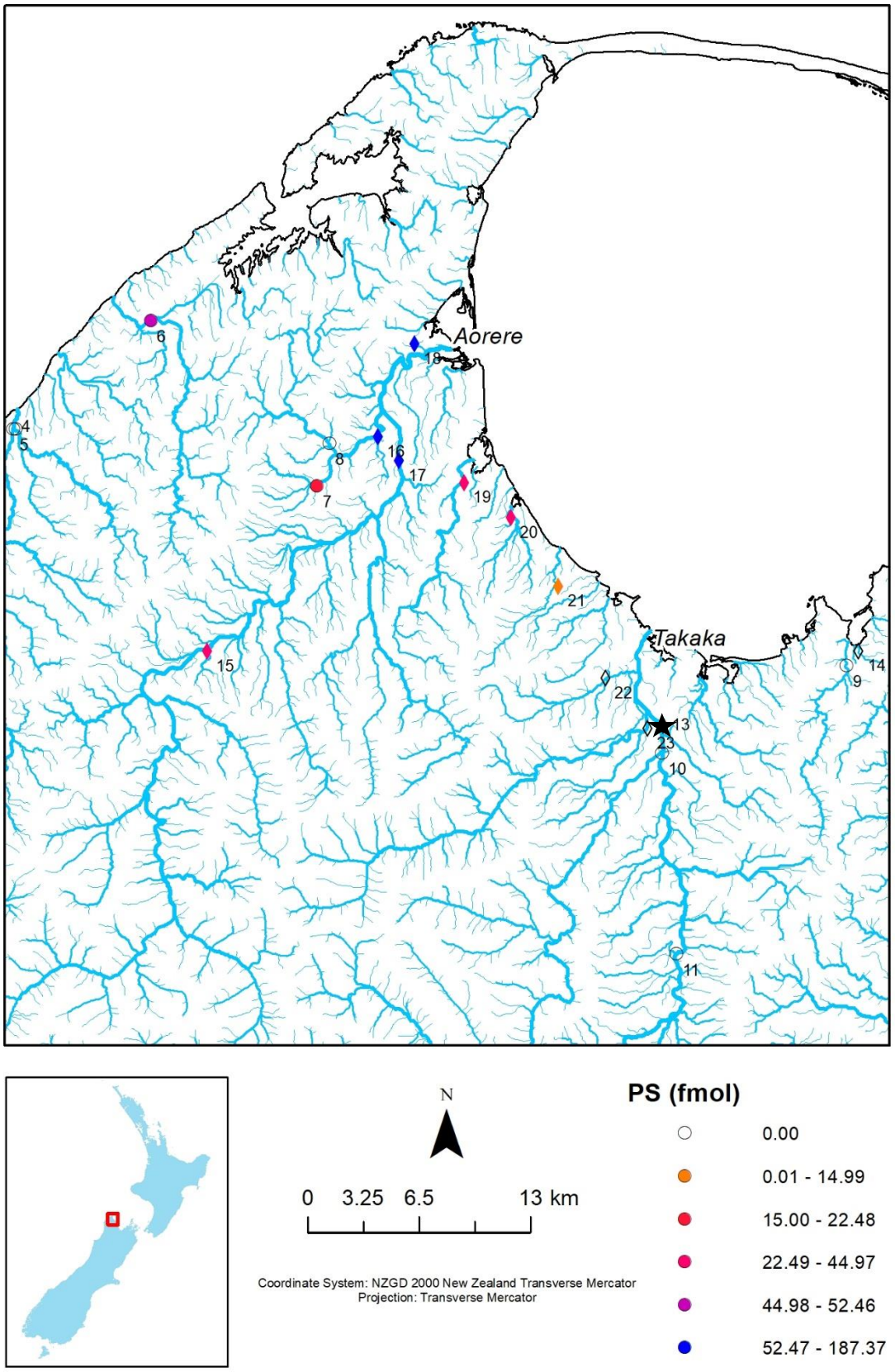

Figure 3-3: Distribution of the larval pheromone (PS) in the North Western coast and Golden Bay area of the Tasman Region. Note: fmol is 10^{-15} M. Circles indicate 2020 samplers and diamonds indicate 2019 samplers. The black star indicates a failed sampler at site 13.

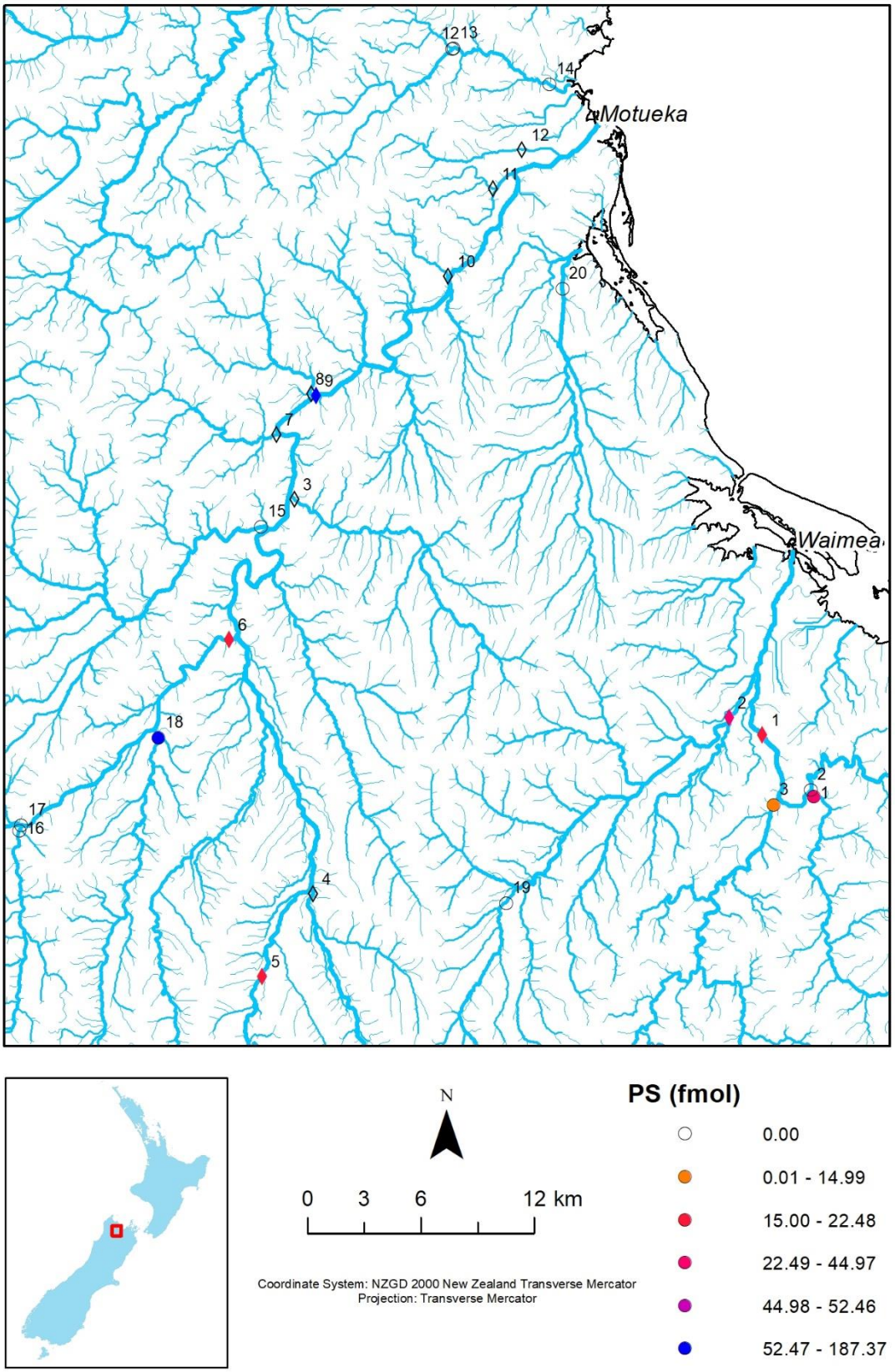

Figure 3-4: Distribution of the larval pheromone (PS) in the Tasman Bay area of the Tasman Region.
Note: fmol is 10-15 M. Circles indicate 2020 samplers and diamonds indicate 2019 samplers.

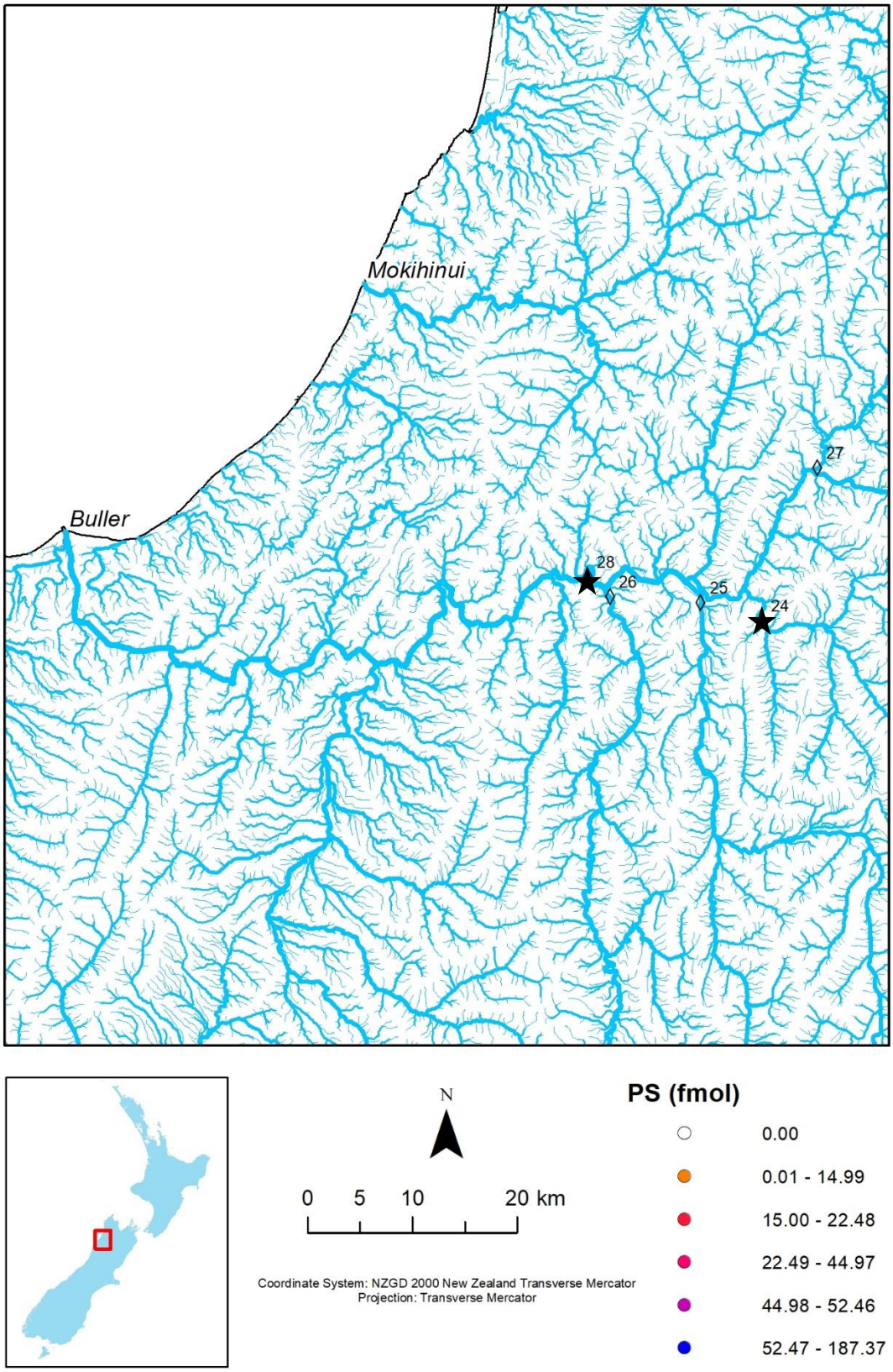

Figure 3-5: Distribution of the larval pheromone (PS) in the Buller River of the Tasman Region. Note: fmol is 10^{-15} M. Circles indicate 2020 samplers and diamonds indicate 2019 samplers. The black stars indicate where the sampler either failed (24) or was lot/stolen (28).

4 Recommendations for the conservation and protection of lamprey populations

Lamprey are a culturally important taonga species that are currently in decline. However, conservation efforts are hampered by the limited knowledge of their distribution and ecology in the freshwater environment.

4.1 Habitat use by larval and adult lamprey

Lamprey larvae generally burrow and reside in soft, sandy substrates, with a low water velocity, and some amount of organic detritus (Figure 4-1). Potter et al. (1986) found the highest densities of larval lamprey in medium sand 0.2-0.6 mm in diameter. However, ammocoetes will also occur in coarse sand and small gravels and cobbles (Figure 4-2 & Figure 4-3). Habitat suitable for larval lamprey often occurs in eddies, backwaters, pools and along stream margins. Depositional areas downstream of boulders, logs and other obstructions to flow can also provide pockets of sediment that ammocoetes exploit (Figure 4-3).

Figure 4-1: Fine sand habitat preferred by larval lamprey. Inset shows two larvae burrowing into the sediment.

Figure 4-2: Ammocoete burrowing into coarser substrates in Kaniwhaniwha Stream after being removed from the area during electric fishing.

Figure 4-3: Larval lamprey habitat in Kaniwhaniwha Stream (indicated by the red ellipses).

In contrast, adult lamprey form spawning pairs underneath large boulders (Figure 4-4). In Kinloch Stream, Banks Peninsula, boulders utilised for spawning were located in backwaters adjacent to riffle habitat, and amidst boulder clusters within shallow riffles (Baker et al. 2017). The boulders chosen for spawning beneath were on average 0.70 x 0.49 m (l x w), whereas during their 12-14 month maturation period prior to spawning, adult lamprey utilised smaller boulders for cover (average size 0.44 x 0.32 m; l x w). In the Waikawa River, Southland, lamprey pairs were located underneath bedrock slabs or in cavities within the rock lining of the stream banks (Figure 4-5). Based on the nests we have located in both Kinloch Stream and the Waikawa River between 2013 and 2019, the microhabitat lamprey are seeking appears similar. That is, fish are choosing cavities that minimise predation, with good water flow and that have hard surfaces for egg laying.

Figure 4-4: X marks the spot! Typical spawning habitat utilised by adult lamprey in Kinloch Stream, Banks Peninsula, with a nest located under the boulder marked with an "X" in the foreground.

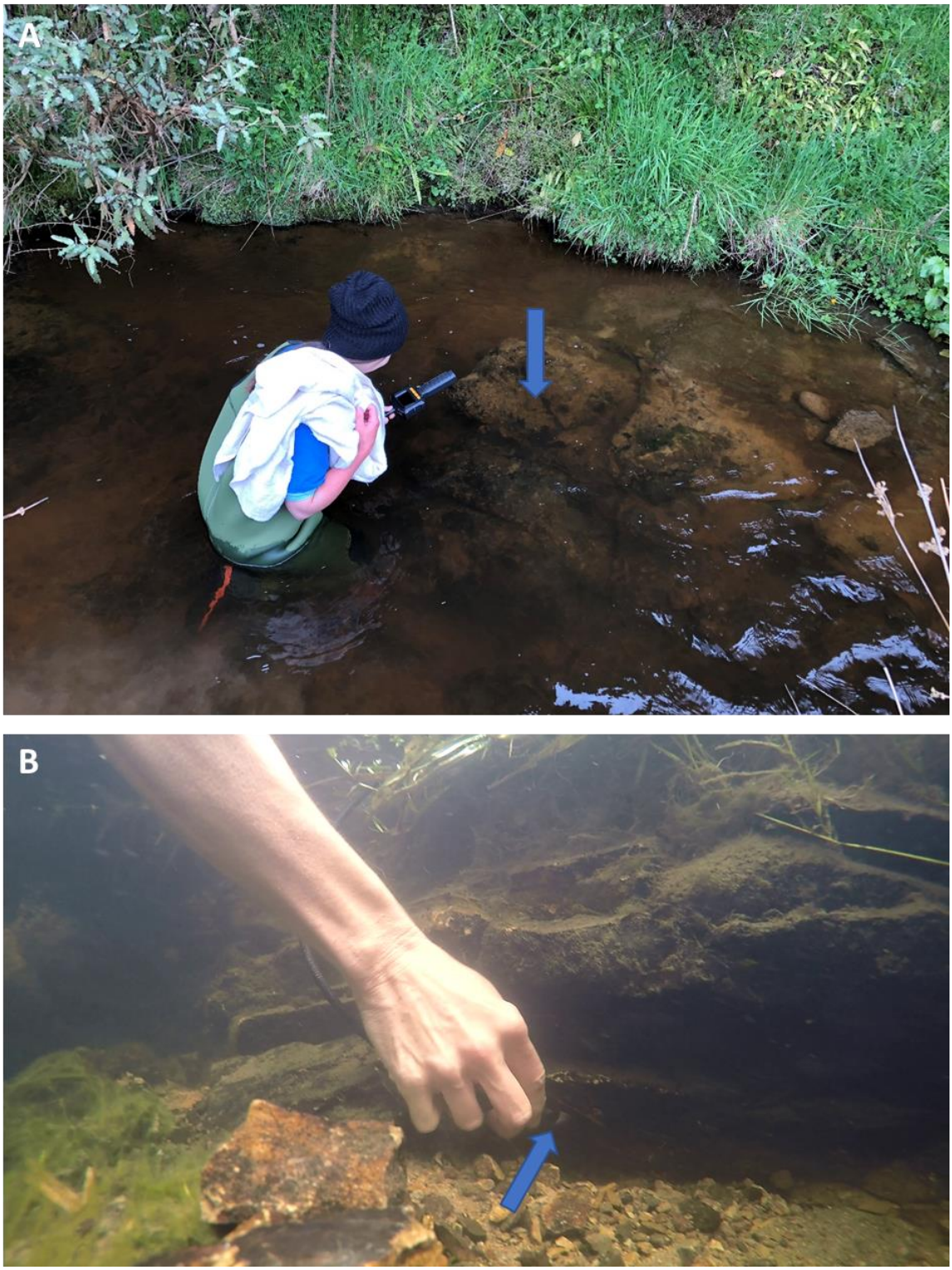

Figure 4-5: Typical spawning habitat utilised by adult lamprey in the Waikawa River, Southland, New Zealand. A, a nest located under a bedrock slab (depicted by blue arrow); B, inserting an endoscope camera into a lamprey nest located under the rock lining the river bank (blue arrow indicated entrance to the nest).

4.2 Next steps

Identification of larval populations using the POCIS methodology helps determine the current distribution of lamprey within the Tasman region. This assessment has identified a number of rivers and locations with moderate to high levels of lamprey pheromones over the past two years. This creates a baseline for further investigations to help pinpoint areas of larger catchments where lamprey are resident and determine what parts of the catchment are key habitat for lamprey. In particular, the Waimea River, Motueka River, and Aorere River warrant further investigations.

The current POCIS results have identified river catchments that contain important spawning and larval rearing streams. This is because the pheromone signature of larvae is used by migratory adults to select spawning streams. Based on the POCIS data, catchments should be prioritised for surveying lamprey and their habitats to ground truth results and to determine the extent of critical habitats for spawning and larval rearing. Prioritisation should focus on those rivers estimated to contain high larval numbers as this is an indication that streams/areas contain suitable spawning habitat for adult lamprey, but should also consider sites of significance within the region. Identification of critical life-stage habitats will enable Tasman District Council to meet their requirements under the NPSFM (2020) and devise management strategies for the protection of lamprey populations.

5 References

Alvarez, D.A., Petty, J.D., Huckins, J.N., Jones-Lepp, T.L., Getting, D.T., Goddard, J.P., Manahan, S.E. (2004) Development of a passive, in situ, integrative sampler for hydrophilic organic contaminants in aquatic environments. *Environ. Toxicol. Chem*. 23: 1640–1648.

Baker, C.F., Stewart, M., Fine, J.M., Sorensen, P.W. (2009) Partial evolutionary divergence of a migratory pheromone between northern and southern hemisphere lampreys., In: Haro, A.J., Smith, K.L., Rulifson, R.A., Moffitt, C.M., Klauda, R.J., Dadswell, M.J., Cunjak, R.A., Cooper, J.E., Beal, K.L., Avery, T.S. (Eds.) Challenges for Diadromous Fishes In a Dynamic Global Environment. *American Fisheries Society Symposium 69.* Bethesda, Maryland: 845–846.

Baker, C.F., Jellyman, D.J., Crow, S., Reeve, K., Stewart, M., Buchinger, T., Li, W. (2017) First observations of spawning nests in the pouched lamprey (*Geotria australis*). *Canadian Journal of Fisheries and Aquatic Sciences 4:1603-1611* DOI: 10.1139/cjfas-2016-0292.

Colotelo, A.H., Pflugrath, B.D., Brown, R.S. et al. (2012) The effect of rapid and sustained decompression on barotrauma in juvenile brook lamprey and Pacific lamprey: implications for passage at hydroelectric facilities. *Fish. Res*. 129, 17–20.

Dunn, N.R., Allibone, R., Closs, G., Crow, S., David, B., Goodman, J., Griffiths, M., Jack, D., Ling, N., Waters, J., Rolfe, J. (2018) Conservation status of New Zealand freshwater fish 2017. *New Zealand Threat Classification Series* 24.

Harman, C., Allan, I.J., Vermeirssen, E.L.M. (2012) Calibration and use of the polar organic chemical integrative sampler—a critical review. *Environ. Toxicol. Chem. 31*: 2724–2738.

Leathwick, J.R., Elith, J., Francis, M.P., Hastie, T., Taylor, P. (2006) Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees. *Mar. Ecol. Prog. Ser.* 321: 267-281.

Leathwick, J.R., Elith, J., Hastie, T. (2006a) Comparative performance of generalized additive models and multivariate adaptive regression splines for statistical modelling of species distributions. *Ecol. Model.* 199: 188-196.

Morin, N., Camilleri, J., Cren-Olivé, C., Coquery, M., Miège, C. (2013) Determination of uptake kinetics and sampling rates for 56 organic micropollutants using “pharmaceutical” POCIS. *Talanta,* 109: 61–73.

Moser, M.L., Keefer, M.L., Pennington, H.T., Ogden, D.A., Simonson, J.E. (2011) Development of Pacific lamprey fishways at a hydropower dam. *Fish. Manag. Ecol.* 18: 190–200.

Potter, I. C.; Hilliard, R. W.; Neira, F. J. (1986) The Biology of Australian Lampreys. In: De Deckker, P.; Williams, W. D. eds. Limnology in Australia. Dr W. Junk. Pp. 207-230.

Polkinghorne, C.N., Olson, J.M., Gallaher, D.G., Sorensen, P.W. (2001) Larval sea lamprey release two unique bile acids to the water at a rate sufficient to produce detectable riverine pheromone plumes. *Fish Physiol. Biochem.* 24: 15–30.

Stewart, M., Baker, C., Cooney, T. (2011) A rapid, sensitive, and selective method for quantitation of lamprey migratory pheromones in river water. *J. Chem. Ecol*. 37: 1203–1207.

Stewart, M., Baker, C. (2012) A Sensitive Analytical Method for Quantifying Petromyzonol Sulfate in Water as a Potential Tool for Population Monitoring of the Southern Pouched Lamprey, *Geotria australis*, in New Zealand Streams. *J. Chem. Ecol.* 38: 135–144.

Stewart, M., Baker, C.F., Sorensen, P.W. (2013) Chemical Analysis of Aquatic Pheromones in Fish, in: Touhara, K. (Ed.) *Pheromone Signaling.* Humana Press: 55–69.