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Biomass survey and condition index for kina (*Evechinus chloroticus*) in SUR 7A

New Zealand Fisheries Assessment Report 2023/60

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Anderson, O.F.[1]; Olsen, L.; Marriott, P.; Stead, J.; Hayden, M.; Olmedo-Rojas, P. (2023).
Biomass survey and condition index for kina (*Evechinus chloroticus*) in SUR 7A.

***New Zealand Fisheries Assessment Report 2023/60.* 20 p.**

A survey to estimate the absolute abundance of kina (*Evechinus chloroticus*) in the Tory Channel/Kura Te Au region of the SUR 7A kina Quota Management Area was conducted in November/December 2022. The survey objectives were to provide estimates of the current absolute abundance of kina, to develop a gonad condition index following concerns about poor roe recovery, and to provide estimates of kina abundance within defined categories of the index.

A key component of the project requirements was to develop the survey design using an integrated mātauranga Māori and conventional science-informed strategy. This was to be done by engaging with customary and commercial fishers and seeking input from Te Tau Ihu Fisheries Forum and Fisheries New Zealand to focus the surveys on key aspects and locations of the fishery that were determined to be of most importance. Agreement on these aspects was achieved through numerous kōrerorero as well as presentations to the forum and the Fisheries New Zealand Shellfish Working Group, resulting in some fine-tuning of the project objectives and delimitation of the survey area boundaries to maximise the benefits of the research.

The survey design development strategy identified Tory Channel/Kura Te Au as an area of high importance to traditional, commercial, and recreational fishing and also as a place that is sheltered from adverse wind and sea conditions that might hamper survey efforts in other locations. The availability of high-resolution bathymetry data for the channel was also of considerable benefit to the survey. The survey methodology comprised a combination of towed camera transects and diver transects at 55 randomly selected sites within three strata differing in perceived fishery value. Kina density was calculated at each site and biomass was estimated through onboard measurement of kina at dive sites and post-survey analysis of image data from towed camera sites, with roe condition determined from dissections of samples of kina.

Biomass of kina in Kura Te Au was estimated in four categories. The total greenweight of kina in the survey area was estimated to be 596 t, with a CV of 19%. Roe recovery calculations (gonad weight/total weight) were used to produce estimates of total kina roe weight (63 t, CV 21%), and a three-level condition index was developed to separate total roe weight into 'good' (32.3 t, CV 23%), 'medium' (18 t, CV 23%), and 'poor' (12.6 t, CV 26%) classes.

Several sources of uncertainty, beyond sampling error, were identified in the procedure—including approximations required for estimation of kina weight from size, and from mean size for unmeasured kina, stratum mean recovery and condition indices for unsampled sites, catchability assumptions, and kina presence outside the survey depth range. However, these were not considered to be substantial, and all can be addressed to some extent in future modifications of the survey design, especially if a higher level of sampling effort is possible.

[1] All authors: National Institute of Water and Atmospheric Research (NIWA), New Zealand.

1. INTRODUCTION

Kina (*Evechinus chloroticus*, SUR) in the Marlborough Sounds support substantial commercial, customary, and recreational fisheries and are an important taonga species for many iwi, hapū, and whānau nationwide. Separate allocations of the current annual 238 t Total Allowable Catch (TAC) for the SUR 7A Quota Management Area (QMA) are made to customary (80 t), recreational (20 t), and commercial (135 t) interests. Fisheries catch return data show that the commercial catches have been close to the Total Allowable Commercial Catch (TACC) in SUR 7A in most fishing years since 2007–08 (Fisheries New Zealand 2023), but there are few recent data relating to kina catches by recreational or customary fishing. There is no formal stock assessment of sustainable yield for kina in this or any other fishstock, and no estimates of biomass or trends in abundance (Fisheries New Zealand 2023).

Increasing concerns by customary fishers and Te Tau Ihu (Nelson-Marlborough) iwi about the presence of kina barrens (areas where kina densities are >2 m^2 (Shears & Babcock 2003, Leleu et al. 2012) and kina with roe in poor condition, heavy fishing pressure on key areas, and a lack of any assessment of the stocks in SUR 7A led Fisheries New Zealand to commission development of a research project and survey that would begin to address some of these issues.

A key aspect of the research project was to develop an integrated mātauranga Māori and conventional science-informed strategy by engaging with customary and commercial fishers and seeking input from Te Tau Ihu Fisheries Forum and Fisheries New Zealand through wānanga and kōrerorero to focus the surveys on key aspects of the fishery that were of most concern. This approach would ensure that kina abundance and biomass surveys considered all relevant factors and were carried out at locations of importance to iwi, hapū, and whānau in the Marlborough Sounds region of SUR 7A. The design also required provision of an index for gonad (roe) condition, to enhance the utility of the survey outputs by focussing assessment on the most valuable component of the species.

The level of resources available to the project meant that it would not be possible to undertake a survey which could provide estimates of kina abundance for the entire SUR 7A QMA, and so an important aspect of the engagement processes was to identify areas of most value and importance to customary, commercial, and recreational kina fishers. A comprehensive assessment of the entire SUR 7A kina stock, or assessment of relative abundance, e.g., through assessment of catch and effort data from the commercial fishery, was not part of the project specifications.

This report therefore describes the development of a research survey through a consultative process, details the dive and towed camera-based methodology used to carry out the survey, outlines the process of estimating the abundance of kina in a selected area of SUR 7A, and provides these estimates, along with measures of uncertainty.

1.1 Objectives

After consultation with Te Tau Ihu Fisheries Forum and Fisheries New Zealand the objectives of the project were revised to better reflect the concerns identified and to acknowledge previous and current research on the ecological aspects of kina in the region, and therefore allow more of a focus on estimating abundance in locations of the greatest importance to all participants in the fishery. These revised objectives are as follows:

Overall objective for Fisheries New Zealand project SUR2021-01

To assess the status of the stock in a selected area of SUR 7A within the Marlborough Sounds. This project is intended to incorporate mātauranga Māori. This involves conducting a biomass survey that will allow completion of Objectives 1–3.

Specific Objective 1

Provide estimates of current absolute abundance (numbers and biomass in tonnes greenweight), length frequency, density, and depth profile for kina in a selected area of SUR 7A in the Marlborough Sounds.

Specific Objective 2

Allow the development of a condition index following reports of “skinny” kina.

Specific Objective 3

Combine the outputs from Objectives 1 and 2 to provide estimates of kina abundance in terms of roe weight in each condition category.

2. METHODS

2.1 Engagement

A preliminary survey design was developed at the research proposal stage which comprised a combined dive and towed camera survey strategy to assess kina abundance in an efficient manner that utilises the strengths of each approach in differing environments. Considerable efforts to collect incidental information at survey sites were also initially proposed to develop statistical models that may help to understand spatial variability in kina condition, but this aspect was down weighted in the revised objectives to focus resources on the estimation of abundance.

This preliminary survey design was discussed initially at a meeting of the Te Tau Ihu Fisheries Forum on 10 October 2022, at which the underlying survey methodology and general approach was presented. To aid discussion on survey design development at this meeting a short presentation was also made by Dr Nick Shears of the University of Auckland. Dr Shears is conducting experimental research into the relationship between kina abundance and kelp communities in Tōtaranui, research that potentially overlaps with some of the concerns of mana whenua around kina populations in the region. The potential for a formal workshop where customary fishers, local experts, and leaders could engage with the NIWA project scientists to finalise the survey approach was discussed, but ultimately ruled out due to logistical issues mostly relating to the significant delays encountered in the project to this point, and the lack of flexibility in the survey dates which, it was agreed, needed to be immediately prior to the summer spawning period in the region (Brewin et. al. 2000, Dix, 1970b). However, agreement was reached at this meeting to individually engage with customary fishers, commercial fishers, and other experts to come to a consensus on a survey approach that could be put to the Fisheries New Zealand Shellfish Working Group for their consideration.

A revised survey plan, incorporating input from a range of experts, was then presented to the Fisheries New Zealand Shellfish Working Group on 23 November 2022, and agreed to.

2.2 Survey design

To assist the consultative process for the delineation of a subset of SUR 7A (Figure 1) in which to base the survey, an examination of commercial catch records of kina was made. The requirement for fine-scale reporting of catch and effort data was introduced into this fishery in 2019; therefore four years of data were available to assist in identifying key areas for commercial fishing, to add to information provided by the experts.

Once the location of the survey area was established, random sampling sites within it were selected using a high-resolution (2×2 m) bathymetry raster. Firstly, cells at the coastline were isolated from deeper water, approximated by selecting those with a depth of 2 m or shallower, with the row and column numbers of these cells combined to make a list of all coastal grid cells. Then a random sample of these cells was taken (initially of a size larger than required) and the distance between the centres of each cell and all other cells in the list was calculated. Elements were then removed from the list so that the distance between any remaining cell locations was at least 250 m. This left a set of sites to potentially survey, somewhat more than considered possible given the available time, but ultimately selected from, at random, to assign final sampling location points along the shoreline.

Stratification of the survey area was made based on the consultative process and examination of catch-effort data to approximate areas of differing abundance or importance to the fishery.

Two NIWA aluminium power boats were used for the survey: the 7.1 m RV *Nereis* and the 5.9 m RV *Rahope*.

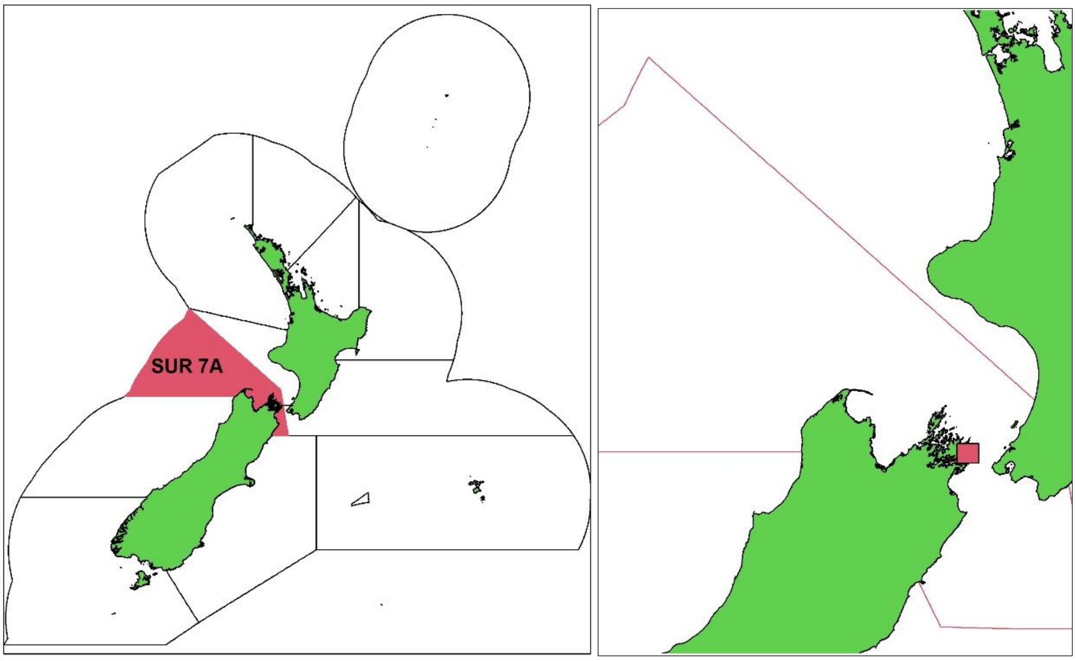

Figure 1: Left, kina QMA boundaries, with SUR 7A highlighted in red; Right, close-up of SUR 7A, with location of Kura Te Au survey area highlighted in red.

2.2.1 Dive transect sampling

Dive transects were the primary method used for measuring abundance and were critical for locations where it was found to be impractical to conduct camera transects; i.e., where the camera view would have been obscured at times due to complex terrain or high algal cover, or where strong currents or adverse sea conditions would have made camera operation difficult. Dive transect sampling was also necessary to enable collection of kina for measurements and examination of roe size and condition.

At each selected random site, a lead-weighted transect line was deployed by dropping one end at a point perpendicular to the shoreline location at a depth of 18 m (or if in, for example, a shallow bay, a maximum distance of approximately 100 m from the shore); the other end of the line was then deployed at the shore, or close to it. Each end of the line was connected by a light line to a surface float to aid diver navigation and enable the dive vessel to monitor the operation and accurately record transect start and end positions. The transect line was marked at 5-m intervals, to allow divers to monitor their progress and divide the transect into a deep and shallow half for the purpose of collecting kina at different depths.

Each transect was sampled by two divers searching a 1-m wide section of the seafloor along each side of the transect length from the start to the end point, by holding a 1-m wide bar on their side of the transect line. Divers collected all kina within the first half (usually 50 m) into a catch-bag (until it was full) then repeated this in the second half, so that differences in kina sizes and roe condition with depth/distance from shore could be determined. The number of un-collected kina in each half of the transect and the average depth of each half of the transect were recorded on a slate. Divers also collected coarse-level information on sediment type (e.g., bedrock, sand, mud, gravel, pebbles, boulders, etc.), along with other faunal (invertebrates and fish) and main algal species observed.

In addition to the counts and collections, at most sites one of the divers also used a head-mounted GoPro camera to collect underwater video footage of the search during each transect; this footage was not expected to be formally analysed within the project but was considered potentially useful for cross-checking or for subsequent collection of incidental information, if required.

All kina collected from each transect were transferred to the surface and measured for test diameter (the diameter of the kina, excluding the spines, at the height where it is widest) to the next whole millimetre down using callipers, with a subsample of 20 kina randomly selected from these for dissection.

2.2.2 Camera transect sampling

A 'Tow-Cam' underwater camera system was used to conduct the video transects (Figure 2). The Tow-Cam has two parts: the topside display (SplashCam ProPacl200 HD, Ocean Systems Inc©) and recording unit (GeoAudio+ GPS audio encoder, Intuitive Circuits©), and the underwater towed camera unit comprising an underwater video camera (SplashCam Delta Vision HD and HD cable, Ocean Systems Inc©), video lights and two scaling lasers (Bigblue VL8000P Tri Colour lights & Bigblue Spot Light lasers, Bigblue Dive Lights©), and a second video camera (GoPro Hero 9, GoPro Inc.), all attached to a NIWA-designed custom tow frame. The Tow-Cam system was lowered from the surface and towed along the seafloor from the shoreline random location in a direction perpendicular to it, from as close to the shore as possible to a maximum water depth of approximately 18 m if available. The camera system was connected to the vessel by a data and power cable and the camera image relayed to the topside display to allow navigation around obstacles and maintenance of an appropriate height above the seabed to balance between the field of view and image clarity (depending on visibility conditions)—approximately 0.5–1.0 m.

The total Euclidean length of the transect length along the seafloor was calculated from the vessel GPS positions, logged at the start of the transect (when the camera first starts filming the seabed) and at the end of the transect (when camera retrieval commences), and the start and finish depths. Due to wind, currents, or imperfect navigation the transects did not always form a straight line; therefore the total surface distance (i.e., not accounting for changes in depth) of the vessel track, as determined from GPS data using TIMEZERO© navigation software, was also recorded. Neither measurement method perfectly estimates the length of the transect along the seafloor, especially as the Tow-Cam is likely to deviate from a straight path less than the vessel through the dampening effect of the tow cable. Therefore, the transect length used to calculate the swept area for the site was calculated as an average of the values from the two measurement methods. The width of the camera transects was determined from the saved video files and calculated as a mean from multiple measurements of the camera field of view at a series of haphazardly selected points along the transect. This was done using Fiji ImageJ© image-processing software to measure the view width based on the known distance between the scaling lasers on the camera frame.

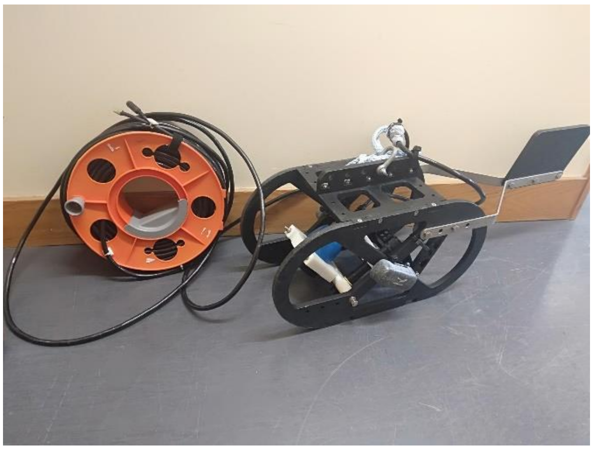

Figure 2: NIWA's Tow-Cam system.

Fiji ImageJ was also used to measure kina sizes. Using tools in this software a line was drawn across each individual kina in a freeze-frame image, excluding the spines, and converted to a length (in mm) using the known distance between the scaling lasers (180 mm) where these lights are visible on the image (the lights were sometimes obscured but an adjacent frame could usually be found in which they were not).

2.2.3 Condition Index

A random selection of 20 kina (or fewer where less than 20 were collected) was taken from the samples collected at each dive transect site (10 per 50 m section) for examination of the roe, based on methods used in kina assessments in Fiordland (SUR 5) (McShane et al. 1994a). Each kina was broken open with commercial kina-splitters to remove the gonads, the total gonad volume was measured using water displacement in a measuring cylinder, and gonad colour was assigned using a colour wheel (Figure 3). In addition, a method was trialled in which photographs were taken of the roe from each kina examined alongside a calibrated colour card so that roe colours could be more accurately standardised and Red/Green/Blue (RGB) values assigned to allow development of a numerical classification of roe colour. Images were calibrated to the documented hue, saturation, and luminance values of the white grey and black squares of the colour card in the images. This enabled a correction to be made for the variability of the ambient light encountered while capturing the images in the field. Finally, taste quality (scale of 1–5 where 1 is worst-tasting and 5 is best-tasting) was assessed haphazardly and subjectively. All transect and station data were recorded electronically and on paper forms.

A 3-level index of roe condition, based on recovery (roe volume/test weight) combined with a colour-based categorisation, was calculated for each kina in the up to 20 opened at each dive transect site (Table 1). Note that kina size was not directly considered in this index, as smaller kina will be excluded in any case if recovery is low.

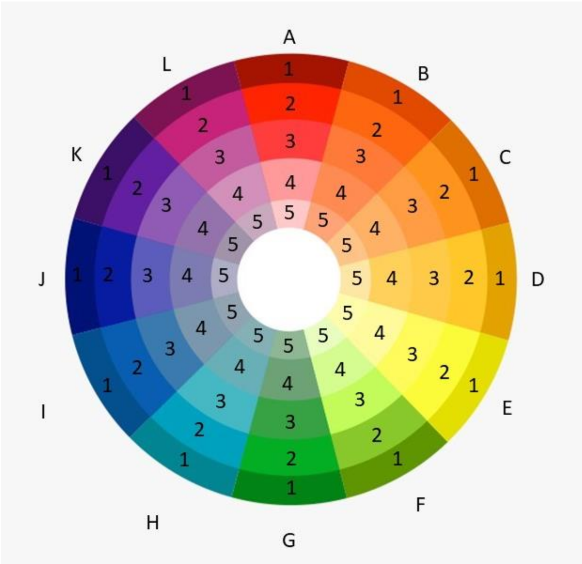

Figure 3: Colour wheel used to categorise kina roe colours. Roe colour was matched to the closest colour on the wheel and given a code based on the column letter and ring number.

Table 1: Roe condition index.

Index	Roe colours (see Figure 3)	Recovery (%)
Good:	C2, C3, D1, D2, D3, or D4	>10
Medium:	As above PLUS B2, C1, C4, or C5	≥8 & ≤10
Poor:	Any	<8

2.2.4 Biomass estimation

The process for estimating biomass for the Tory Channel/Kura Te Au survey area was relatively straightforward. Estimates of kina biomass were made for each sampled site based on the number of kina observed, the recorded kina sizes, and the calculated transect area.

- Individual kina weights were estimated from their test diameter using a size-weight formula as follows,

$$W = (6.27 \times 10^{-4}) \times TD^{2.88}$$

where W is whole weight (g) and TD is Test Diameter (mm).

- For dive transect sites, the biomass of measured kina for the site (both 50 m sections combined) was calculated using the size-weight formula above, with the biomass of any unmeasured kina at the site (those in each half of each side of the transect not fitting into a catch bag) estimated from their number and the mean weight of the measured kina at that site; the two values were then added to obtain an estimate of the total biomass of kina at the site. A similar procedure was used for camera transect sites, but at many of these sites too few kina were measured for a reliable mean weight to be applied to the unmeasured individuals. In these cases, the mean weight for all kina measured from dive transects in the stratum was used,

$$BM_s = \sum_{i=1}^{M} x_i = (6.27 \times 10^{-4}) \times TD_i^{2.88}$$

$$BU_s = \bar{x} \times U_s$$

$$BT_s = BM_s + BU_s$$

where BM_S, BU_S, and BT_S are the biomass of all M measured kina (i), all U unmeasured kina, and total kina (T), respectively, at site s.

- The area of the seafloor surveyed along each transect was calculated from the transect width and length, and a kina density for the site calculated from this value and the estimated total weight of kina at the site,

$$A_s = TW_s \times TL_s\,, \quad D_s = \frac{BT_s}{A_s}$$

where A_s, TW_s, and TL_s are the seafloor area (m^2), transect width (m), and transect length (m), respectively, at site s, and D_s is the density of kina (g m^{-2}) at site s.

- The total surface area of the seafloor in each stratum (SFA_{str}) was calculated from a high-resolution (2 × 2 m) bathymetry raster[2]. The raster was first masked to exclude all cells outside the survey depth range (0–18 m), then the 3-dimensional surface area (the surface area taking into account the sloping/uneven nature of the surface) was calculated using the *sp::surfaceArea* function in R.

- Estimates of total biomass, B, for the survey area were made by multiplying the stratum seafloor area (SFA_{str}) by the mean kina density in each stratum ($\overline{D}_{str}$), and adding across the three strata,

2 https://marlborough.maps.arcgis.com/apps/MapSeries/index.html?appid=155a89b0beb74035bd1c4c71f6f36646

$$B = \sum_{str=1}^{3} SFA_{str} \times \overline{D}_{str}$$

- Uncertainty (*CV*) around the estimate of total biomass was estimated from its variance *V(B),*

$$V(B) = \sum_{str=1}^{3} SFA_{str}^{2} \times V(\overline{D}_{str})$$

where $V(\overline{D}_{str})$ is the variance of the densities at the *n* sites in each stratum divided by sqrt(*n*) and,

$$CV(B) = \frac{\sqrt{V(B)}}{B}.$$

3. RESULTS

3.1 Engagement

Valuable discussions on the current state of the kina fishery in SUR 7A were had by phone call or in person with the following experts:

Te Ātiawa o Te Waka-a-Māui
- Justin Carter
- Rachel Hāte
- Rita Powick
- Mark Barcello
- Ron Riwaka

Customary and commercial fishers (past and present)
- Isaac Love
- Campbell McManaway
- Steve Webb
- Rex Gapper

A summary of the most relevant information stemming from these discussions is provided below. Note that this summary was produced by the authors and therefore represents the authors' interpretation of the points made. Furthermore, as all discussions were held one-to-one, these points do not in any way represent a consensus of the individuals listed above:

- High quality kina (i.e., good roe weight to whole weight ratio, colour, and taste) can be found in many parts of SUR 7A, especially the outer reaches of the Queen Charlotte Sound, the outer coast south of Tory Channel (in deeper water, 10–20 m), and the more exposed coasts of D'Urville Island.
- The bays south of Tory Channel, especially Cable Bay, Fighting Bay, Glasgow Bay, Jordy Rocks all support high densities of high-quality kina at times. Port Underwood is also a good kina fishing area, especially the outer parts.
- Deeper into Queen Charlotte Sound there are more areas of kina barrens; kina are smaller and in very poor condition. Most of the inner sounds are not fished for kina for this reason.
- Customary fishing effort is concentrated around Tory Channel, and frequently Underwater Breathing Apparatus (UBA) is used.
- Kina tend to prefer areas with higher water clarity.

- There is little knowledge and little commercial fishing of kina stocks in Pelorus Sound, but kina are presumably sparse, in barrens, or generally in poor condition.
- Kina roe are typically in better condition where they are living in some tidal currents, especially around exposed points.
- Roe recovery can be very high at times in SUR 7, occasionally over 20% by weight, but this can drop very sharply, often seemingly overnight after a large-scale mass-spawning event. Such an event occurred in the summer of 2021/22 in Queen Charlotte Sound (and again in 2022/23).
- Some dredging for kina still occurs but is generally limited to the outer parts of Tory Channel and targets kina in waters beyond diving depth.
- Kina in parts of outer Tory Channel in deeper water beyond that in which algae typically grows are supported by vast amounts of drift algae.
- Okukari Bay to East Head (Tory Channel) is all good kina country but to avoid strong currents needs to be worked (fished) on the ebb tide; the other side of the channel, from West Head to Scraggy Point, is also good kina country, but needs to be worked on the flood tide.
- Further along the Channel on the northern side, Jacksons Bay and Te Awaiti Bay, kina tend to be smaller—but still very good quality.
- Kina in Tory Channel are often found in abundance on a gravel-dominated substrate well away from the shoreline in relatively deep water, up to 18 m at least.
- A top location for kina is right in the middle of the entrance to Tory Channel, where tidal currents are strongest and boating traffic (especially Cook Strait ferries) intense.
- Kina from deeper water will move shallower to replace those harvested.

One key aspect of the SUR 7A kina fishery that was agreed by most if not all of this group of experts was that the most productive and best fishing locations for kina are found in Tory Channel/Kura Te Au and for this reason this area in some ways represents the very heart of the kina fishery not only in SUR 7A but in Aotearoa New Zealand as a whole. Most experts independently stated that kina from this area are unrivalled for quality and taste, and previous research in the general area has shown some of the highest levels of roe recovery (up to 21–27%) of anywhere in New Zealand (Brewin et al. 2000, Barker 2020).

3.2 Development of survey location and timing

Examination of fine-scale commercial catch records for kina for the 2019 to 2022 period indicated a strong focus of recent effort throughout Kura Te Au, especially at the eastern end, along the exposed outer coastline of Queen Charlotte Sound from Cape Koamaru in the north to Port Underwood in the south, and along the outer coastlines of the north-eastern Marlborough Sounds from D'Urville Island to the northern entrances to Queen Charlotte Sound. For reasons of commercial sensitivity, and conditions of release of these data, no figure can be shown here to fully illustrate the location of these catches.

As a result of the engagement process, consideration of the current commercial fishing grounds, and after consultations with the Fisheries New Zealand Shellfish Working Group including representatives of Te Tau Ihu, Tory Channel/Kura Te Au was chosen as the most appropriate area in which to conduct a kina biomass survey. As well as being central to the commercial, customary, and recreational fishery in SUR 7, it is also an area that is sufficiently sheltered to be confident that a survey could be completed in almost any weather conditions—unlike some of the other kina fishery areas noted by experts that are located on the much more exposed coastlines of Cook Strait. The survey area was delimited at the western end by a line between Dieffenbach Point and Kaitapeha Bay, and at the Cook Strait eastern entrance to the channel by a line between East Head and West Head (Figure 4). The survey area was divided into three strata, reflecting observations by the experts consulted that there is a gradient in preferred harvesting locations from west to east along the channel. Nine deep bays that branch off the channel were treated separately from the main channel as these were considered by the experts to be poor kina locations due to lack of current, algae, and higher sedimentation. The survey boundaries associated with these bays are shown in Figure 4.

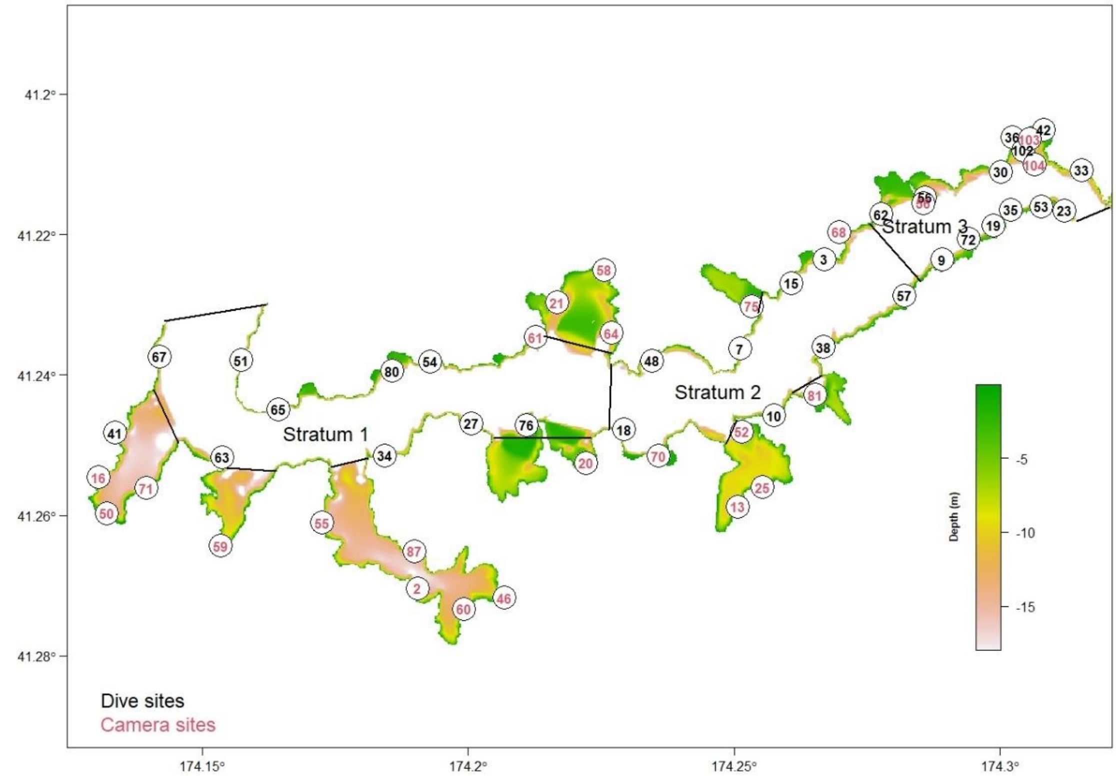

Figure 4: Survey location and stratum boundaries (black lines). Random site locations (site numbers) are shown in black (dive transects) and red (camera transects) text. Areas outside the survey extent (land and depths below 18 m) are shown in white.

The survey was carried out between 29 November and 5 December 2022 with a total of 55 sites completed, comprising 31 dive transects and 24 camera transects (Table 2).

Table 2: Number of survey sites completed by stratum, transect method (dive/camera), and site type (channel/bay).

Stratum	Dive		Camera		Both methods	
	Channel	Bay	Channel	Bay	Channel	Bay
1	9	1	1	13	10	14
2	8	0	2	3	10	3
3	13	0	3	0	16	0
All	30	1	6	18	36	17

3.3 Dive transects

The dive method developed for this survey functioned well, with divers able to confidently count all emergent kina within the transect boundaries. The very smallest individuals, those below about 35-mm TD, tend to be cryptic and hide in crevices (Dix 1970a, Shears & Babcock 2002, Andrew & Choat 1985) and are likely to have been under-represented in the counts and samples taken at some sites, but larger individuals were obvious and had little place to hide across much of the terrain covered.

Kina were encountered at all but 4 of the 31 dive transect sites. Size frequency and roe condition data were collected from each of the remaining 27 sites. A total of 1727 kina were measured for test diameter, and a subsample of 495 of these were dissected to measure roe volume and condition.

Although many kina were checked for taste (by a single taster), with a 1–5 rating applied, for logistical reasons it was not possible to obtain a rating for all kina. In particular, less palatable looking specimens were often overlooked by the taster in favour of the plumper, brighter coloured specimens, introducing a degree of sampling bias. Kina were generally in very good condition, however, as may be expected at this time of year (just before the expected spawning season), and the taster remarked upon the fine flavour and texture of many of the samples tested. In all, just over a quarter of all kina dissected (133/495) were tested for taste with about 70% assessed as a 4 or 5, and the remainder as a 2 or 3.

3.4 Camera transects

The camera method was reliant on more even terrain and lower algal cover for acceptable results, and data from two of the camera transect sites in Oyster Bay (Stratum 2) were disregarded as kina counts could not be made due to poor image quality caused by low visibility. Otherwise, this method worked well at the remaining sites within the bays selected for its application, and the image quality was considered sufficient for accurate and reliable counts. Nevertheless, there is a chance that some individuals will have been overlooked when making counts due to occasional algal cover and variability of camera height.

An assessment of kina size was made at each camera transect site from examination of random freeze-frame video images using Fiji ImageJ as described above (Figure 5). Only a fraction of the observed kina were able to be measured in this way due to poor visibility affecting image quality, non-visibility of laser lights in the image, orientation or partial obscuration of the kina, and limited resources for this time-consuming task. Nevertheless, a total of 511 size measurements were made using this technique, encompassing 12 of the 15 camera transect sites with visible kina. These measurements were mostly from a single site, site 56 (425 kina), due to the density of kina at that location and good image quality. Only at three other sites were more than 10 kina able to be successfully measured in this way.

Measurements of the camera's field of view were made at 160 locations across 21 camera transect sites, and either 5 (on shorter tows) or 10 (on longer tows) measurements taken per site, to estimate the total area of the seafloor covered by the camera transect. Mean widths of the transects among these sites ranged from 58.3 cm to 184.8 cm. Transect lengths (determined from the mean of track length and the point-to-point distance between the recorded start and finish locations, as described above) ranged from 76 to 442 m.

Figure 5: Image processing for measurement of kina test diameter. A (yellow) line is drawn using Fiji ImageJ software and the scaling lasers (red dots) used to convert the line length to an estimated test diameter.

3.5 Algae and invertebrates

Many species of macroalgae thrive in the cool, nutrient-rich waters of Tory Channel/Kura Te Au and such plants are the preferred diet of shallow water temperate species of sea urchin such as kina (Andrew

1989, Wing & Wing 2015). Although identification and estimation of the prevalence or abundance of algae was not a priority for the survey, divers took note of the main species or species groups encountered on each dive.

All divers had a good knowledge of the common algae species but are not experts, and so the list produced (Table 3) in no way represents a comprehensive account of the flora of the survey area, and identifications were limited to genus level where there was any uncertainty. The algae species most frequently recorded by divers was *Ulva lactuca* (sea lettuce), which was found at 13 of the 31 dive sites. The other main species observed included: the brown kelps *Ecklonia radiata*, a common native species, and *Undaria pinnatifida*, an invasive species common in many parts of New Zealand; the red algae *Asparagopsis* spp.; and the fucoids *Cystophora* spp., *Carpophyllum maschalocarpum*, and *C. flexuosum*.

Table 3: Algae species observed at the dive transect sites. The table is ordered from the most frequently encountered taxon (number of sites, out of 31, where the taxon was observed) to the least encountered taxon.

Algae taxon	Number of dive sites where observed
Ulva lactuca	13
Ecklonia radiata	10
Undaria pinnatifida	9
Asparagopsis spp.	8
Cystophora spp.	8
Carpophyllum maschalocarpum	7
Carpophyllum flexuosum	5
Codium spp.	5
Halopteris spp.	2
Zostera spp.	2
Xiphophora spp.	1

Invertebrate species were recorded by divers mostly only when they were a distinctive component of the seafloor habitat at a site. The parchment worm *Chaetopterus variopedatus*, a possibly introduced species that can dominate sandy substrates with a dense mat of tubes to the detriment of other bottom-dwelling fauna, was found at 8 sites. Unidentified species of hydroids were also frequently encountered and were also seen at 8 sites. In addition, a few tubeworms were noted, as well as occasional pāua (*Haliotis iris*).

3.6 Kina size

A total of 1727 kina were measured from the dive transect site collections within the three survey strata; nearly half of these were collected from Stratum 1, with Stratum 2 having the least numbers measured (Figure 6). There was a clear difference in kina sizes among strata, with the smallest kina coming from Stratum 1 (mean = 78 mm TD), the largest from Stratum 2 (mean = 107 mm TD), and intermediate size kina in Stratum 3 (mean = 94 mm TD). Kina fishers tend to target the larger kina (over about 100 mm TD), therefore sites in Stratum 1 may be less preferred.

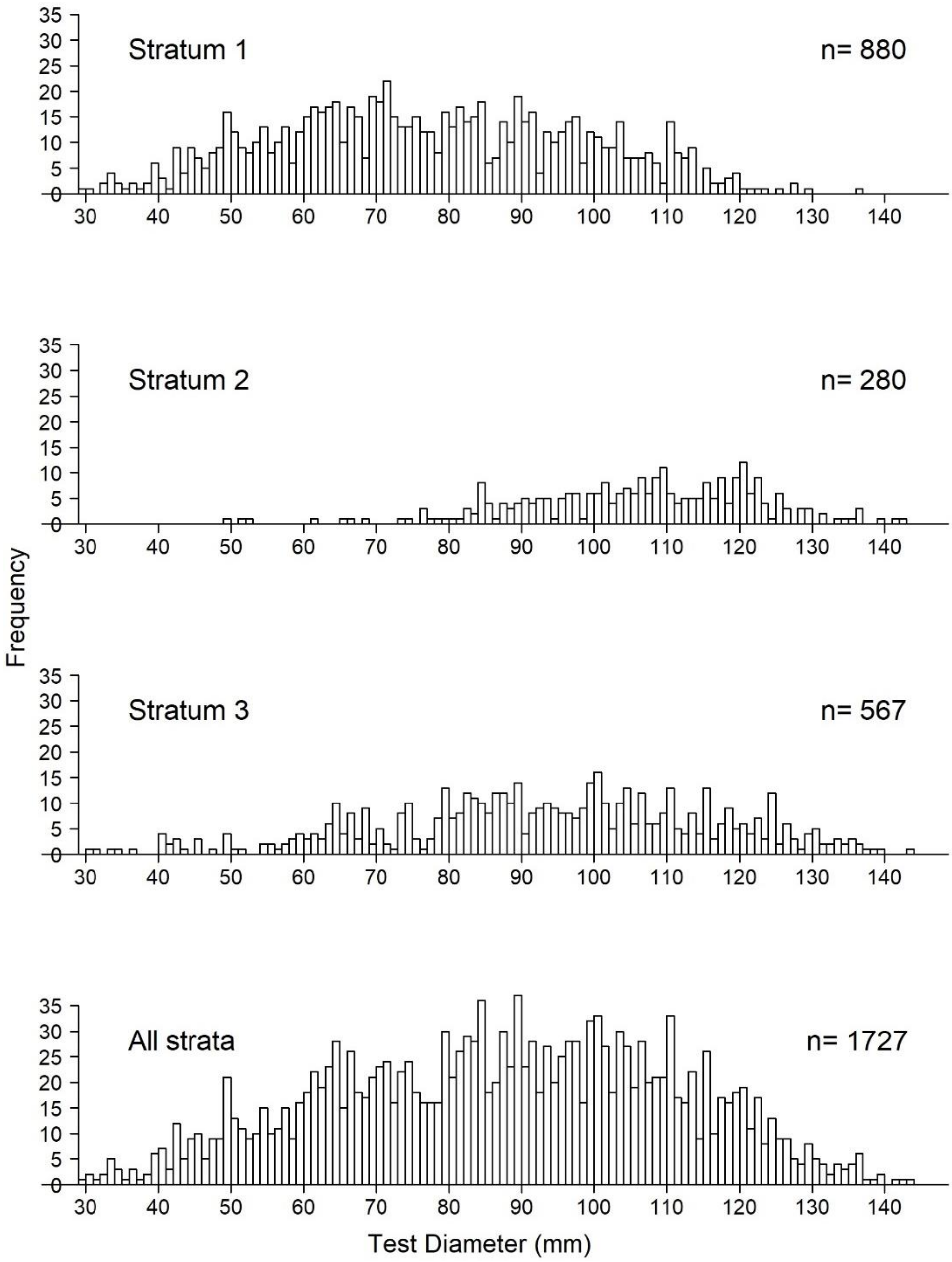

Figure 6: Size frequencies of kina in each stratum, and overall.

3.7 Roe condition index

3.7.1 Standard Index

Based on the index of roe condition, about 41% of the 412 kina examined had roe in 'good' condition, 23% had roe in 'medium' condition, and 22% had roe in 'poor' condition (Table 4). A further 13.6% of kina had immature gonads. Kina in strata 2 & 3 were in the best condition overall, with 84–88% in 'good' or 'medium' condition; immature kina in Stratum 1 were about 10 times more prevalent than in the other strata and this stratum also had the poorest roe condition with 39% in the 'poor' category.

Due to the generally ripe condition of most mature kina examined, it was possible in most cases to determine the sex of the individuals dissected for examination of the roe. Of the 415 kina across all sites that could be sexed, 202 were male and 213 female—a ratio of 49:51. Sex ratio by stratum was similar to the overall ratio in Stratum 1 (49:51) and Stratum 3 (45:55), but favoured females slightly in Stratum 2 (52:48).

Table 4: Roe condition by category (%) in the survey area, by stratum and overall.

	Stratum			
Roe condition	1	2	3	All
Good	16.4	64.0	51.4	41.3
Medium	14.5	24.3	32.4	23.3
Poor	39.0	9.0	12.7	21.8
Immature	30.2	2.7	3.5	13.6

3.7.2 Numerical classification index

A numerical representation of roe colour into RGB values was derived from photographic data in an attempt to produce an objective classification. A 3-D plot was used to examine the ranges of the RGB primary colours, where the value for each colour lies between 1 and 255 (Figure 7). Although RGB values for kina roe could be reasonably well defined for each category, e.g., colours matching those in the colour wheel assigned to the 'good' category (Table 1) had values of approximately R: 200–250, G: 150–200, and B: 50–120, it was problematic to derive an easy-to-use categorisation from these numbers. Although this approach proved to be useful for providing an empirical basis for roe classification, the standard index in Table 1 was adopted for the following analyses as it was simpler to apply and use.

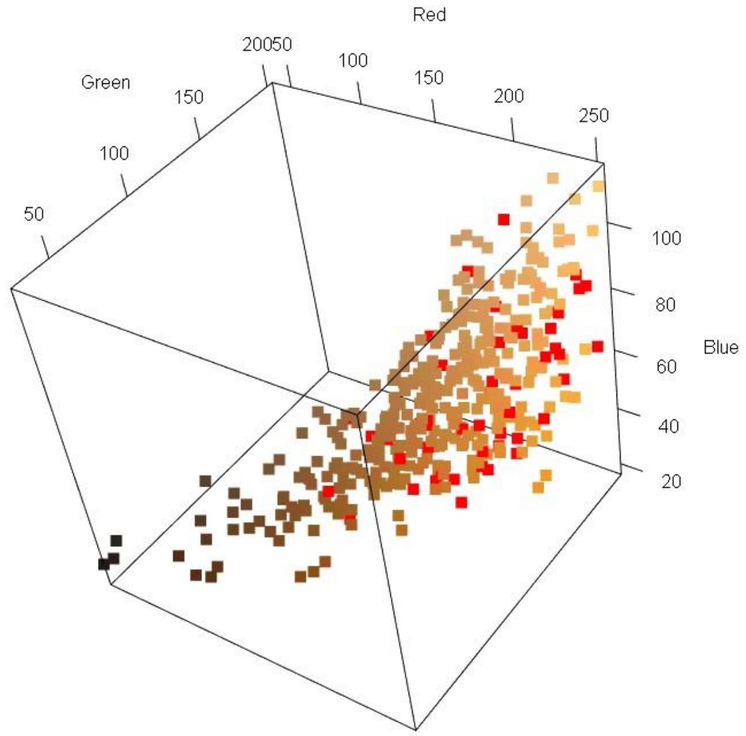

Figure 7: 3-D plot of RGB values measured from photographs taken of roe from each kina dissected for examination of roe condition. Values of Red, Green, and Blue on each axis range from 0–255, and the plotted points represent the variability in the observed roe colour; red coloured symbols indicate roe that were rated a 5 on the taste scale.

3.8 Biomass estimation

Estimation of kina biomass in the survey area was based on sampling carried out only in the main harvesting locations, i.e., excluding the nine bays identified in Figure 4, which were mostly sampled using the towed camera method. Therefore, biomass estimation was based on a total of 36 sites: 30 dive sites and 6 camera sites (see Table 2). For the 6 camera sites and the 2 dive sites with between 1 and 10 kina collected, where roe recovery and condition index could not be reliably estimated, these values were calculated from stratum means; this enabled estimation of total roe biomass and roe biomass for each of the three condition index categories.

Some simple metrics were calculated to test the assumptions behind the stratification of the survey area, i.e., that there is a general progression in the quality of the kina fishery (kina densities, mean sizes, recovery) from west to east, with Stratum 3 at the eastern end of the channel supporting the best quality kina, and Stratum 1 in the west producing the lowest quality kina (Table 5).

Excluding bay sites, mean kina densities by weight (g m^{-2}) were greatest at sites in Stratum 3. Although mean kina densities by number were greatest in Stratum 1, these were overall smaller kina with by far the lowest mean individual weight and size. The central Stratum (2) had the largest individual mean kina sizes and weights but lowest kina density in both weight and numbers.

Roe recovery (roe volume/total weight) in Stratum 1 was barely half that of the other two strata, which were similar (Table 5, Figure 8). These data indicate that kina in the study area reached maturity at about 60–65 mm TD (similar to estimates for nearby Kaikōura, Dix 1970b), although some kina in Stratum 1 had no significant volume of roe at sizes up to 85 mm TD, showing similar variability to that seen in other locations (e.g., McShane et al. 1996, Barker et al. 1998).

Table 5: Overall kina density (weight and numbers), mean kina weights and equivalent sizes (TD) from survey sites excluding bays, by stratum.

	Kina density				
Stratum	Weight (g m^{-2})	Numbers m^{-2}	Mean kina weight (g)	Equivalent TD (mm)	Mean roe recovery (%)
1	127	0.526	242	87	6.5
2	113	0.252	448	108	12.8
3	165	0.464	356	99	12.5

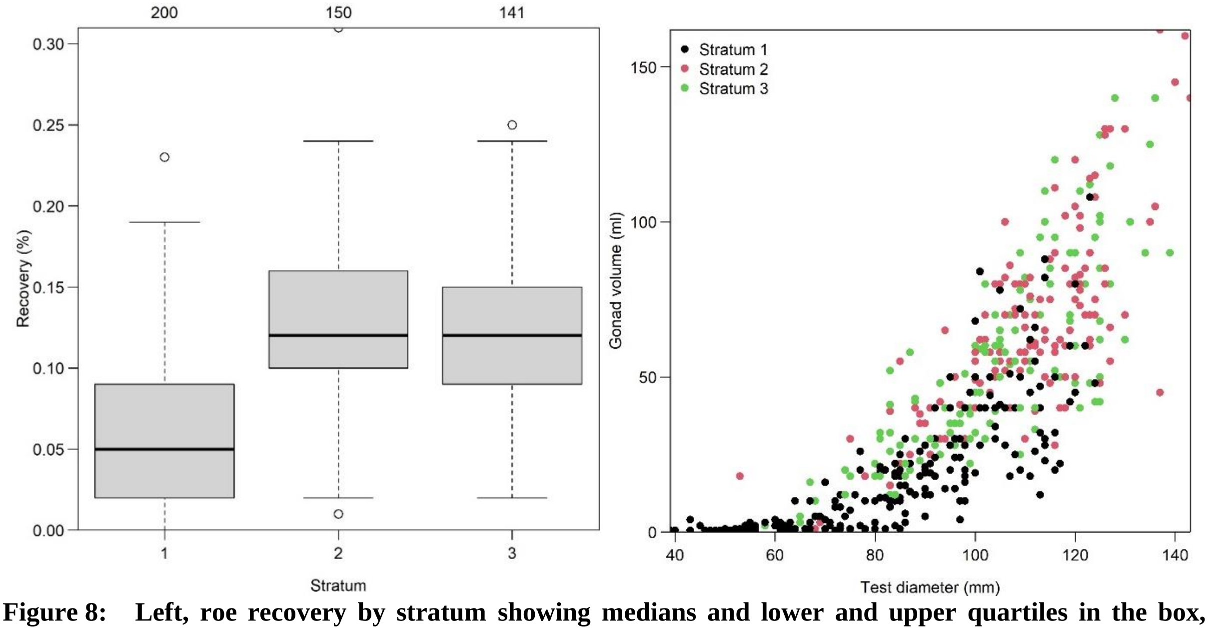

Figure 8: Left, roe recovery by stratum showing medians and lower and upper quartiles in the box, whiskers extending up to 1.5 × the interquartile range with outliers individually plotted, and numbers indicating the number of kina examined; right, relationship between kina size (test diameter) and gonad volume.

Because all dive transects began at a depth of 18 m where possible and ran shorewards, in some cases the inner end of the transect did not reach the shoreline within the length of the transect line (100 m Max.). Therefore some further checks were made to test whether this caused any bias due to differences in kina sizes, densities, or recovery between the deep and shallow portions of the transects.

An assessment of differences in recovery between deep and shallow transect sections was made using a two-sample *t-test*; this indicated that there was no significant difference (p=0.732). Kina at the deeper end of the transect were slightly larger than those at the shallow end overall (99 mm vs. 95 mm TD) and although the difference was statistically significant (*t-test*, p=0.02), the difference was not significant in terms of the fishery. Kina densities were slightly greater at the shallower end of the transect, but again the difference was not significant (*t-test*, p=0.75).

Total estimated biomass of kina for the Kura Te Au survey area was 596 t (Table 6). Total biomass was highest in Stratum 3 and was about twice that of the Stratum 2, with estimated biomass in Stratum 1 about midway between the other two strata. Estimated roe biomass was also highest in Stratum 3 and was also about twice that of Stratum 2; however roe biomass was lowest in Stratum 1 where overall recovery was low. Total roe biomass for the survey area was 62.9 t.

Most of the biomass of kina roe in the survey area was in the 'good' condition category (32.3 t), with only about 20% of the total categorised as 'poor'. By stratum, 13% of the roe was in 'poor' condition in Stratum 3 and only 6% in Stratum 2 but, conversely, in Stratum 1 most of the roe (55%) was in 'poor' condition.

Estimated precision (CVs) of the biomass estimates among the categories and strata ranged between 30% and 46% and were consistently lowest in Stratum 3.

Table 6: Estimated biomass (t) of kina in the Tory Channel/ Kura Te Au survey area. Biomass estimates are given separately for greenweight and roe weight, the latter further separated by the three condition indices. Coefficients of Variation (CVs) are shown (as percentages) in parentheses.

		Roe			
Stratum	Greenweight	Good	Medium	Poor	Total
1	199 (33)	3.2 (36)	3.0 (46)	7.5 (40)	13.7 (40)
2	135 (38)	11.8 (43)	4.3 (39)	1.0 (36)	17.1 (39)
3	261 (30)	17.3 (32)	10.7 (34)	4.1 (33)	32.1 (31)
All	596 (19)	32.3 (23)	18.0 (23)	12.6 (26)	63.0 (21)

3.9 Bay sites

Kina were generally present in relatively low numbers in the bay sites sampled. Of the 17 bay sites (1 dive, 16 camera) excluded from the biomass calculations, 5 had kina counts of zero. Mean kina density at these sites was 14.7 g m^{-2}, about a tenth or less than that of the kina in any of the 3 strata used for biomass estimation. Although 143 kina were observed at one bay site (the single dive site), these were mostly immature and small (mean TD 52 mm) so that overall kina density at the site was relatively low (48 g m^{-2}) and recovery was poor (2.5%). As these sites were excluded from the biomass estimation, no further examination of data from the bay sites was undertaken.

4. SUMMARY AND DISCUSSION

The kina survey and biomass estimation described here for the Tory Channel/ Kura Te Au region of SUR 7A represents the first attempt to assess the biomass of any part of any kina stock since the end of the Fiordland (SUR 5) Kina Development Programme in the mid-1990s (McShane et al. 1993, McShane et al. 1994b), although some estimates of kina density (and biomass from extrapolation) are available for D'Urville Island and Arapaoa Island from a survey carried out in 1993 (McShane & Naylor 1993, McShane et al. 1994a). The 596 t biomass estimated here for Kura Te Au compares with estimates of 500 t for Arapaoa Island and 2500 t for D'Urville Island by McShane & Naylor (1993). Although there is considerable overlap between the coasts of Kura Te Au and Arapaoa Island, notably there was no sampling in Kura Te Au in the McShane & Naylor (1993) study.

The main result of this assessment is the estimate of biomass that was able to be produced from kina density estimates at 31 towed camera and dive sites carried out in the channel. The total biomass of kina in the channel was estimated to be 595 t. For the first time in New Zealand estimates of biomass were produced for processed kina, i.e., their roe, and for three categories of roe based on quality. Over half of the estimated 62.9 t of roe in the survey area comprised the highest quality grade. However, both the total roe biomass and the biomass by grade are highly seasonally dependent. The survey was conducted during the period immediately preceding kina spawning in the area and so results are likely to represent close to the best possible in terms of roe recovery and quality.

The integrated mātauranga Māori and conventional science-informed strategy utilised in the development of the survey design proved to be extremely valuable. This approach led to a better understanding of the issues this fishery faces, the current state of knowledge and related research activities already occurring in SUR 7A and resulted in some key changes to the project objectives and survey design that focussed the available resources more specifically on biomass estimation in an area that is central to the fishery in this QMA. The engagement process revealed the depth of knowledge held by tangata whenua of Tōtaranui and the desire by all who contributed to see the health of this valuable fishery maintained into the future, alongside restoration of the overall marine habitat of the area.

The general survey approach, combining diver sampling with towed camera sampling, worked well and was able to provide density estimates across a range of habitat types in an efficient manner. The towed camera system, although extremely rapid compared with diver sampling, was limited to locations where algal cover and reef complexity was low enough for reliable counts to be made and most of these locations were in the bay areas, which were ultimately excluded from biomass calculations. Nevertheless, the combination of methods should be considered in any future surveys. The estimation of biomass benefitted substantially from the ability to accurately estimate the 3-D seafloor area of the survey strata. Without the 2 × 2 m resolution bathymetry data estimated would have relied on far less accurate estimates of the survey area, likely based on coastline length and assumed distance from shore to the 18-m contour. Unfortunately, few other kina fisheries are likely to currently have such detailed and accurate bathymetry data available for this purpose.

The successful development of an objective, numerical measure of roe colour using RBG values from colour-corrected photographs was a useful exercise for grading kina and may have application in commercial operations; however, a simpler, more practical gonad condition index was ultimately applied as it is more straightforward to determine and can be easily done in the field. The assignment of colours to condition index categories and the recovery values chosen to further refine categories can easily be modified for future assessments if necessary. This should be informed by feedback from commercial operators as colour (strongly driven by spawning season and temperature (James & Heath 2008)) is an important aspect of kina value. However, the general procedure proved to be workable and easy to apply and provided a means of assessing and comparing the value of the kina resource within different areas (strata) of the Tory Channel/Kura Te Au.

There are several sources of uncertainty that were not able to be taken into account in the biomass estimates presented here.

- To minimise processing time and the amount of equipment taken on the small vessels individual kina weights were estimated using a size-weight formula rather than being directly weighed.
- Mean weights of sampled kina were used to estimate weights of kina that were not able to be measured (those at many of the camera sites and those not fitting into the 4 catch bags full collected at dive sites).
- Roe recovery and condition index were not able to be measured at each site, and stratum-wide values were used in some cases.
- Site areas are imperfectly measured, especially camera sites where the actual path of the camera is imprecisely recorded and the transect widths are based on a limited number of measurements of the camera field of view.
- The measurement of total stratum area, although relatively accurate due to the high-resolution bathymetry data used, will have an unknown amount of error.
- The detection rate (catchability) of kina from each sampling method is unknown, although likely to be low. Some smaller individuals may have been missed due to cryptic behaviour or by shadowing in camera sites.
- The survey extent was limited to the 0–18 m depth range that is the effective limit of the breath-hold fishery. Kina are known to occur deeper than this in Kura Te Au, especially in areas where they are supported by a plentiful supply of drift algae—but these are not accounted for in our assessment.

Individually these sources of uncertainty are not likely to be substantial and each of them can be addressed to some extent in future modifications or development of the survey design, especially if a higher level of sampling effort is possible at individual sites to allow larger samples of kina to be collected.

5. ACKNOWLEDGEMENTS

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APPENDIX 1: STATION DATA

Table A1: Summary details for each sample location of the Kura Te Au kina survey carried out between 29/11/2023 and 5/12/2023. –, no data.

Station	Site	Stratum	Source	Channel/Bay	Total kina (n)	Mean TD (mm)	Transect length (m)	Transect width (m)	Recovery (%)
1	36	3	Dive	Channel	0	94	75	2	–
2	42	3	Dive	Channel	0	94	75	2	–
3	33	3	Dive	Channel	1	94	75	2	12.3
4	53	3	Dive	Channel	55	99	75	2	12.4
5	56	3	Dive	Channel	174	–	75	2	12.2
6	62	3	Dive	Channel	0	–	75	2	–
7	30	3	Dive	Channel	62	111	75	2	11.2
8	35	3	Dive	Channel	32	106	75	2	12.9
9	19	3	Dive	Channel	1	94	100	2	15.3
10	72	3	Dive	Channel	119	–	75	2	12.5
11	9	3	Dive	Channel	0	–	75	2	–
12	3	2	Dive	Channel	23	98	75	2	13.5
13	15	2	Dive	Channel	11	110	75	2	13.1
14	57	2	Dive	Channel	26	–	75	2	14.0
15	38	2	Dive	Channel	176	103	75	2	12.8
16	7	2	Dive	Channel	35	117	75	2	9.2
17	48	2	Dive	Channel	35	102	75	2	14.7
18	56	3	Camera	Channel	914	112	443	2	12.2
19	68	2	Camera	Channel	0	–	356	2	–
20	75	2	Camera	Bay	2	107	173	1	–
21	64	1	Camera	Bay	25	99	133	1	–
22	58	1	Camera	Bay	2	78	173	1	–
23	21	1	Camera	Bay	20	78	155	2	–
24	61	1	Camera	Channel	0	–	312	1	–
25	10	2	Dive	Channel	31	97	75	2	11.4
26	18	2	Dive	Channel	26	121	75	2	13.6
27	34	1	Dive	Channel	120	86	90	2	9.1
28	63	1	Dive	Channel	44	–	75	2	2.7
29	81	2	Camera	Bay	0	–	220	1	–
30	52	2	Camera	Bay	0	–	262	1	–
33	70	2	Camera	Channel	32	107	209	1	–
34	20	1	Camera	Bay	15	78	361	1	–
35	27	1	Dive	Channel	58	95	80	2	7.9
36	80	1	Dive	Channel	193	–	75	2	7.9
37	41	1	Dive	Bay	143	52	90	2	2.5
38	67	1	Dive	Channel	31	–	75	2	6.5
39	51	1	Dive	Channel	243	68	75	2	2.1
40	55	1	Camera	Bay	42	78	201	1	–
41	87	1	Camera	Bay	3	78	147	1	–
42	2	1	Camera	Bay	8	78	194	1	–
43	60	1	Camera	Bay	1	78	137	1	–
44	46	1	Camera	Bay	0	–	77	1	–
45	71	1	Camera	Bay	47	76	109	1	–
46	50	1	Camera	Bay	0	–	172	1	–
47	16	1	Camera	Bay	8	83	183	1	–
48	59	1	Camera	Bay	0	–	188	1	–
49	65	1	Dive	Channel	91	–	127	2	5.6
50	54	1	Dive	Channel	20	89	73	2	8.6
51	23	3	Dive	Channel	90	95	75	2	10.7
52	102	3	Dive	Channel	349	–	75	2	13.6
53	Wheke	3	Camera	Channel	30	77	121	2	–
54	Wheke2	3	Camera	Channel	53	77	157	1	–
55	76	1	Dive	Channel	49	–	75	2	8.3