POP2019-02
Fish shoal dynamics in north-eastern New Zealand

Presentations for POP2019-02

- **Paul Taylor**/Statfishtics - Objective 2, Exploring distributions of pelagic fish using aerial sightings data
- **Lily Kozmian-Ledward** (with Andrew Jeffs and Chris Gaskin) – Objective 1, Identify seabird prey species associated with fish shoal work ups – zooplankton sampling
- **Chris Gaskin** (with Lily Kozmian-Ledward and Andrew Jeffs) – Objective 1, Identify seabird prey species associated with fish shoal work ups – seabird associations

STATfISHTICS

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Sea Lily Ltd.

Fish shoal dynamics in north-eastern North Island.

Objective 2: Using distributions of inshore pelagic schooling finfish species from the aerial sightings database *aer_sight*

Department of Conservation Project POP2019-02

Paul Taylor
Statfishtics Ltd

Overall objective

- To analyse fish shoal data from the aerial sightings database (aer_sight) and, for the study area in East Northland, Hauraki Gulf and Bay of Plenty (BOP), develop a model of temporal variability in surface schools of the pelagic shoaling finfish species targeted by the domestic purse-seine fishery in terms of relevant environmental variation as a first step in better understanding fisheries pressures on seabird population trends.

Tasks in progress this period

1. Investigate the links between environmental features and distribution of fish schools from *aer_sight*.
2. To continue examining changes in schooling aggregations over time i.e., size of schools, tonnage of sightings, number of schools.

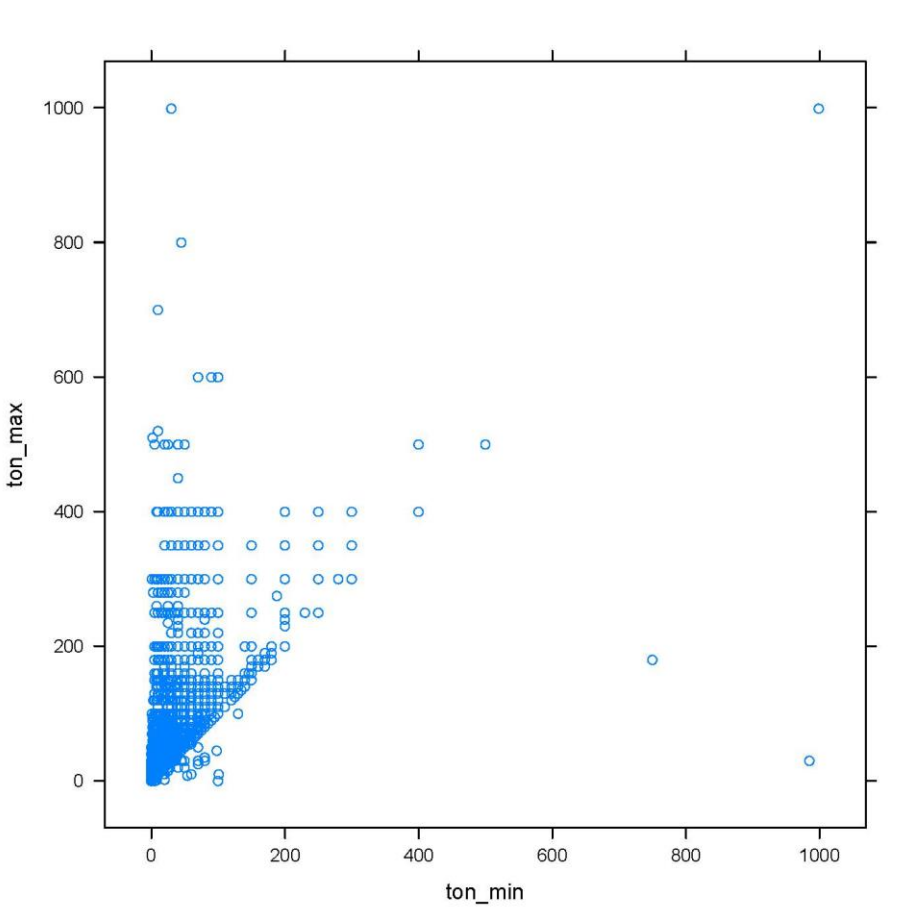
Changes in school size

- Exploring the hypothesis that the aggregation size of surface schooling pelagic finfish species has decreased appreciably over the years since the advent of the purse-seine fishery in 1975–76.
- Sightings are mainly of 8 species: trevally (*Pseudocaranx dentex*), blue mackerel (*Scomber australasicus*), three species of jack mackerel (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*), kahawai (*Arripis trutta*), the highly migratory species skipjack tuna (*Katsuwonas pelamis*) and blue maomao (*Scorpis violaceus*).
- The analysis is not designed to provide biomass estimates, only to investigate possible changes in aggregation size of the various species.
- The analysis does not include mixed schools of these species, but focuses on sightings of mono-specific or single-species schools.
- To maximise the basis for detecting changes in size, the dataset includes sightings from the entire northeast coast, from North Cape to East Cape.

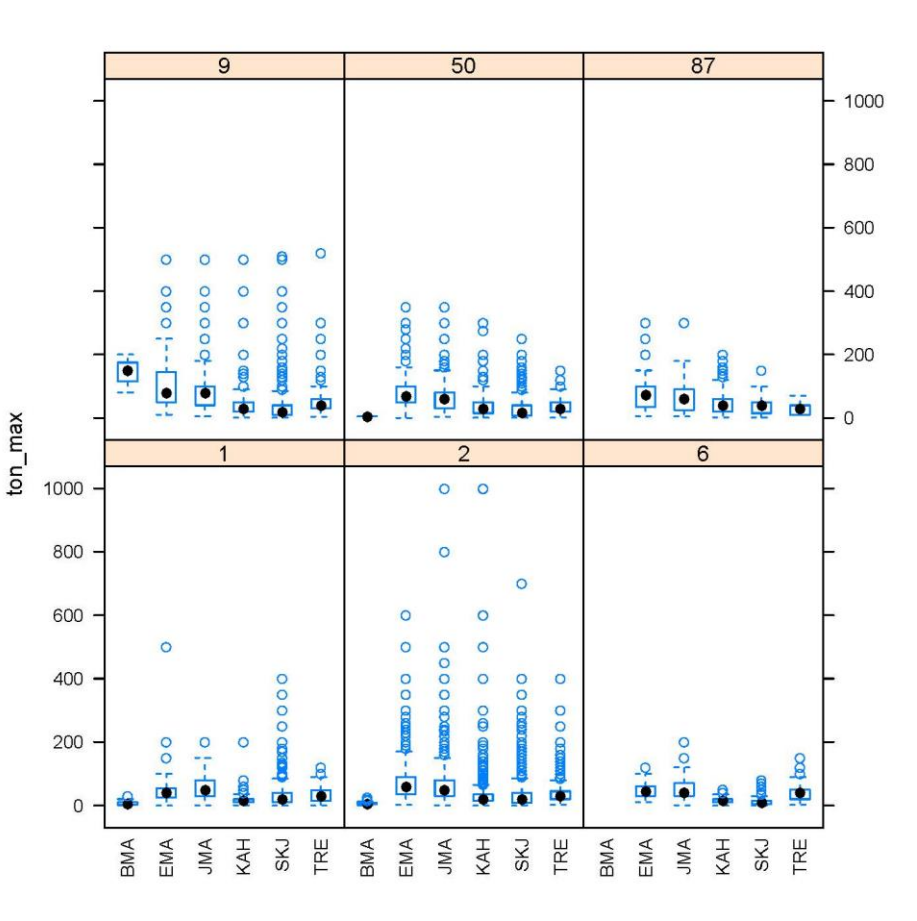
Data selection

- Species composition, the total number of schools, tonnages of the smallest and largest schools (= range of school sizes), and geographical position of the sighting.
- Date, year, month.
- Area (Bay of Plenty, east Northland).
- Decadal reference (1976–83, 1984–93, 1994–03, 2004–13).
- Restricted to the six senior pilots (1, 2, 6, 9, 50, 87).
- Total calculated tonnage (ton_tot_calc).
- $ton\_tot\_calc = num\_of\_schools((ton\_min + ton\_max)/2)$

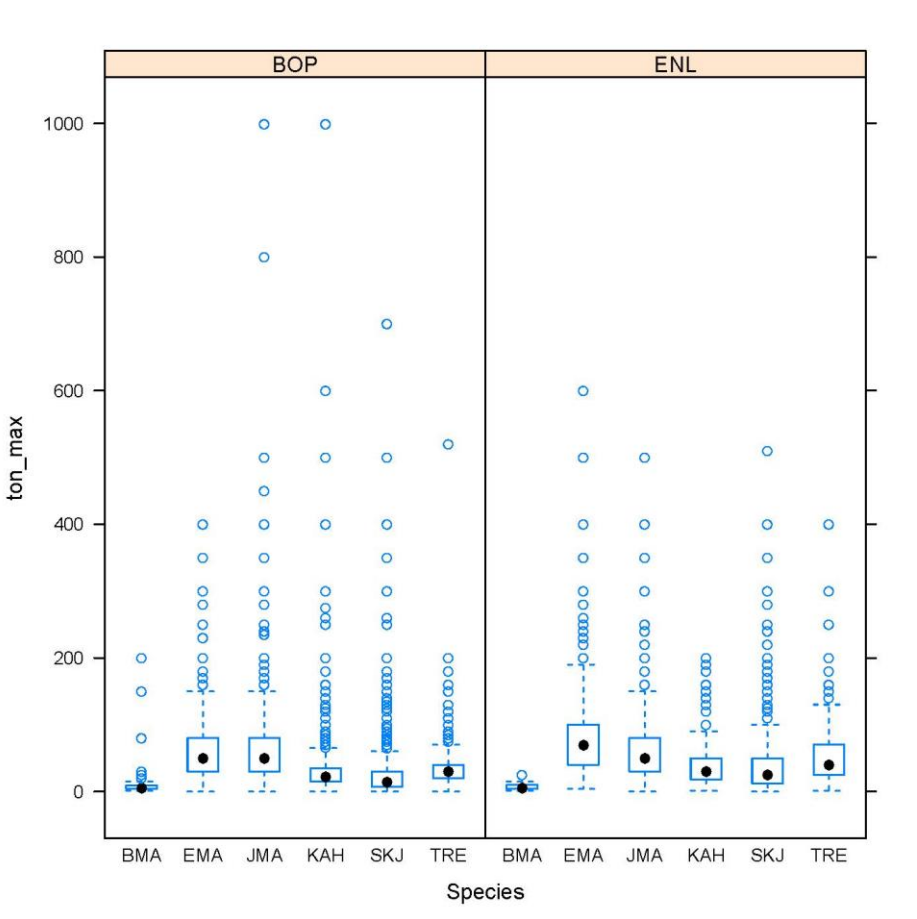
Maximum tonnage on minimum tonnage



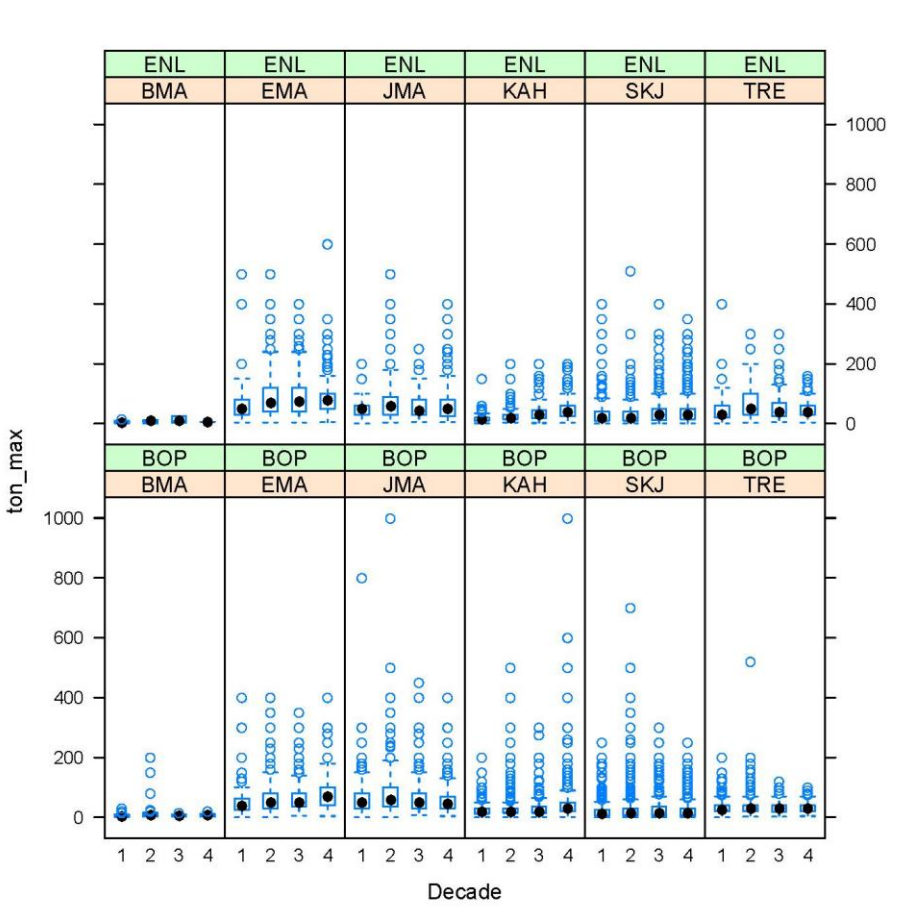
Maximum tonnage by the main species for the senior spotter pilots



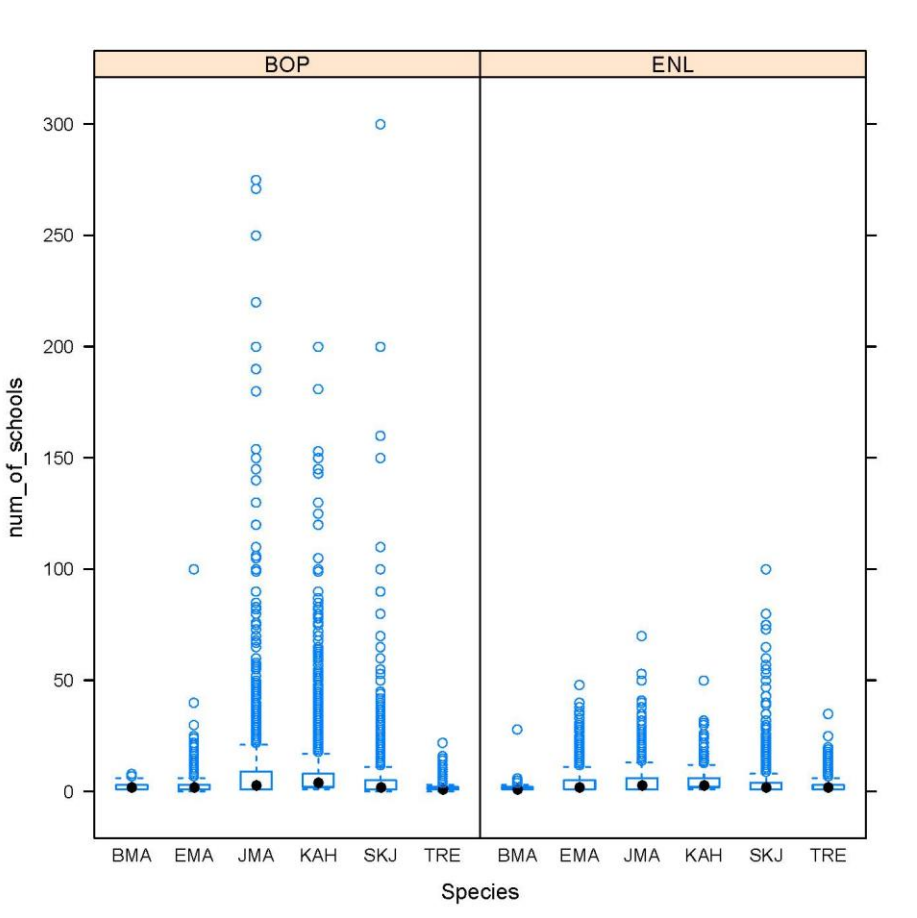
Maximum tonnage by species for the Bay of Plenty (BOP) and east Northland (ENL).



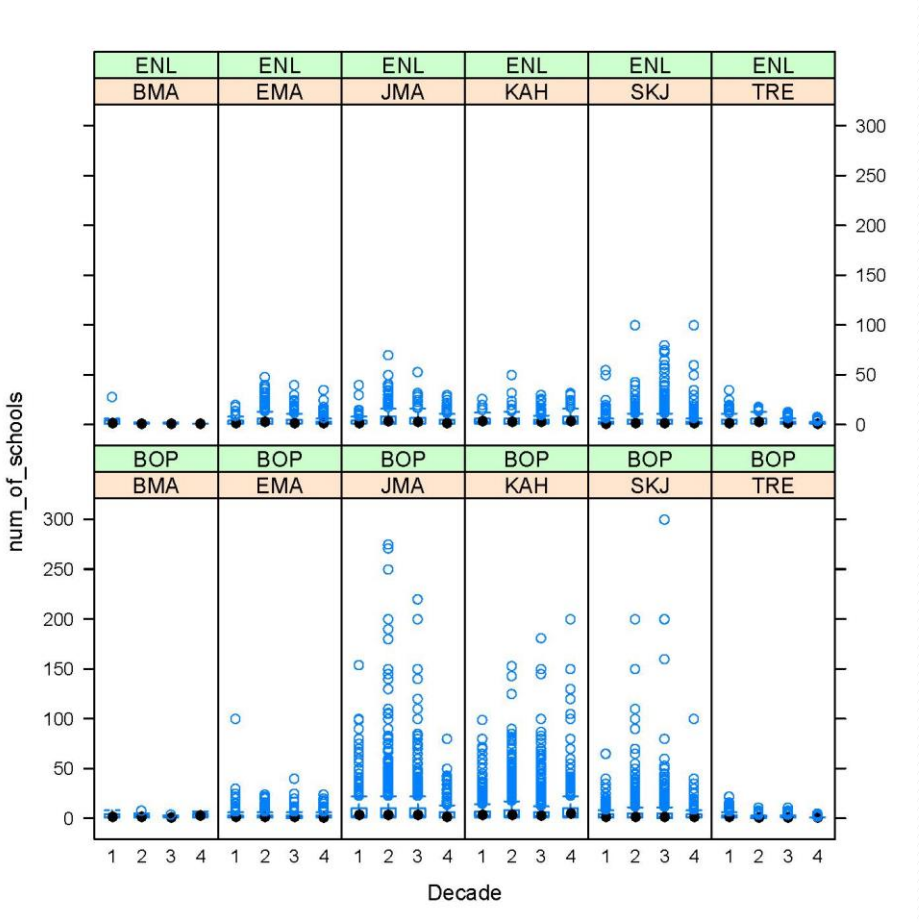
Maximum tonnage by decade (1976–83, 1984–93, 1994–03, 2004–13) for each species in the Bay of Plenty (BOP) and east Northland (ENL).



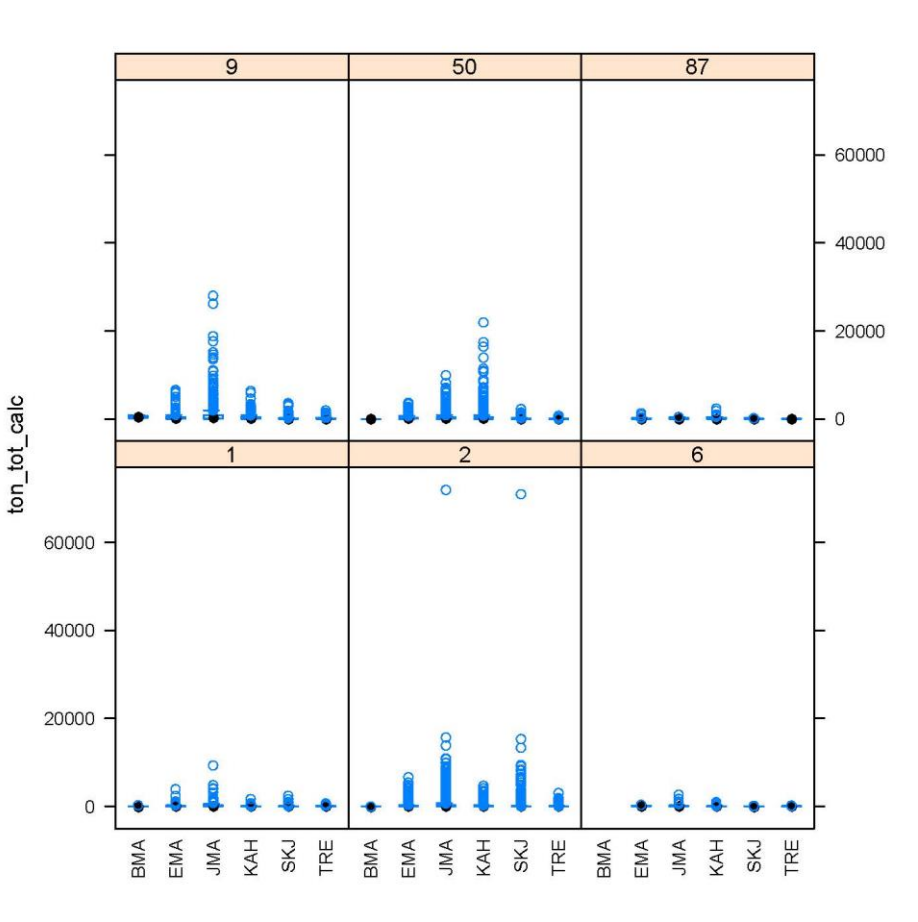
Number of schools by species for the Bay of Plenty (BOP) and east Northland (ENL).



Number of schools by decade (1976–83, 1984–93, 1994–03, 2004–13) for the main species in the Bay of Plenty (BOP) and east Northland (ENL).



Calculated tonnage by species for the senior pilots

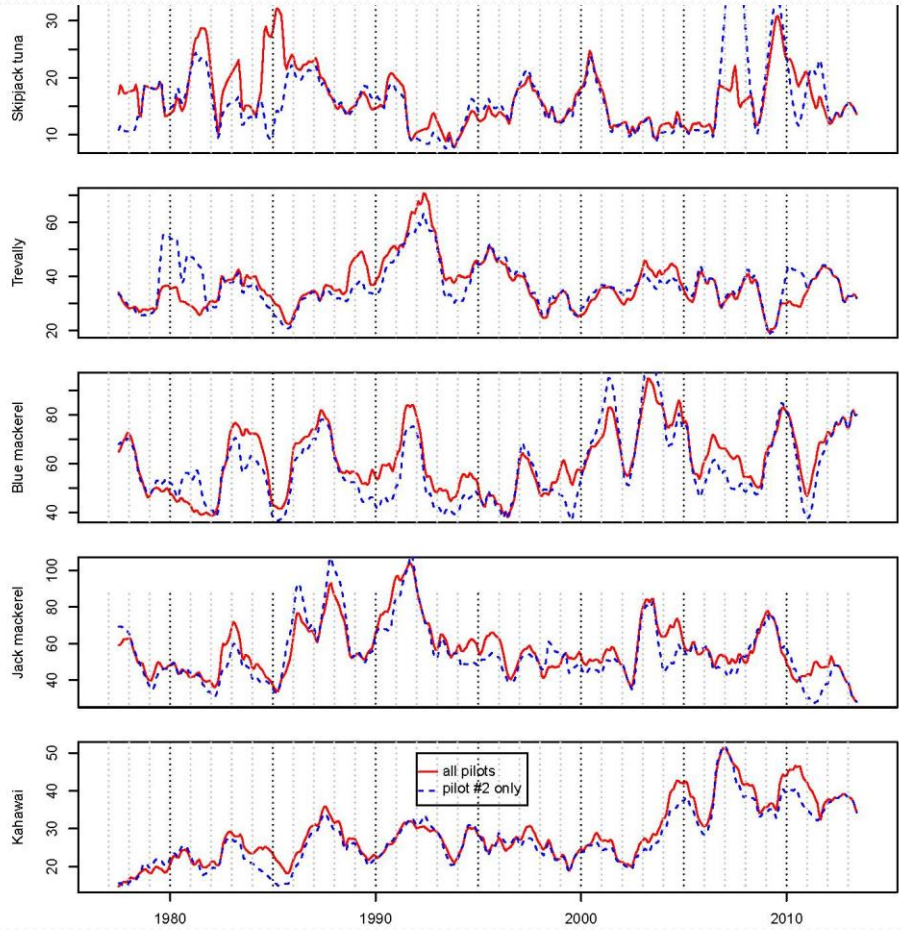


Estimates and significance levels (SL) from the trend analysis and comparison of sequence halves

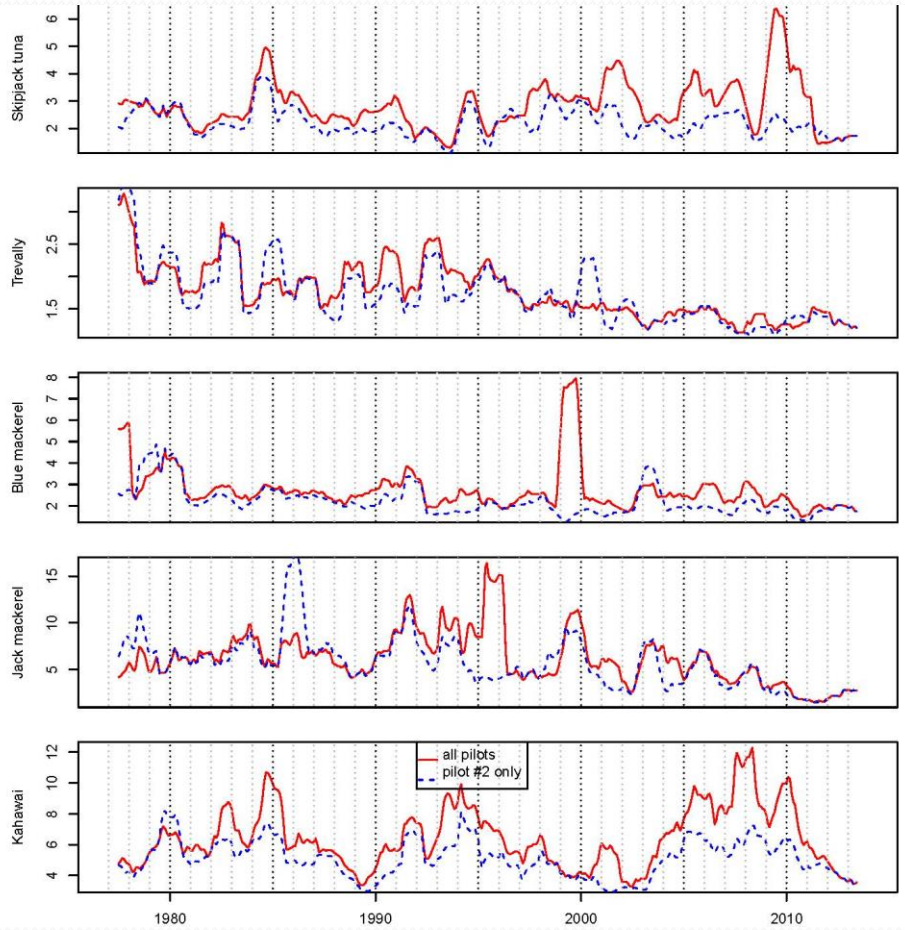
Analysis (statistic)	Sighting measure	SKJ	TRE	EMA	JMA	KAH
Trend (estimates)	ton_max	6.27e-3	9.193e-3	1.306e-2	-3.613e-3	1.810e-2
	num_of_schools					
	ton_tot_calc		†	7.123e-3	-19361e-2	1.964e-2
Trend (SL)	ton_max	0.001	0.001	0.001	0.001	0.001
	num_of_schools					
	ton_tot_calc			0.001	0.001	0.001
Sequence halves (SL)	ton_max	0.001		0.001	0.001	0.001
	num_of_schools			0.05	0.001	
	ton_tot_calc		0.001		0.001	0.001

†estimate = -1.176e-2 with no transformation or 7.024e-4 with a log transformation; the original distribution is closer to normal; neither are significant.

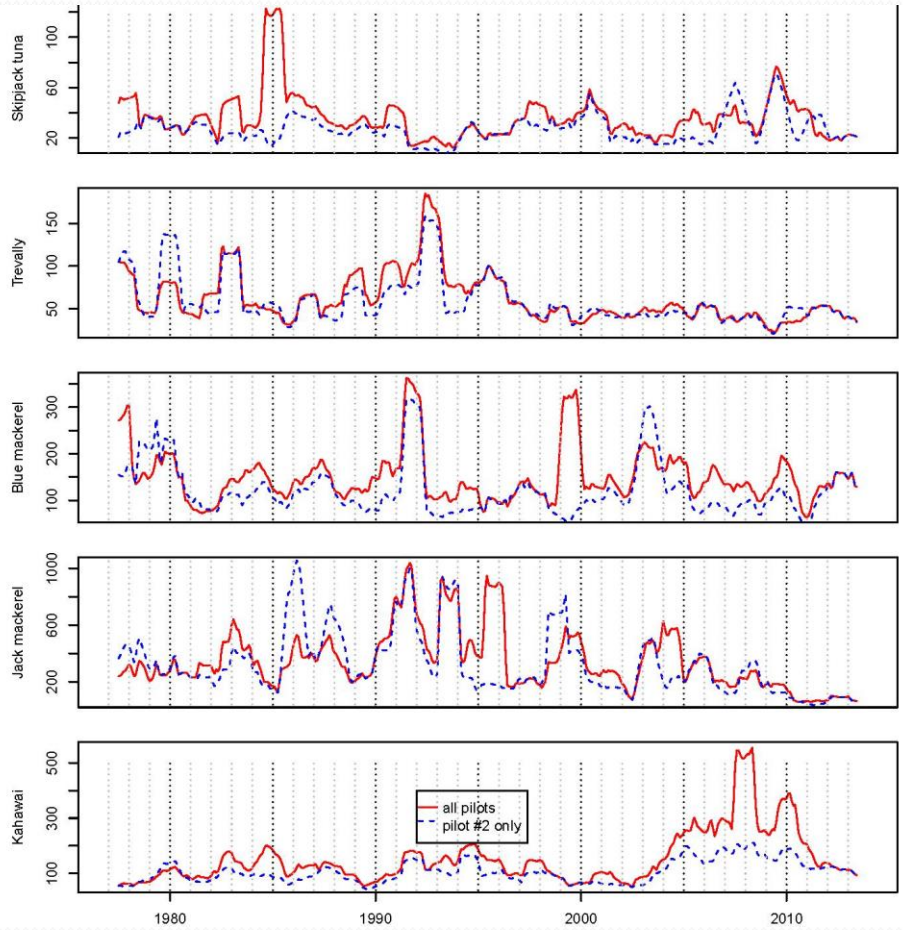
Time series plots of maximum sighting tonnage



Time series plots of the number of schools by sighting for each of the main species



Time series plots of maximum sightings tonnage for each of the main species



Discussion

- The aim here was to examine whether there was any obvious evidence to support the hypothesis that school size in surface schooling finfish species had declined over time since the advent of the purse-seine fishery.
- Although there is clear evidence of downward trends in the measures of school and sighting size, it is also clear that time series plots of the measures are highly variable.
- There are also examples clear positive trends e.g., kahawai.
- Calculated tonnage for trevally: high variability that is a feature of the first half of the series is reduced considerably and accompanied with what appears to be a reduction in calculated tonnage of the sighting as well as num_of_schools.
- It is not reflected in the ton_max time series, indicating that it is the number of schools that is more revealing in this case.

Acknowledgements

- Many thanks to the team at Fisheries Data Management of FNZ for providing the data for this work, in particular to Tyler Northern for the revised extract.
- Thanks also to John Leathwick for discussion on various aspects of the proposed modelling methods.

Fish shoal dynamics in North-Eastern North Island, NZ.

POP2019-02

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Presentation contents

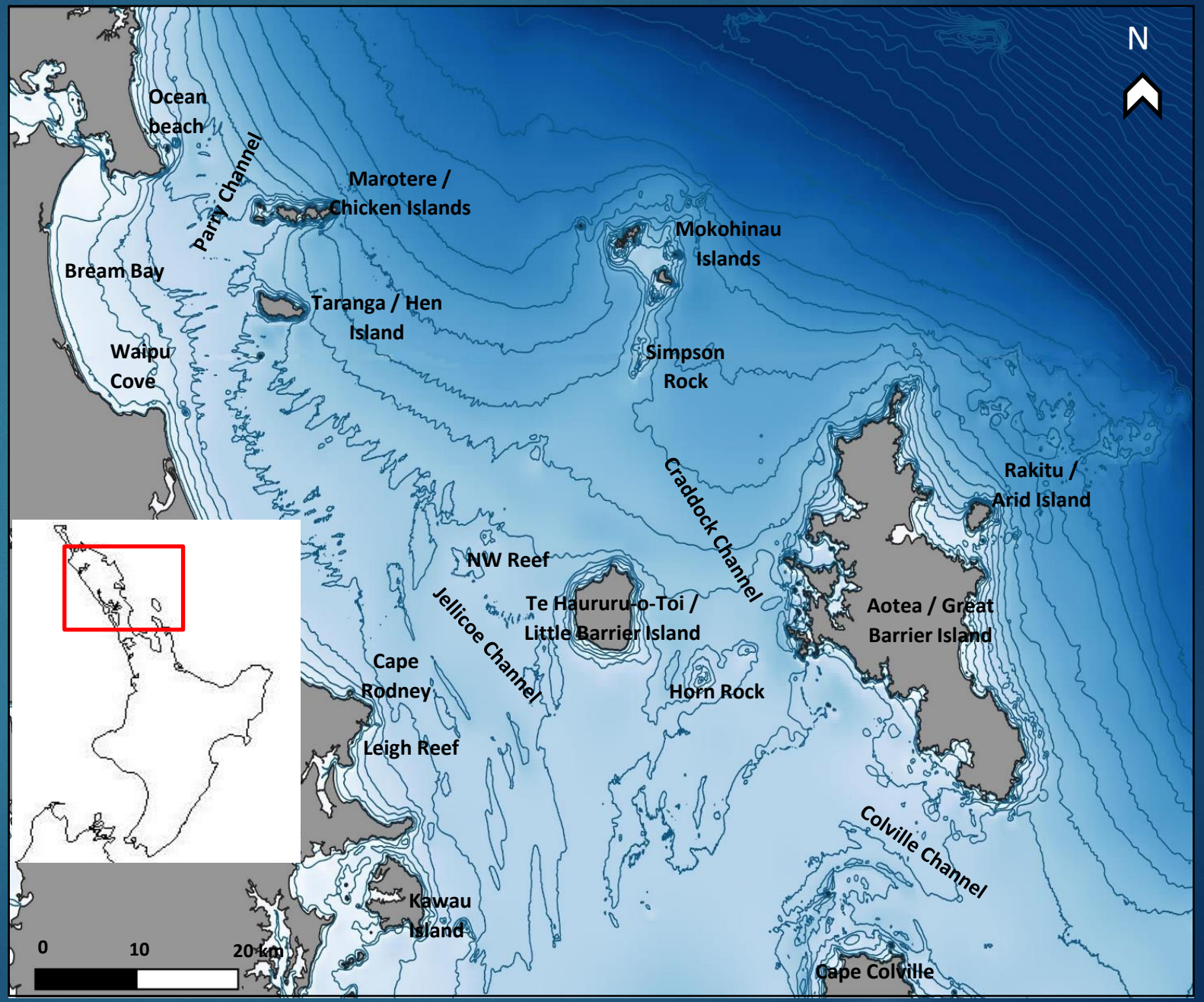
- Project background.
- Study area.
- Methods:
  - Overview,
  - Zooplankton,
  - Fish,
  - Underwater videography
- Results:
  - Fieldwork,
  - Event types,
  - Fish shoal,
  - Non-fish shoal,
  - Krill length,
  - Fish guts
- Discussion:
  - Fish shoal,
  - Non-fish shoal.
- Recommendations.

Manta ray swimming beneath a krill patch near the surface.

Project background

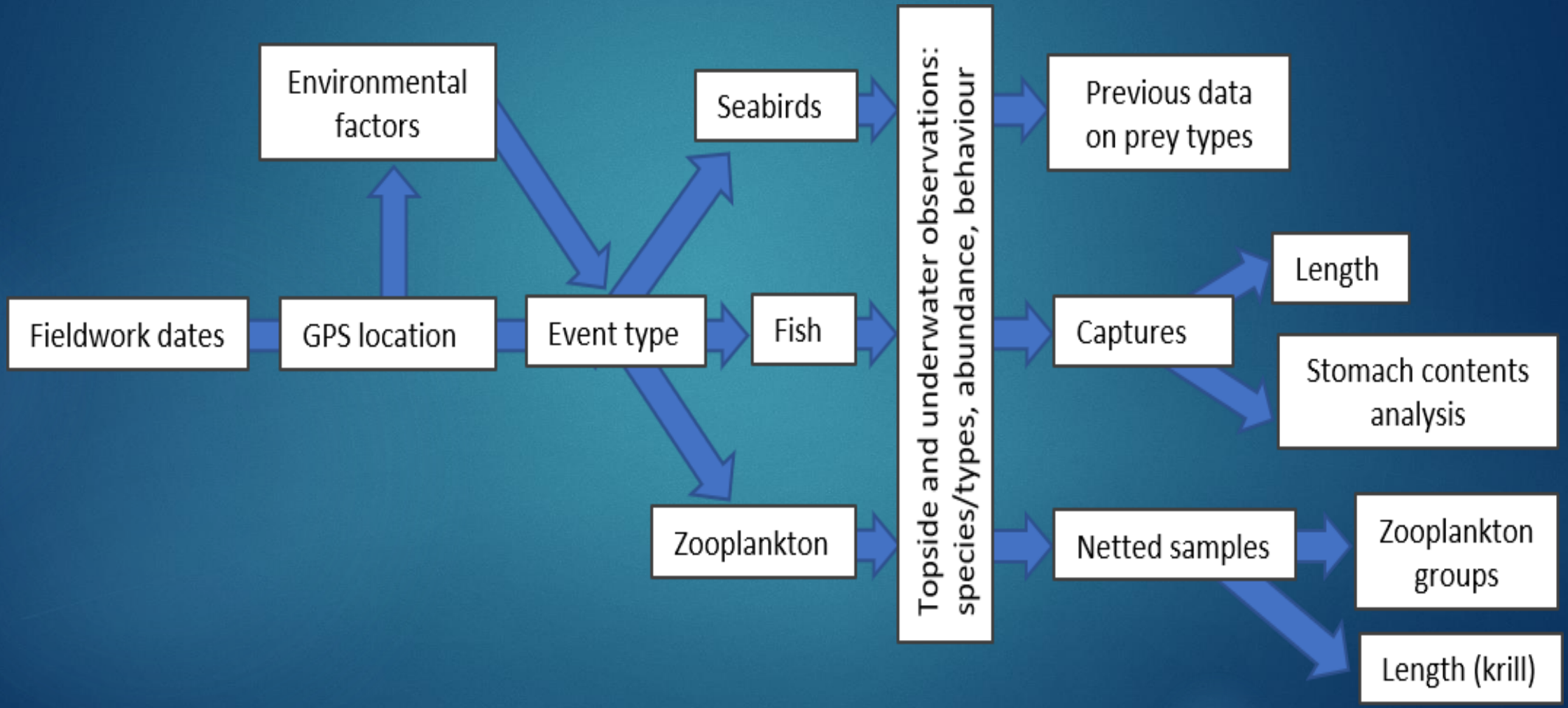
- Primary aim: characterise the biological composition of workups by determining associations among the presence of zooplankton, shoaling fish, and feeding seabirds.
- Continuation of the fish shoal and zooplankton research conducted 2017-2019.
- Notable feature of NE North Island waters are large numbers of seabirds feeding on zooplankton and small fish at “workups”.
- Greater knowledge required on the processes that drive workup formation and the multi-species interactions.
- Purse-seine fisheries target fish species associated with workups, potentially indirectly affecting prey availability for seabirds.

Study area



Map of the study area

Methods: Overview



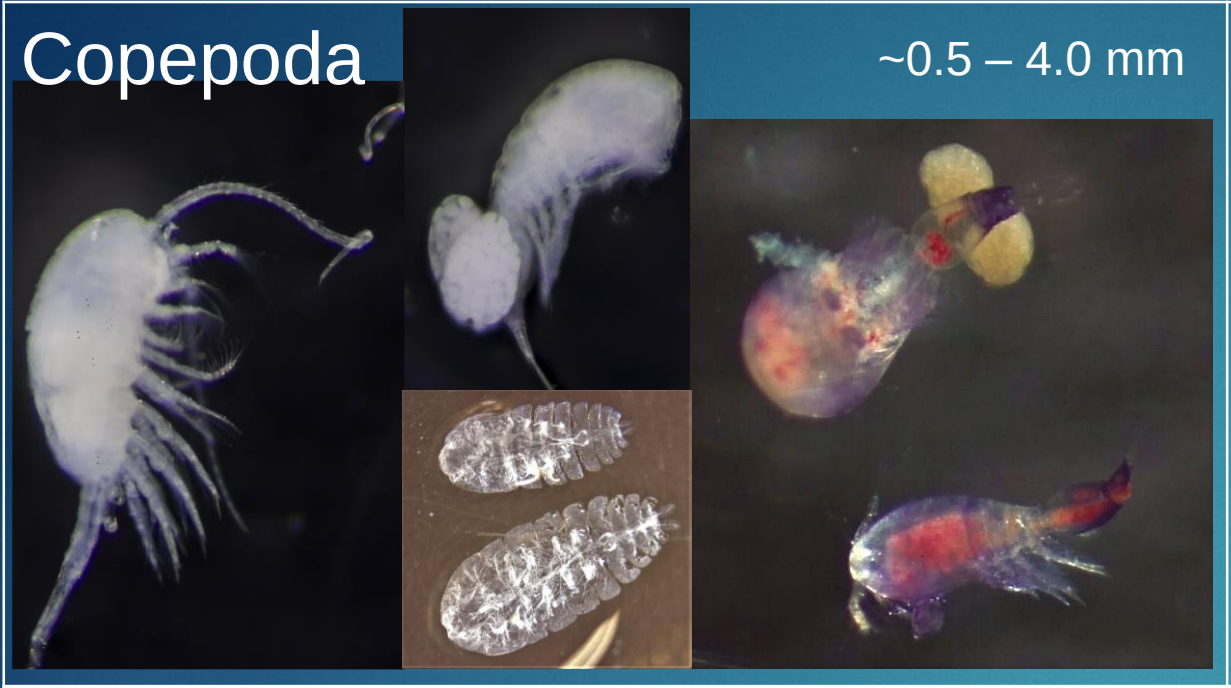
Methods: Zooplankton sampling & analysis

- Horizontal, surface zooplankton net tows conducted within fish shoal workups and nearby areas without workups.
- Two net types, flowmeter installed:
  - ‘high-speed’, 1.32 mm mesh, towed at ~5 knots.
  - ‘low-speed’, 0.25 mm mesh, towed at ~ 2 knots.
- Zooplankton types identified and counted into seven groups (Copepoda, Malacostraca, Krill nauplii, Thaliacea, Appendicularia, Fish eggs, Other).
- Number of individuals per m3 water filtered by net calculated.
- Categorical analysis to determine associations between zooplankton, fish, seabirds (and physical variables).
- Selection of krill lengths measured from each sample.

Methods: Zooplankton groups (I)

Copepoda

~0.5 – 4.0 mm

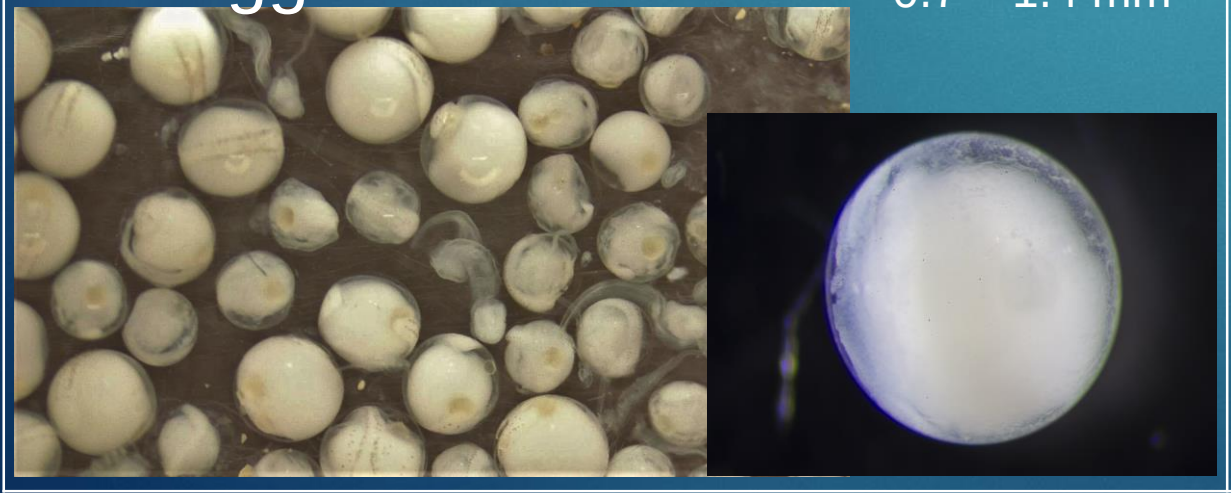


Malacostraca

~1.3 – 18 mm

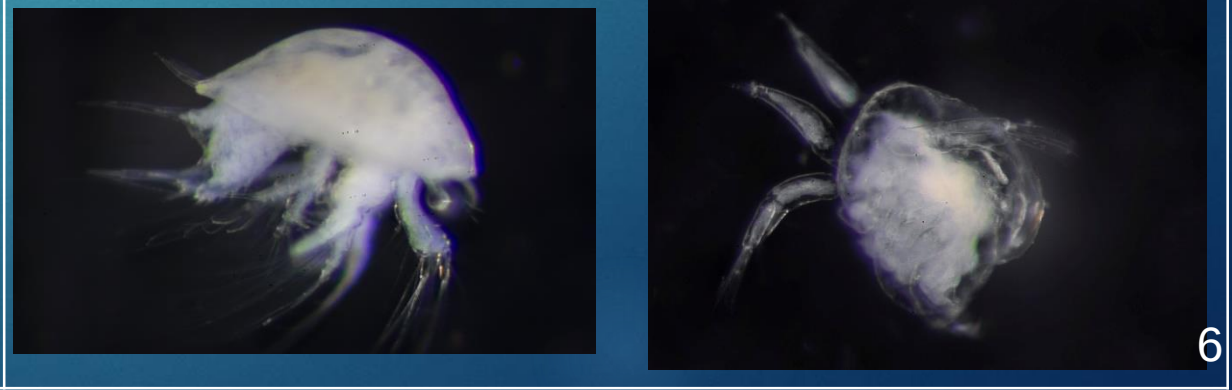
Fish eggs

0.7 – 1.4 mm



Krill nauplii

< 0.5 mm



Methods: Zooplankton groups (II)

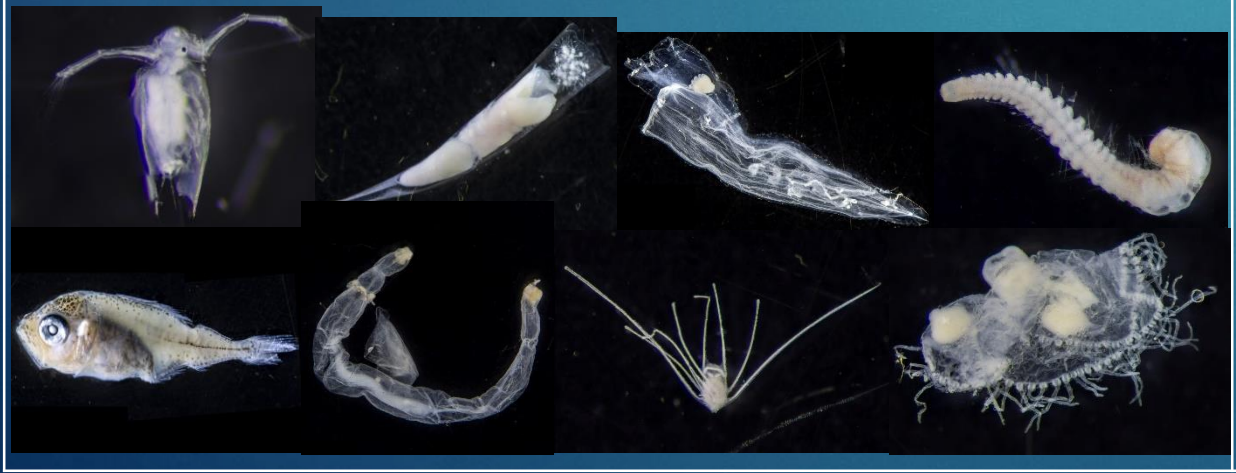
Thaliacea

~1.5 – 13+ mm

Appendicularia

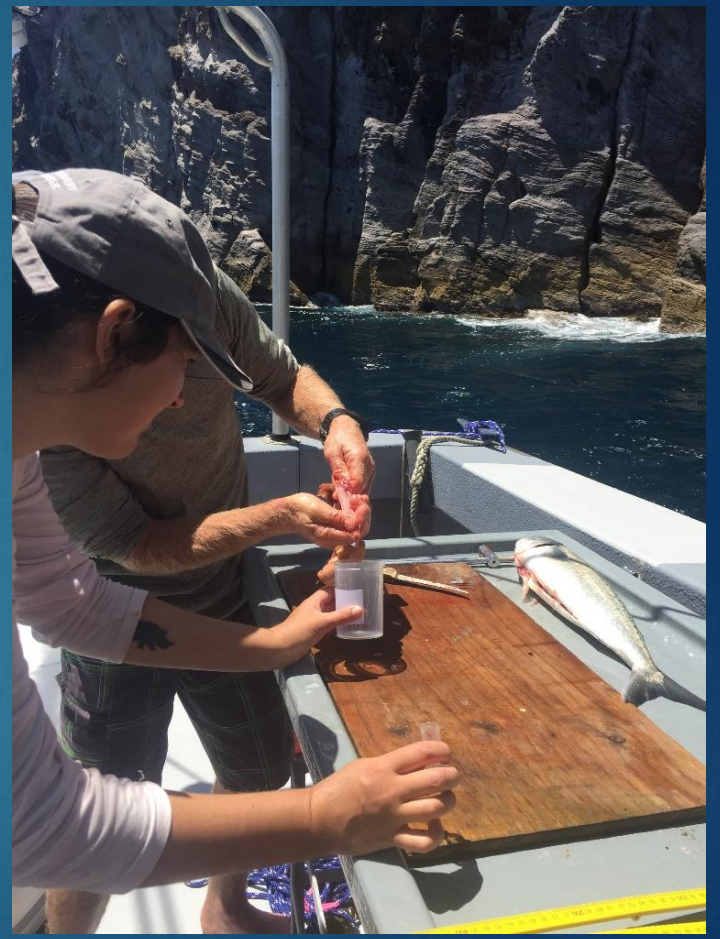
~2.0 – 4.5 mm

Other



Methods: Fish sampling & analysis

- Fish caught from workups using rod and line.
- Species and fish length recorded.
- Stomach contents removed plus a small muscle sample.
- Prey selectivity (Ivlev's index) calculated for fish gut contents vs. associated zooplankton net sample.

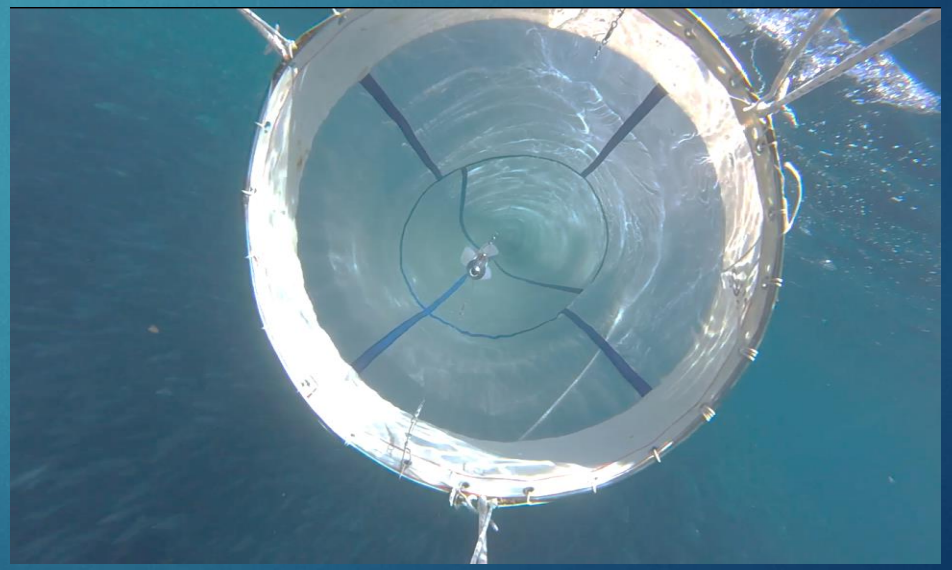


Obtaining gut contents from a kahawai

Methods: Underwater videography

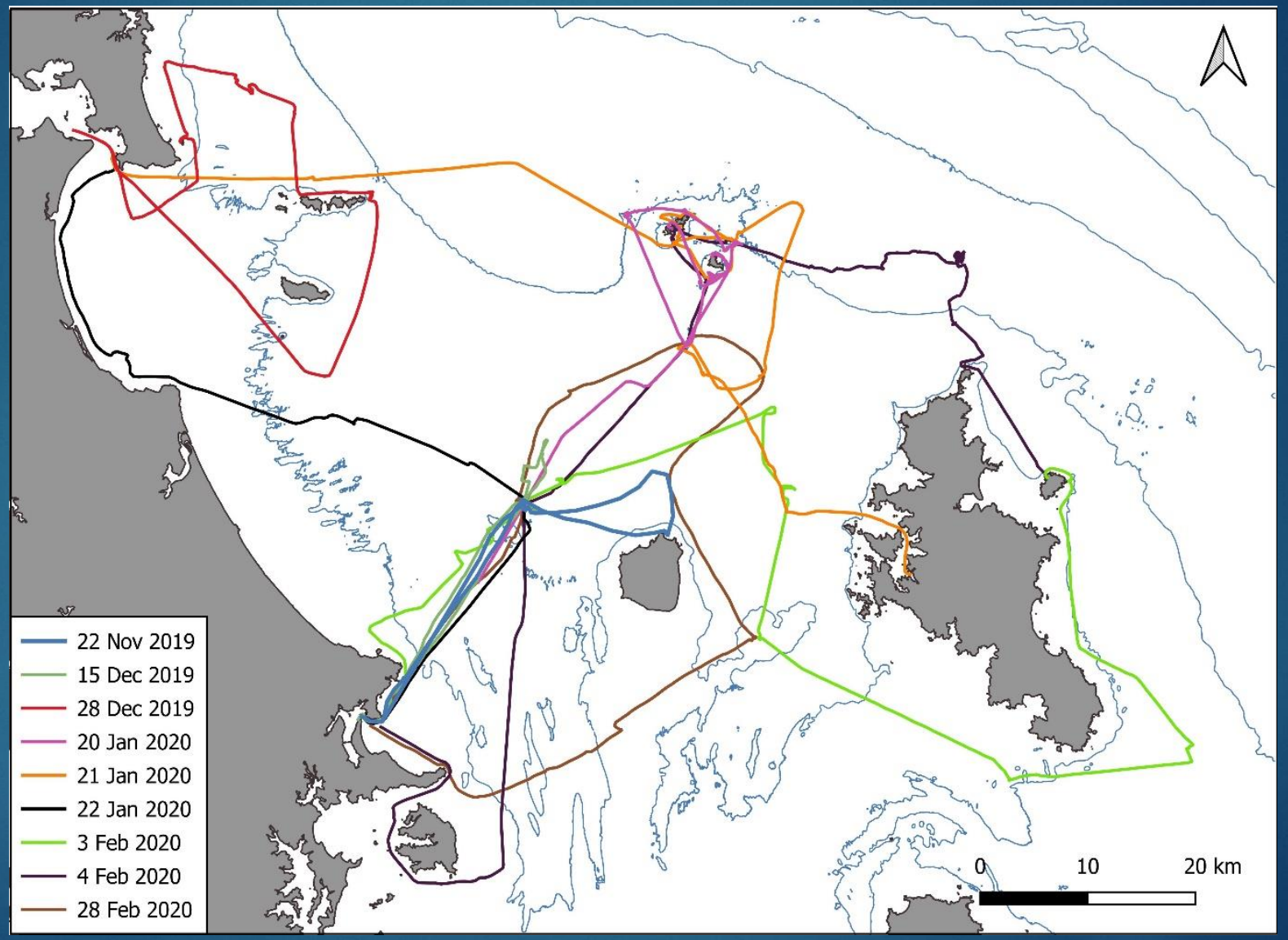
- Floating camera rig deployed into fish shoals / workups.
- Allowed determination of fish species present and larger zooplankton such as krill.
- Behavioural observation of species involved in the workup recorded.
- Camera on net to record any avoidance behaviour of zooplankton.

GoPros on floating camera rig



View of net from tow camera

Results: Fieldwork trips



Map of vessel track-lines for each fieldwork day

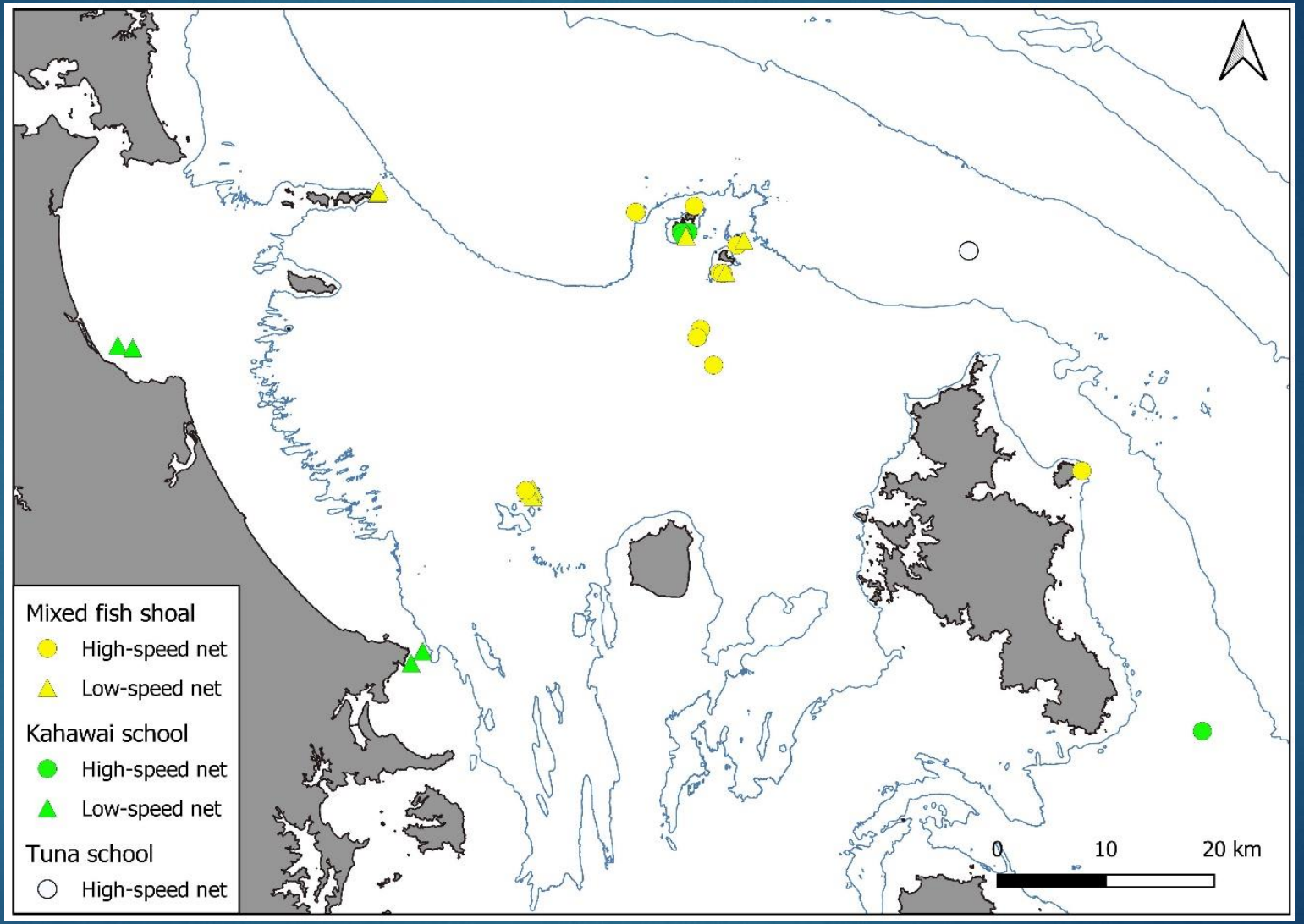
Results: Sampling event types

- Mixed fish shoal
- Control
- Kahawai school
- Tuna school
- Krill patches
- Current line
- Unknown

Mixed fish shoal event: trevally and kahawai.

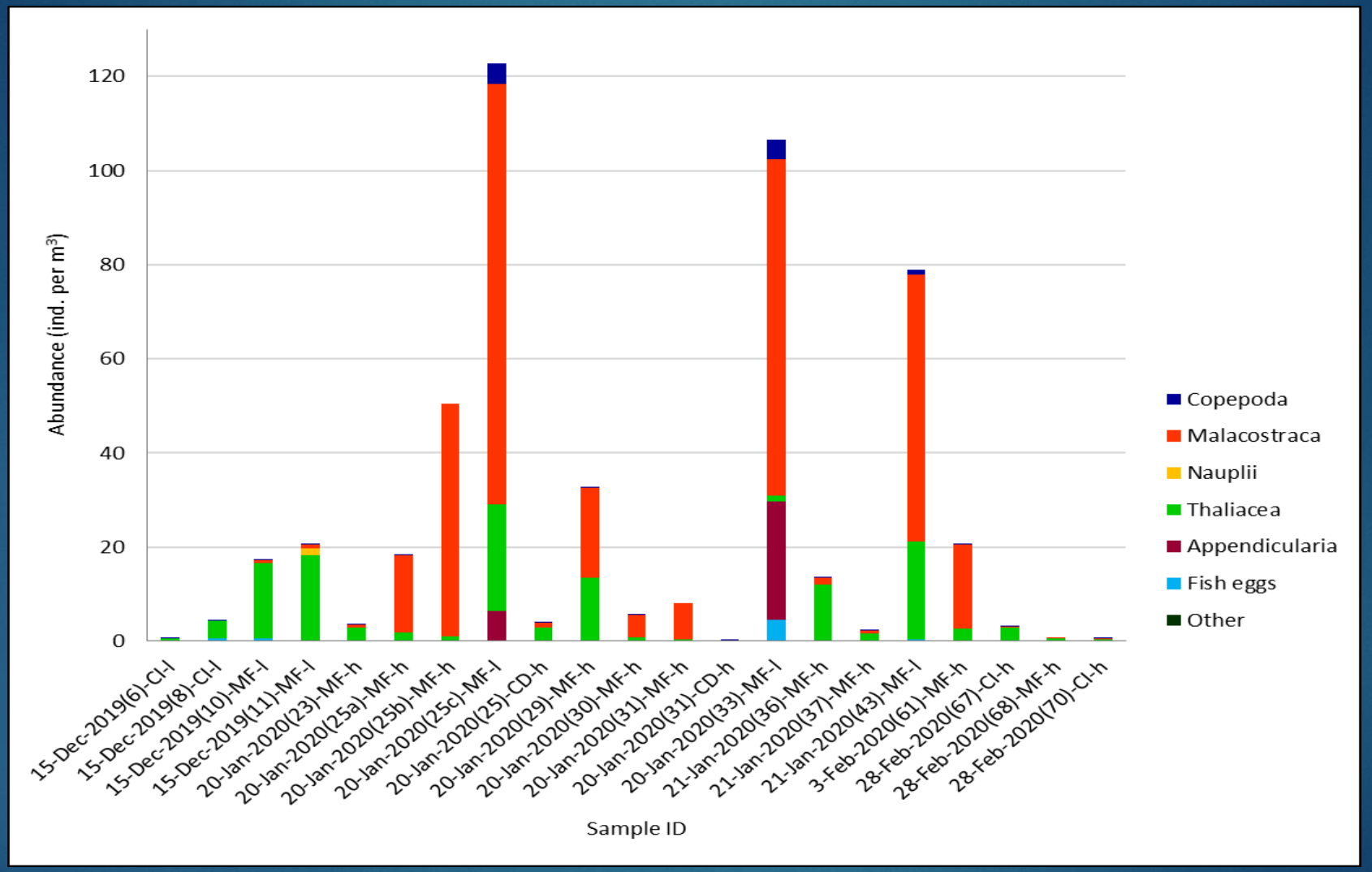
Krill patch event: small mackerel feeding on krill at the surface.

Results: Locations of fish shoal event sampling



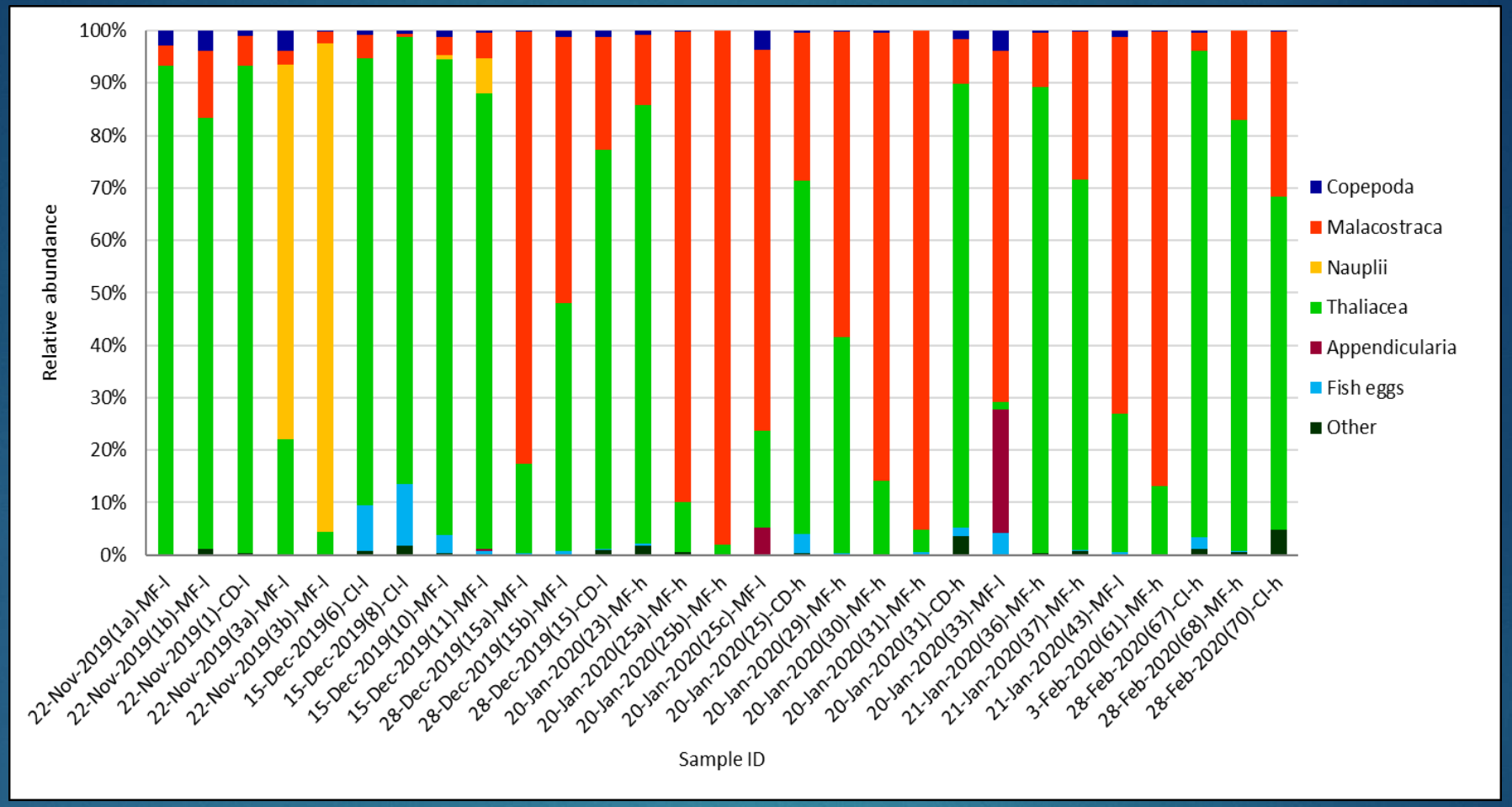
Location of zooplankton samples taken at fish shoal events

Results: Zooplankton at mixed fish shoal events (I)



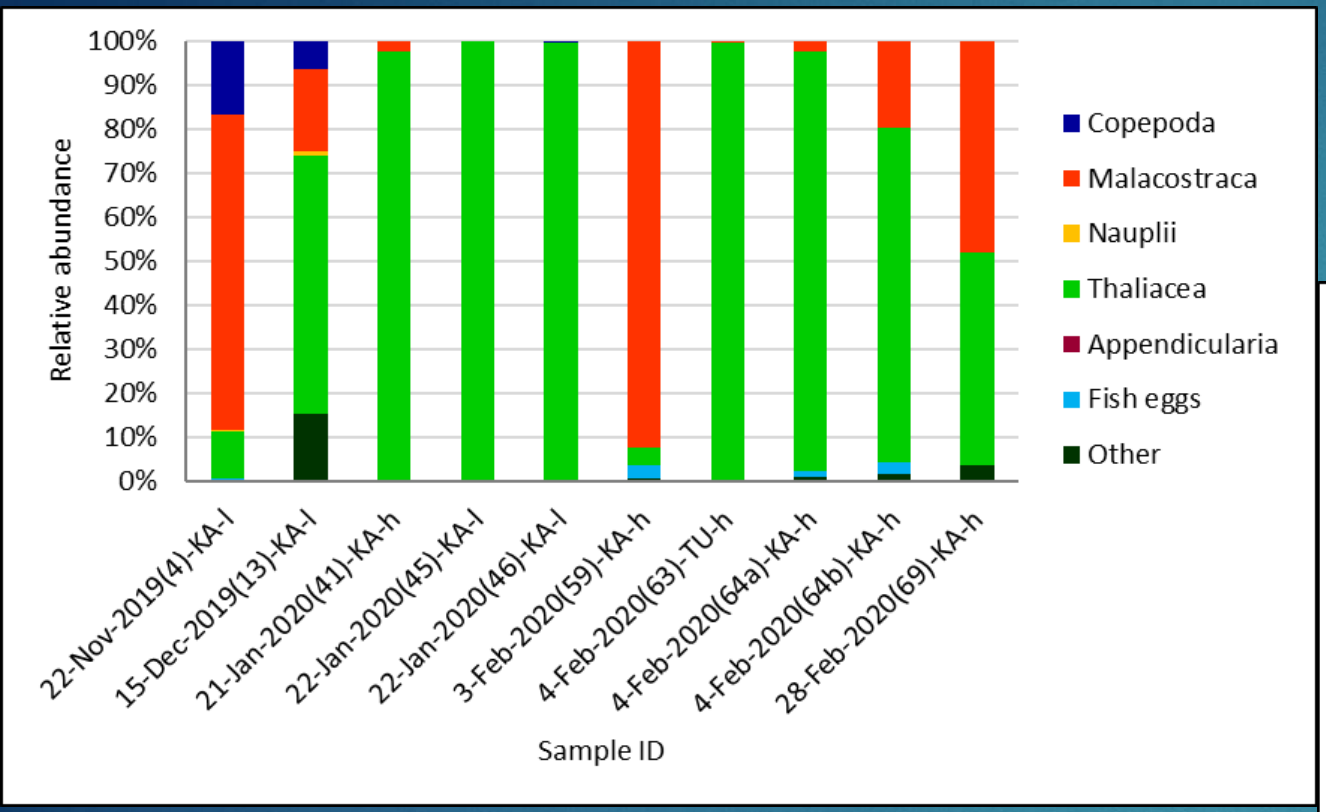
Abundance of zooplankton in each group for samples collected in mixed fish schools and controls.

Results: Zooplankton at mixed fish shoal events



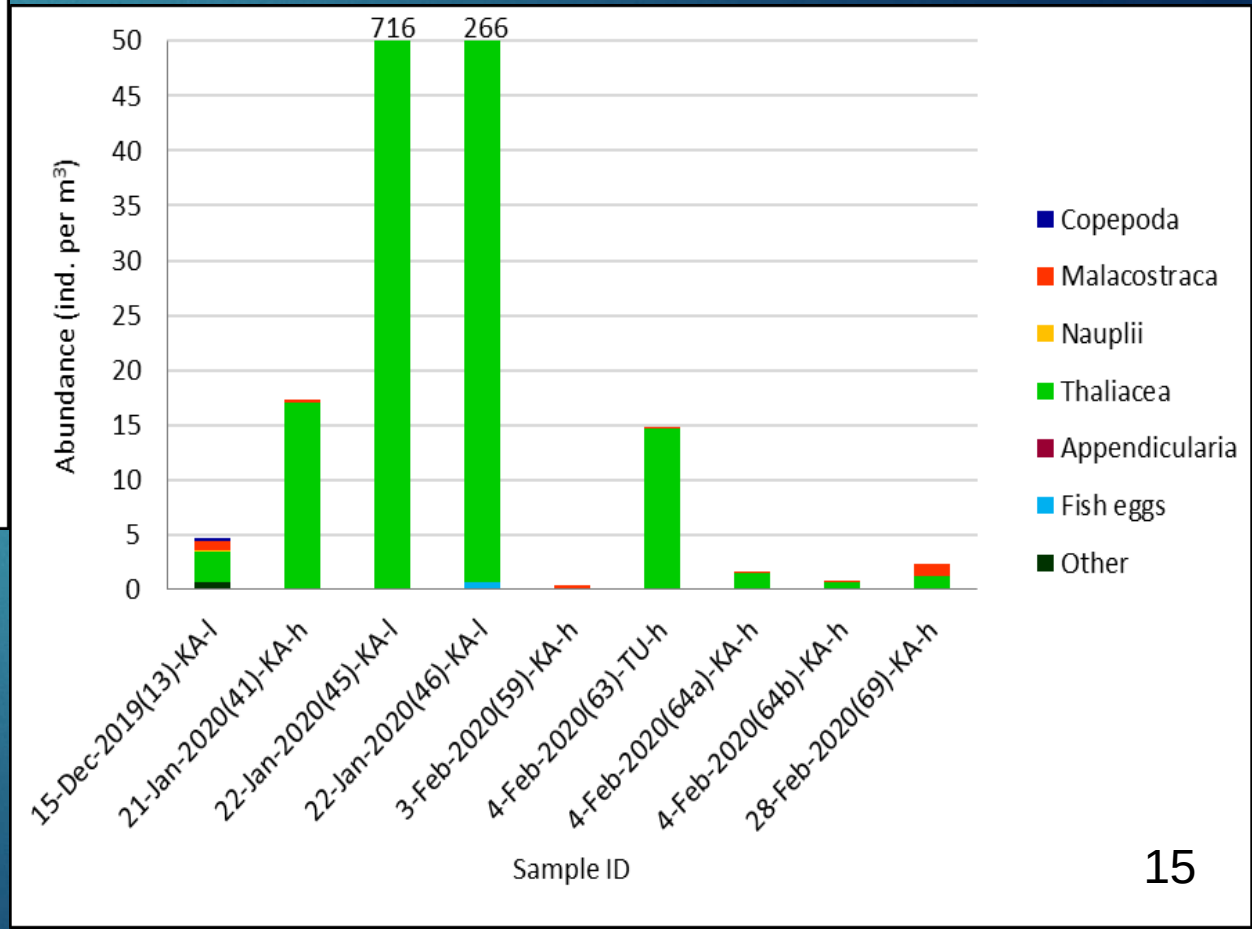
Relative abundance of zooplankton groups in samples taken from mixed fish shoals and controls. The sample ID gives the date, event number, event type (MF – mixed fish, CD – direct control, CI – indirect control) and sampling method: h – high-speed net, l – low-speed net). Where more than one sample was taken at an event this is designated as a, b, etc.

Results: Zooplankton at kahawai and tuna school events

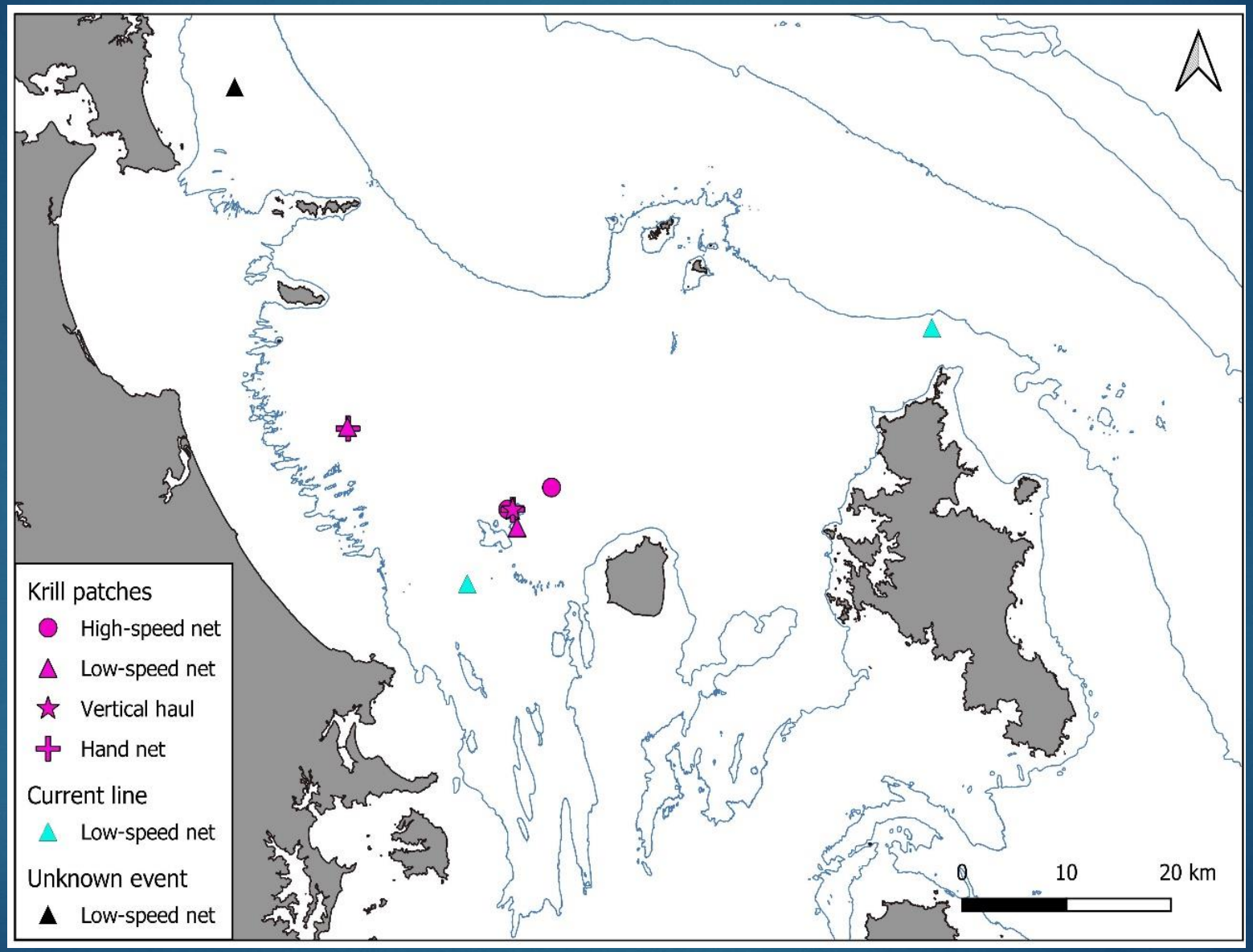


Above: Relative abundance of zooplankton groups in samples taken from kahawai (KA) and tuna (TU) schools.

Below: Abundance of zooplankton in each group for samples collected in kahawai and tuna schools.

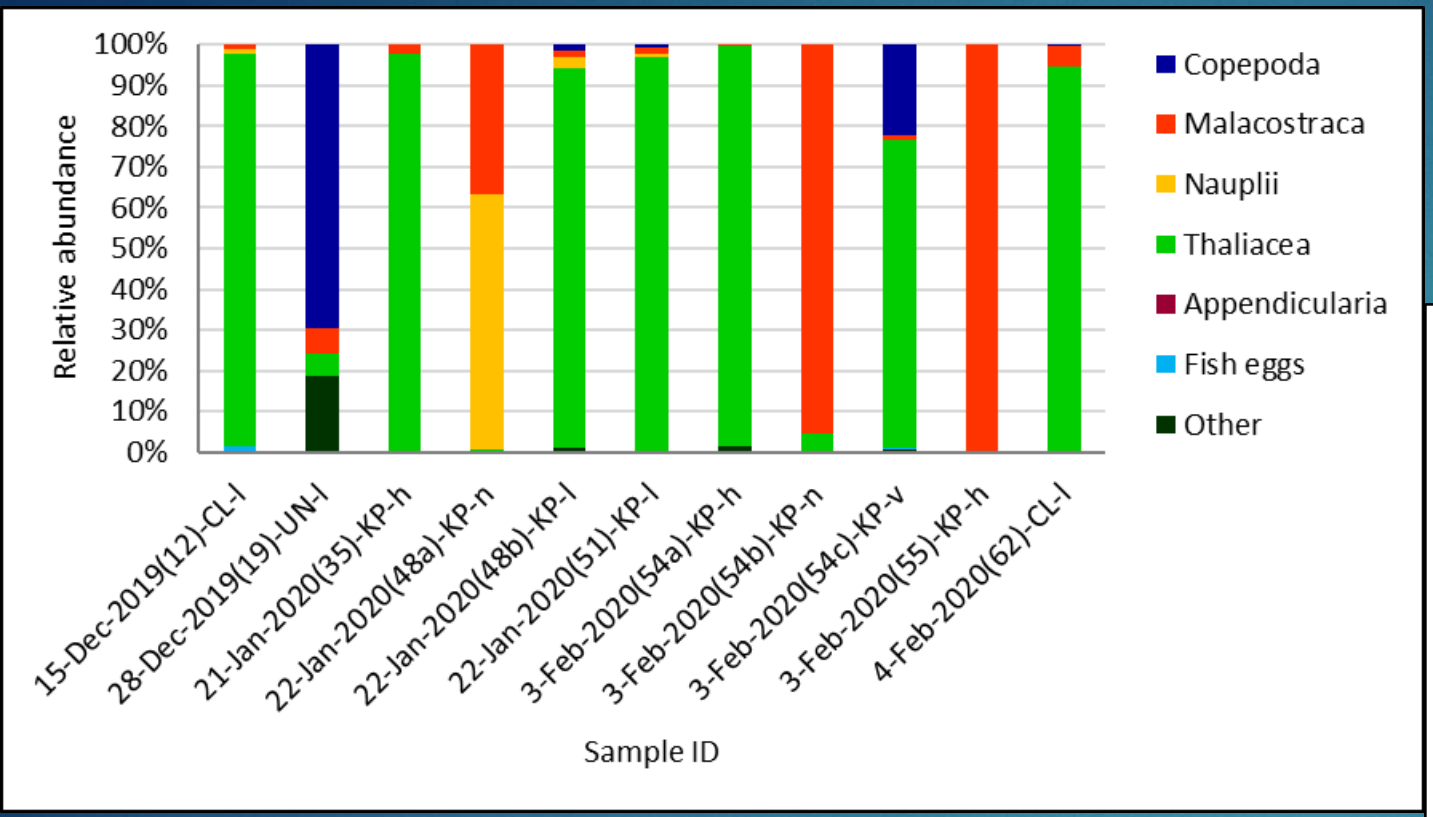


Results: Locations of non-fish shoal event sampling



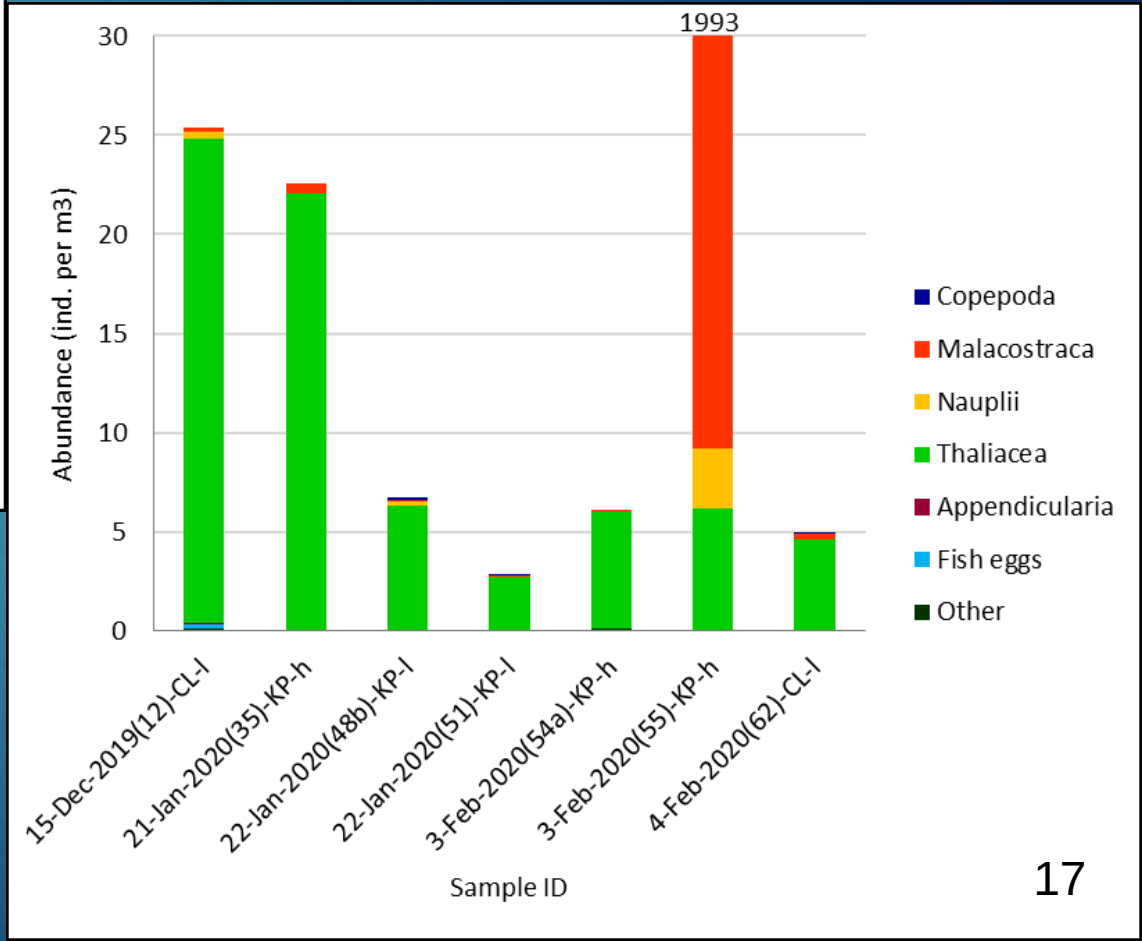
Location of zooplankton samples taken at non-fish shoal events

Results: Zooplankton at non-fish shoal events

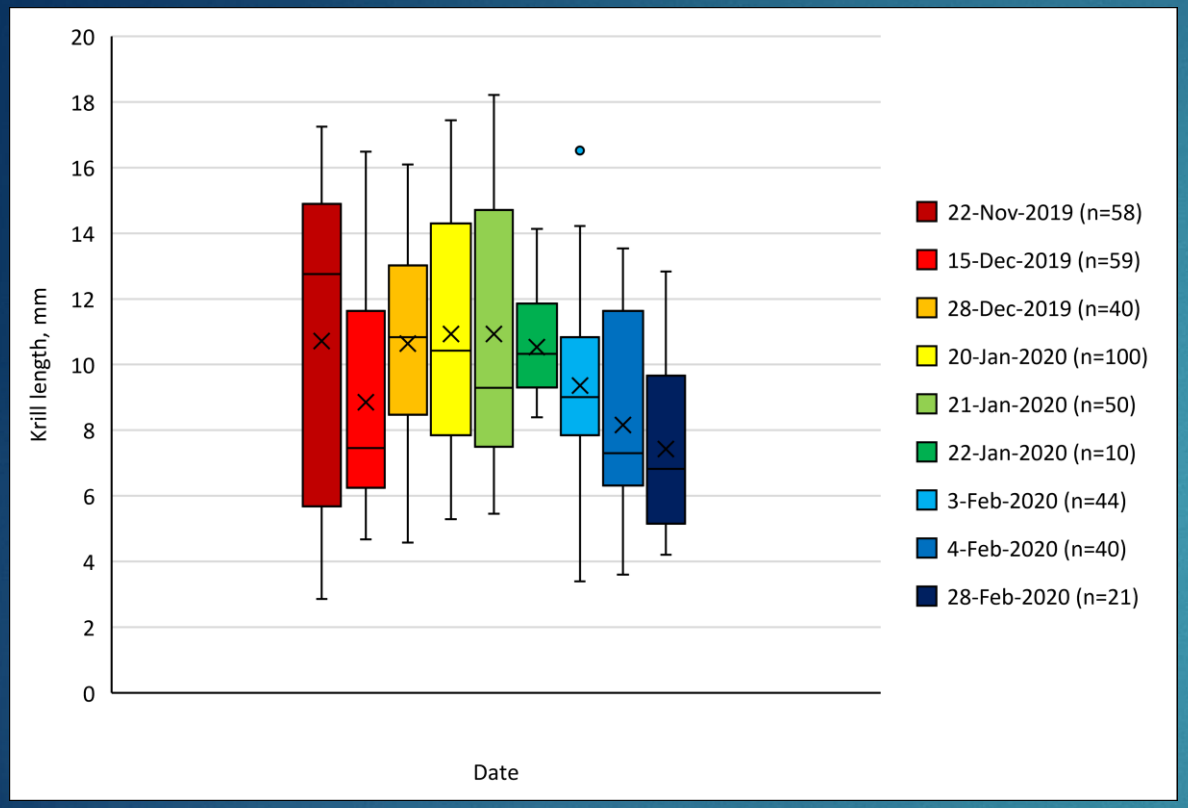


Above: Relative abundance of zooplankton groups in samples taken from current lines (CL), krill patches (KP) and unknown (UN).

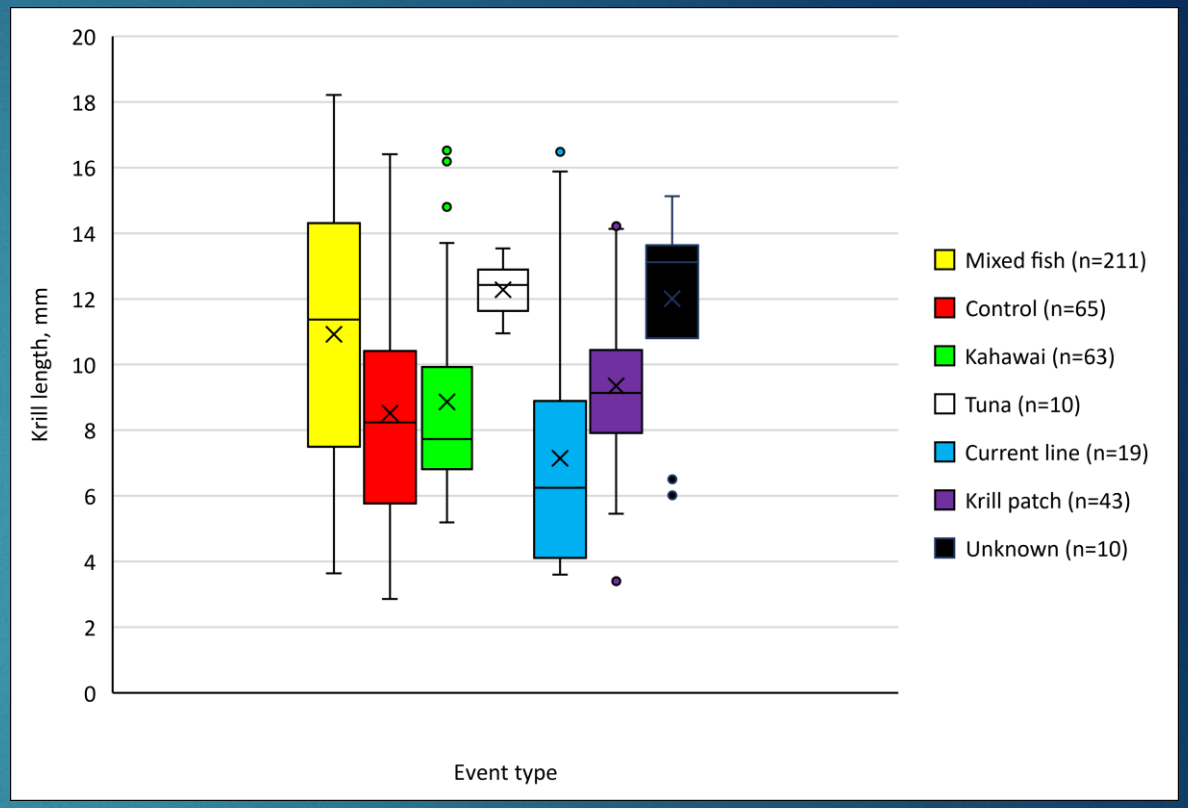
Below: Abundance of zooplankton in each group for samples collected in current lines and krill patches.



Results: Krill length

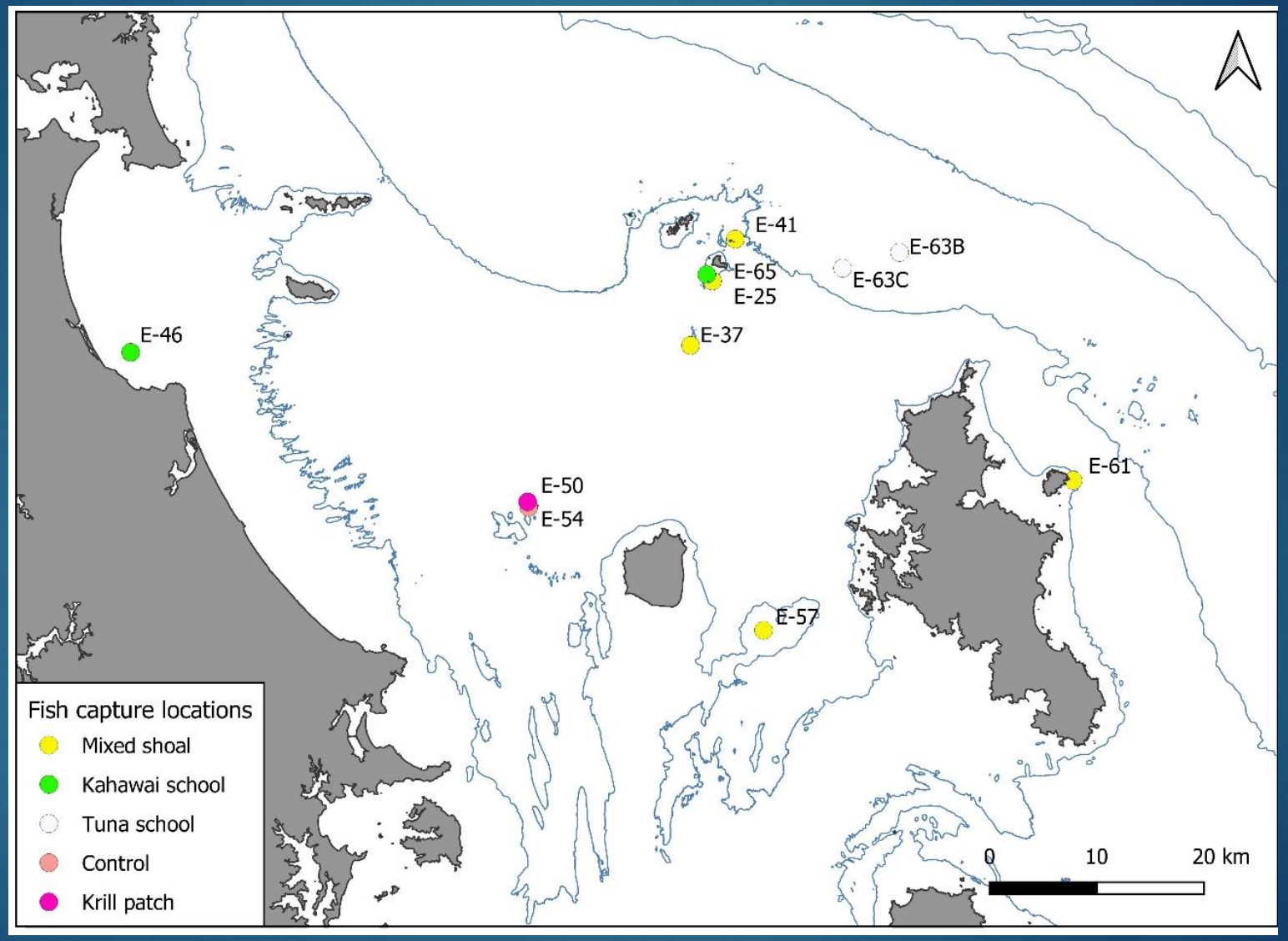


Krill length grouped by sampling trip date. The number of krill measured from each day is given in brackets.



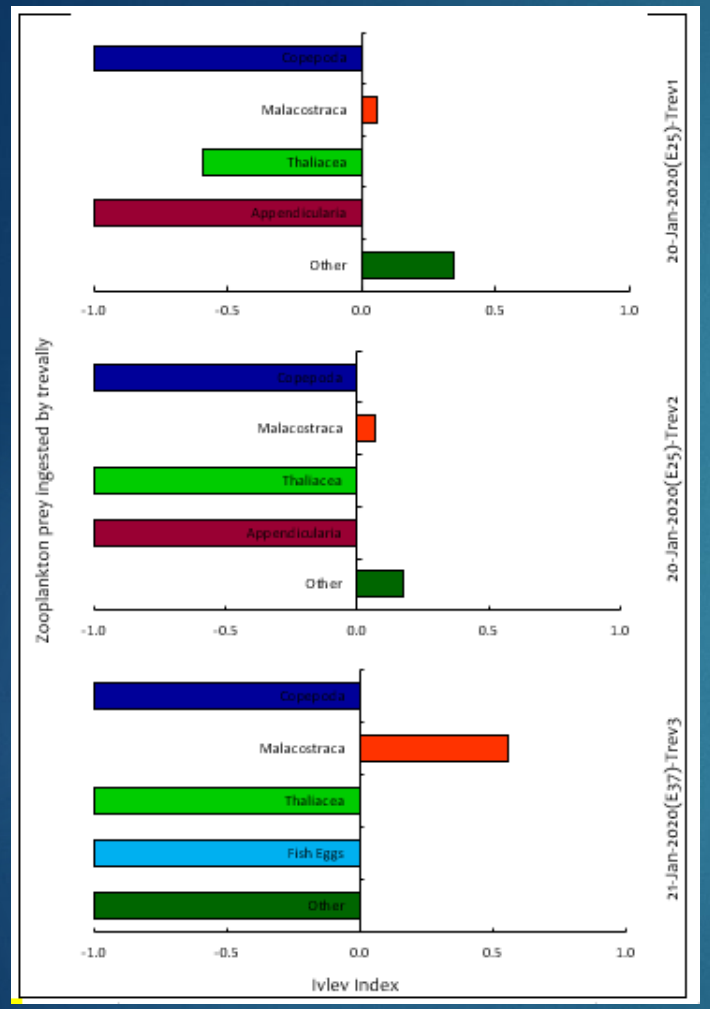
Krill length grouped by event type. The number of krill measured from each event type is given in brackets.

Results: Fish capture locations

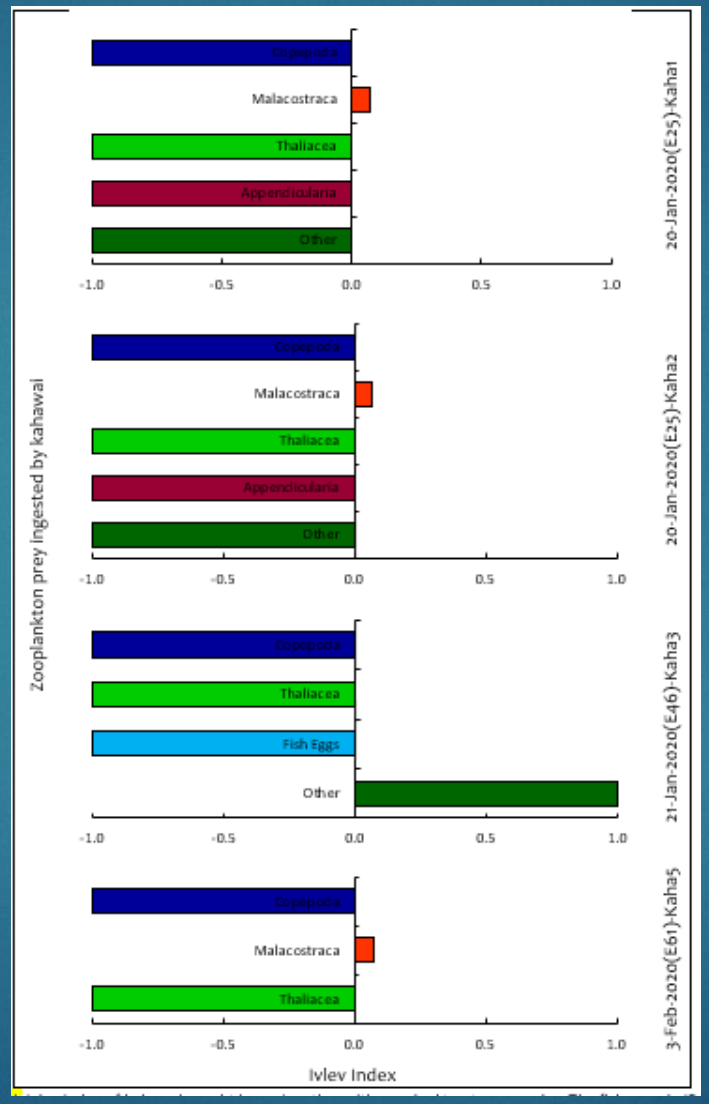


Locations of fish captures and event type.

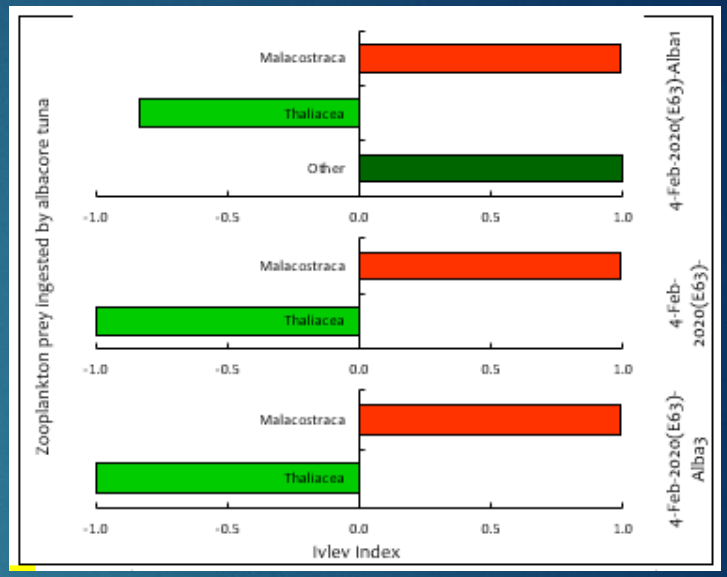
Results: Prey selectivity index



Ivlev index of trevally caught in conjunction with zooplankton tow samples.



Ivlev index of kahawai caught in conjunction with zooplankton tow samples.



Ivlev index of albacore tuna caught in conjunction with zooplankton tow samples.

Discussion: Fish shoal events

- Mixed fish shoal events:
  - Dramatic activity
  - High abundances of Malacostraca.
  - NW Reef and Mokohinau Is. key locations.
  - Control tows had low abundances of Malacostraca.
- Kahawai school events:
  - Two types: Malacostraca of juvenile fish dominated.
  - Located near mainland coast or in areas of current flow/upwelling.
- Tuna school event:
  - Activity spread over large area in deep water.
  - Malacostraca and small fishes.

Discussion: Non-fish shoal events

- Krill patches:
  - Krill swarming at the surface in patches, over large areas.
  - Reason for daytime surface swarming not clear.
  - Juvenile fish and mackerel feeding on krill.
- Current lines:
  - Small zooplankton samples dominated by Thalicea.
  - No fish seen.

Recommendations

- Full suite of biological and oceanographic variables to made at each event.
- Floating camera rig to be deployed at all sampling locations.
- Increase fish sampling at different types of event.
- Develop a technique to capture bait fishes at events.
- Revise zooplankton categories to reflect their relative importance to seabird diet.
- Expand macro-photography of zooplankton and work towards an ID guide.

POP2019-02 Fish shoal dynamics – seabird associations

Chris Gaskin (NNZST) with Lily Kozmian-Ledward (Sea Lily Ltd), Andrew Jeffs (UoA)

This presentation

- Project aims
- Fish species targeted by purse-seine fishery
- Seabird associations & foraging in relation to event types
- Seabirds as indicators
- Going forward
- Recommendations

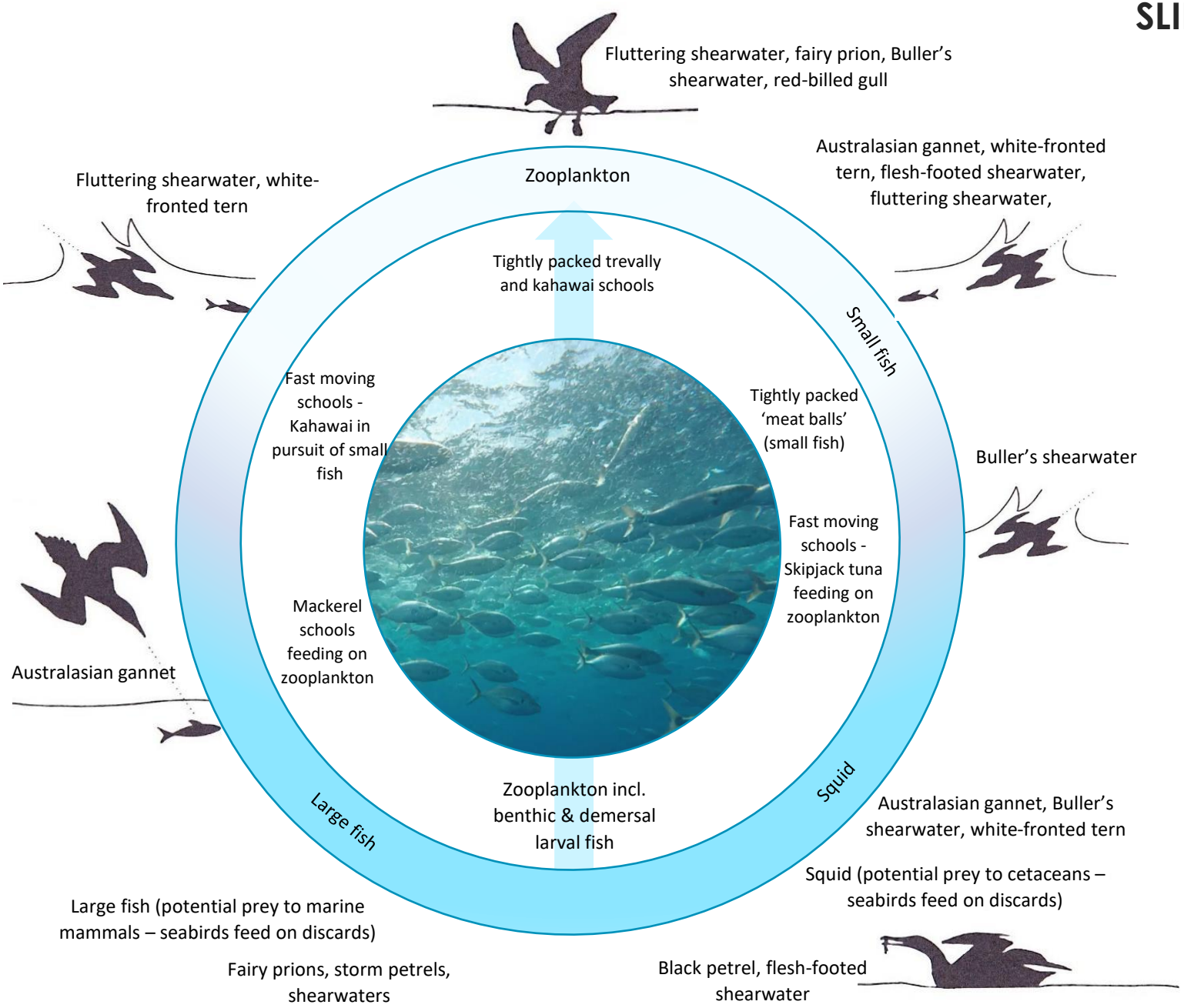
Project aims

- Primary aim: characterise the biological composition of workups by determining associations among the presence of zooplankton, shoaling fish, and feeding seabirds
- Continuation of the fish shoal and zooplankton research conducted 2017-2019
- Notable feature of NE North Island waters are large numbers of seabirds feeding on zooplankton and small fish at “workups”.
- Greater knowledge required on the processes that drive workup formation and the multi species interactions.
- Purse seine fisheries target fish species associated with workups, potentially indirectly affecting prey availability for seabirds.

Fish species targeted by purse-seine fishery

Kahawai
Trevally
Jack mackerel
Blue mackerel
Saury
Skipjack tuna
Pilchards
Anchovies

Diversity of fish school activity



Diversity of seabird feeding activity

Event types

- Mixed fish shoals
- Kahawai
- Tuna
- Current lines
- Krill patches or swarms
- Common dolphins and other marine mammals
- Unknown

Seabird reliance on fish shoals?

Species

Rako Buller's shearwater

Tītī wainui Fairy prion

Pakahā Fluttering shearwater

Tākapu Australasian gannet

Tara White-fronted tern

Tarapunga Red-billed gull

Taonui Flesh-footed shearwater

Takahikare White-faced storm-petrel

Mixed fish schools

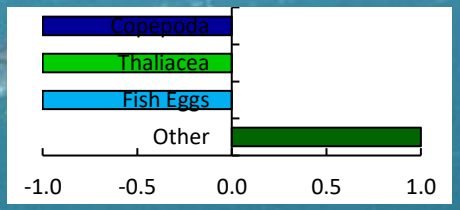
Fairy prion

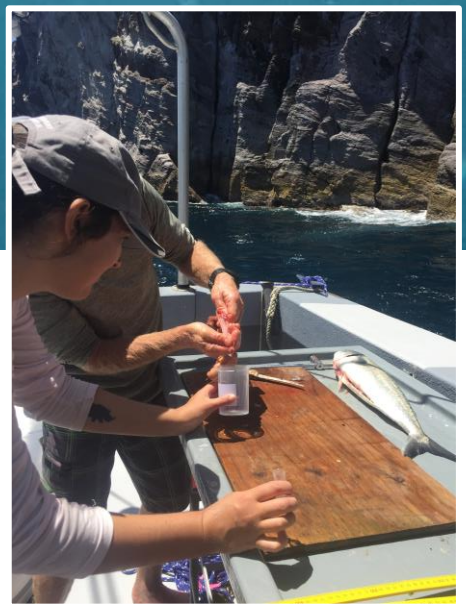
Fluttering shearwater

Red-billed gull

Kahawai schools

Kahawai stomach contents – 22 Jan





Fluttering shearwater

White-fronted tern

Tuna schools

Buller's shearwater

Flesh-footed shearwater

Other petrels

Krill patches/swarms

Shearwaters

Fish

Other

Common dolphins & other marine mammals

Australasian gannet

Flesh-footed shearwaters

Fluttering shearwaters

Current lines

Fairy prion

White-faced storm petrel

Fish shoals signal ‘fast food’ for some seabirds

Do fish shoals:

- Drive krill and other prey to the surface making them more readily available to surface feeding seabirds?

OR

- Krill aggregate naturally at or near the surface in areas of upwelling or current flows which fish shoals target, providing visual and olfactory cues to seabirds?

Or some other dynamic?

And what of seabirds’ reliance on fish shoals?

Seabirds as indicators of change?

Developing tools for monitoring indirect effects and fish associations

Burrow nesters

Strong site fidelity

Prey shifting could mean longer provisioning trips affecting breeding success

Fairy prion

Buller's shearwaters

Surface nesters

Follow the food

Move home in response to changes in diet, prey availability

White-fronted terns

Australasian gannets

Titi Wainui/fairy prion

Zooplankton specialist

Fairy prion

Regurgitation sample collected 5 Dec 2020

Rako/Buller's shearwater

Foraging plasticity

Feeding on krill with fish shoals – up to late January

Trevally/kahawai and mackerel schools

Prey across three trophic levels (stable isotopes).

Includes: krill, fish & squid (from regurgitations)

From late January – following tuna schools

Tākapu/Australasian gannet

Solitary feeder, feeding with cetaceans, feeding with ‘bait ball’ work ups …

Generalists with varied diet

Pakahā/fluttering shearwater

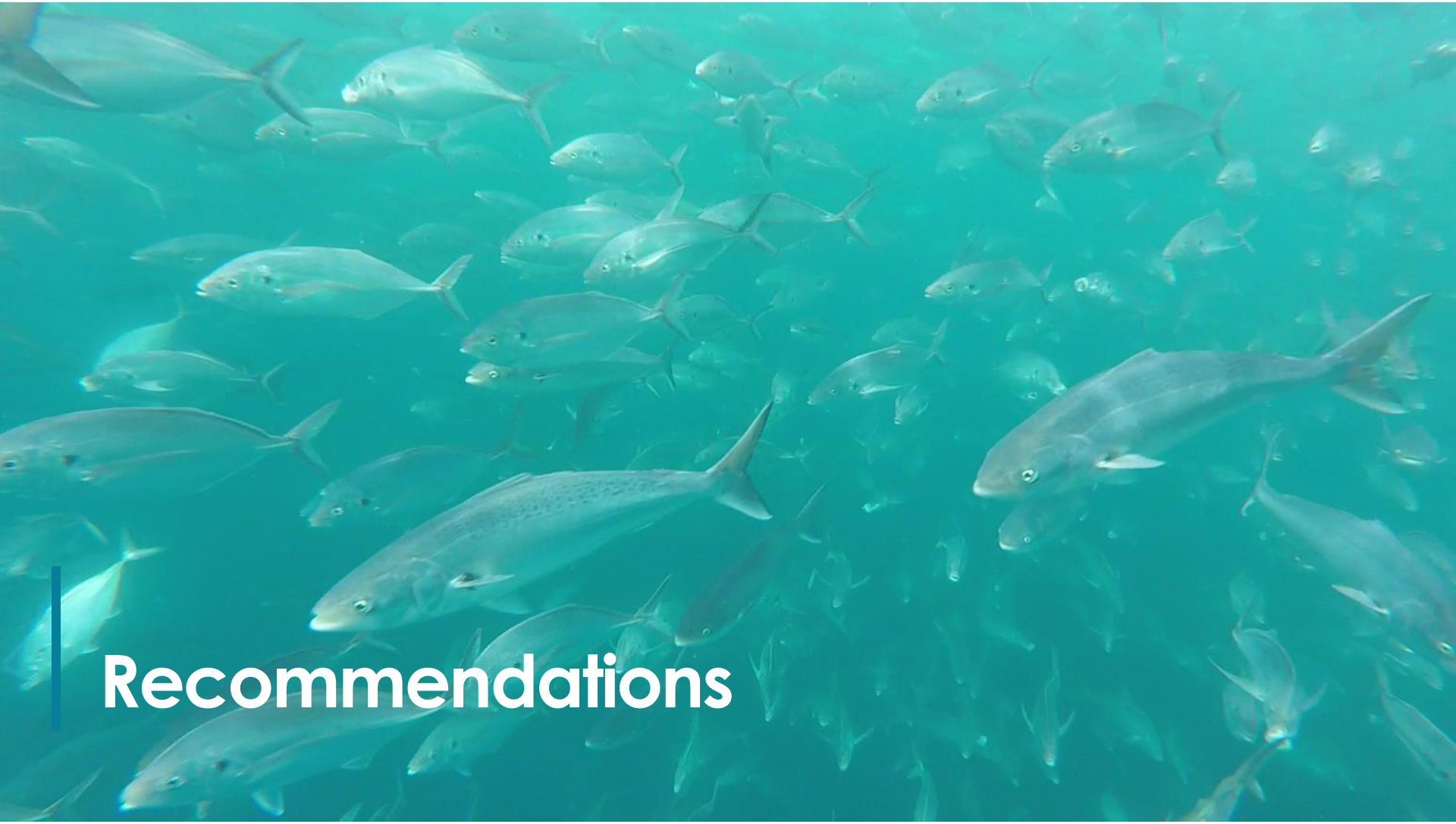
Ubiquitous. Seen in very large flocks throughout year,

Prey – krill and small fish

S. Bartle quote: *"gavia is like gorse easily established, fast breeding (fact) & then easily pushed off islands by larger shearwaters."*

Going forward

- Contract BCBC2020-08 for another season's zooplankton sampling – with samples stored for future analysis



Recommendations

General

- Zooplankton sampling is required over multiple years and across each full season (September to May) for multiple species – i.e., timed to link to seabird breeding cycles.
- This contract (POP2019-02) demonstrated the significant advantages of using a high-speed dedicated research vessel for sampling, enabling large areas to be covered and multiple seabird feeding events to be sampled much more efficiently during periods of good weather. While much more effective, the use of such research vessel comes with significantly more cost.

Complementary research

- A comprehensive integrated tracking programme over multiple years starting with the four indicator species we have identified - Buller's and fluttering shearwaters, fairy prion and Australasian gannet.
- Connect at-sea sampling with areas of sea identified by GPS tracking of seabird species as important feeding grounds.
- Stable isotope analyses from blood and feather samples, and opportunistic diet sampling collected through all key stages of species respective breeding cycles to detect any annual changes in prey and foraging area.

Captures of birds at sea

- Capture of key indicator Procellariform species to collect regurgitations to establish direct links of seabird diets to the zooplankton.
- Net guns have been developed as an effective tool for capturing seabirds at sea for research purposes (Gaskin in prep).

Strategic planning & funding

- North eastern North Island offers the perfect system in which to utilise seabirds as indicators of change in the marine environment at different spatial and temporal scales.
- Future research needs to be planned strategically and over multiple years to be able to provide measurable results and trends.
- Future research requires significant ongoing funding. While much has been achieved through the limited funding available, the snapshot nature of the work to date can compromise analytical outputs and how seriously the results are taken.

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NGĀ MIHI NUI - THANK YOU