Fisheries New Zealand
Tini a Tangaroa

Impacts of the Kaikōura Earthquakes on Marine Environment

Hosted by Fisheries New Zealand and the Kaikōura Marine Guardians

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Where to find further info

http://www.mpi.govt.nz/protection-and-response/responding/adverse-events/kaikouraearthquake/

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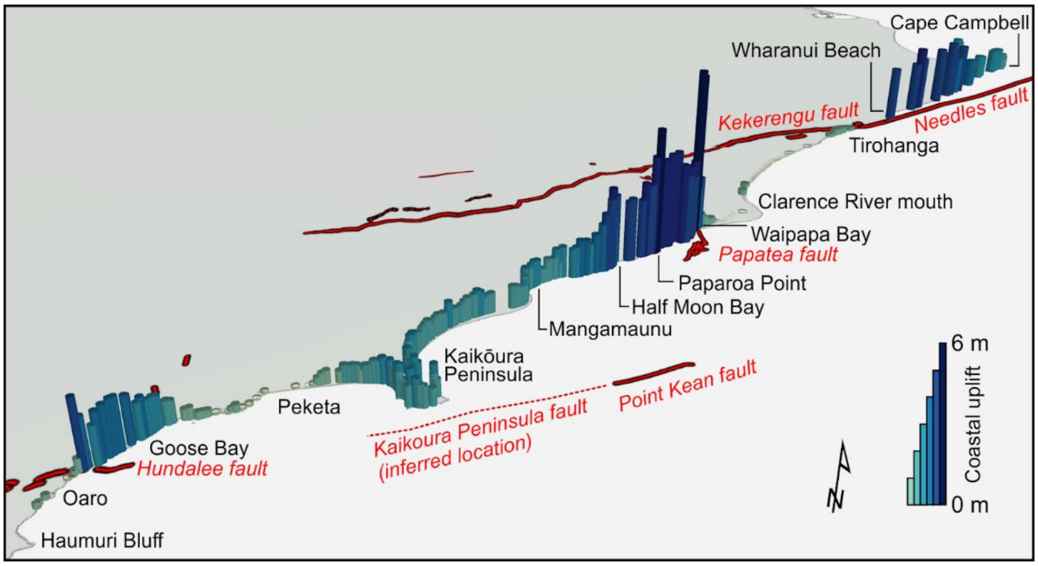
The 2016 M_w 7.8 Kaikōura earthquake and tectonic deformation of the Kaikōura coastline

Kate Clark, GNS Science

The Kaikōura earthquake occurred just after midnight on the 14th November 2016. The M_W 7.8 earthquake initiated at ~15 km depth and ~4 km south of the north Canterbury rural township of Waiau, located 32 km inland from the coast and 60 km southwest of Kaikōura Peninsula. The Kaikōura earthquake, which lasted for ~ 2 minutes, was unprecedented in its complexity, propagating 170 km towards the northeast along a sequence of >20 faults. Fault surface rupture field surveys revealed the largest horizontal displacements of up to 12 m along the Kekerengu fault and vertical movement of up to 9 m on the Papatea fault. The Kaikōura earthquake also generated more than 10,000 landslides over an area of about 10,000 km^2, several hundred of these occurred along the coastal slopes.

The coastal deformation that occurred in the Kaikōura earthquake is the most highly variable observed in any global earthquake in modern times. Along 110 km of coastline, the vertical displacement ranged from -2.5 to 6.5 m. We measured the coastal deformation using a combination of field surveying, satellite measurements and differencing between pre- and post-earthquake high-resolution topographic surveys. If we define the coastal stretch impacted by the earthquake as the region from Haumuri Bluff to Cape Campbell (a straight line distance of 110 km) then 80 km (73 %) of the coastline underwent uplift, with 48 km (44 %) undergoing uplift of > 1 m. Around 28 km (25%) underwent a minor amount of subsidence (<0.5 m), with only a very localised area (2 km around the Kekerengu fault) undergoing > 1 m subsidence. Only a very minor stretch (3 km, 2%) of coastline around Peketa was not impacted by coastal deformation. The entire Kaikōura Peninsula and much of the coastline north and south of the Peninsula was uplifted by between 0.8 and 1 m. Uplift of the Peninsula and the surrounding area is attributed to an entirely offshore fault called the Kaikōura Peninsula fault. Two strands of the Papatea fault cross the coastline at Waipapa Bay and between these faults the land was uplifted 5 - 6 m, creating a new rocky coastal platform extending 200 - 300 m offshore from the pre-earthquake coastline.

The coastal landforms of the Kaikōura coast attest to periodic sudden uplift in earthquakes, evidence of these events is preserved by uplifted beaches, also called marine terraces, that fringe many parts of the coastline from Oaro to Cape Campbell. These marine terraces are the subject of ongoing studies at GNS Science as we seek to understand how often large earthquake like the 2016 earthquake occur.



Mapping change - Kaikoura to Cape Campbell

HS57 Hydrographic Survey: LINZ, Fisheries NZ, iXblue, DML, NIWA

In 2016 Land Information New Zealand (LINZ) completed an evidence based hydrographic risk assessment that identified locations and levels of risk in relation to the accuracy and adequacy of nautical charting in New Zealand. The Kaikoura Peninsula was identified as an area of heightened risk, even more so following the 7.8 magnitude earthquake of November 2016. As a result of the earthquake the seabed rose between 1 and 6 metres along the Canterbury and Marlborough coasts, posing a hazard to safe navigation. Working in partnership with the Fisheries New Zealand, LINZ developed a programme of work to carry out hydrographic surveys for safety-of-navigation and scientific purposes, to understand how the seafloor had changed and how it impacted the marine habitat.

Managed overall by LINZ, two contractors were used to survey this large area. Discovery Marine Limited (DML) focused on collecting hydrographic data around Cape Campbell for safety-of-navigation purposes, and iXblue were tasked with collecting data for safety-of-navigation and science purposes, with National Institute of Water and Atmospheric Research (NIWA) providing scientific assessments. Fisheries New Zealand identified seven specific areas close inshore between the Haumuri Bluffs to Cape Campbell to collect seafloor backscatter (provides an indication of the nature of the seabed substrate) and water column backscatter (provides a three-dimensional view of features that extend into the water column such as kelp and seep plumes), in addition to bathymetry (water depth).

The presentation, in two parts, will first describe the rationale behind the survey and discuss the challenges encountered during the fieldwork, especially working in very shallow water (2-5m), which in some places are poorly charted. Secondly, as the consequences of earthquakes on marine ecosystems are not well understood, this survey data will serve as a baseline to gauge impact and subsequent recovery from the 2016 earthquake, as well as underpin ongoing monitoring and management of marine resources. The data illustrate an accurate characterisation of geomorphic features, classification of substrates and therefore physical habitats, and characterisation of kelp beds present in the water column.

The newly acquired multibeam bathymetry maps allow for the identification and description of rocky reef habitats, areas essential for ecosystem recovery. These reefs extend out from the shoreline and are highly complex. Their rugged hard substrates are often surrounded by patchy boulder and gravel aprons, which are overlain by rippled sands or fine muddy sediments. These reefs provide complex habitats that support dense macroalgal stands that are ideal habitats for paua, crayfish, butterfish and a diversity of sponges and other encrusting invertebrates.

LINZ will use the information to produce world-class nautical charts, making it safer for the vessels that use these waterways. The survey also provides Fisheries New Zealand, the Department of Conservation and Regional Councils with a data-rich appraisal of the coastal marine area to assist decision makers and the community to better understand, sustainably manage and protect the important coastal ecosystems.

The variability and complexity of the Kaikoura seafloor is also revealed in two map products available from Fisheries NZ and the hydrographic partnership tonight. Further copies can be sourced from https://www.niwa.co.nz/publications/posters.

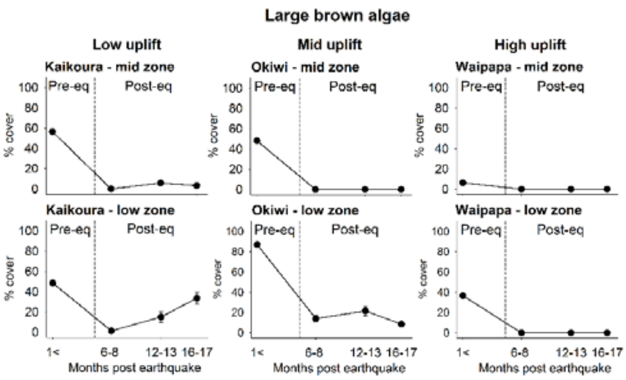
Rocky reef impacts from the Kaikōura earthquake

(David R Schiel, Tommaso Alestra, Shawn Gerrity, Robyn Dunmore, Islay Marsden, John Pirker, Shane Orchard, Leigh Tait, Mads Thomsen); Canterbury University, Cawthron Institute & NIWA

Nineteen months after the North Canterbury earthquakes of November 2016, the devastation to parts of the marine ecosystem has not stabilised. Most people will have seen photos of uplifted coastal platforms, ranging from around 1 – 6m. Our highly detailed sampling since the earthquakes has shown a massive loss of habitat-dominating large brown algae, understory species of red algae, and substantial losses of mobile invertebrates such as pāua and grazing snails. For several months, there was a bloom of green algae (sea lettuce) in the mid and lower tidal zones along most of the coastline from Omihi to Cape Campbell, which was a response to the loss of other algae, the reduction in grazing snails, and the large amounts of fine sediments that emerged from deteriorating sedimentary rocks that comprised most of the coastal zone.

Panels: (1) Uplifted reef at Waipapa, north of Kaikoura. Algae at top of rock are at the former intertidal-subtidal margin. Extensive white is calcareous algae that died. (2) Wairepo Reef (Kaikoura), formerly one of the most diverse reefs in NZ (before and after). (3) Extensive bloom of sea lettuce that lasted for 9 months but died over summer. (4) Post-earthquake recruit pāua on calcareous algae, underside of rock.

To date, there is little recovery of algal beds in the new configuration of rocky reef. On some platforms where tidal inundation still occurs, such as at Kaikōura and Cape Campbell, the water is shallow, immersion times are short, and temperatures can reach lethal levels. In other areas, there is a vastly changed intertidal morphology, with often near-vertical topographies. Sediments are still clouding the nearshore waters in many areas, which reduces primary productivity and, therefore, the amount of food available to small invertebrates and other species in the coastal food web.



***Left**: Decline in habitat-defining large brown algae in the mid- and low tidal zones across three levels of uplifted sites. Note there is some recovery in the low tidal zone of 'Low Uplift' sites.*

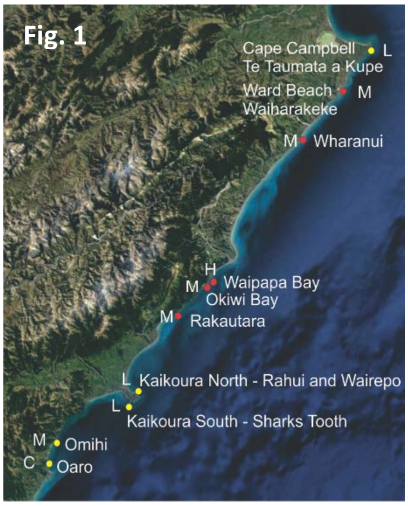
On the positive side, post-earthquake recruit pāua (those up to around 50mm in shell length) are abundant in many sites where appropriate habitat exists. The ongoing task it to figure out how much juvenile pāua habitat remains on the coastline and how quickly these recruits can make their way into the fishery.

Based on 25 years of experimental work along the coast of the South Island, recovery of algal populations is likely to take many years and will depend both on natural recovery from highly fragmented remaining algal stands, and on efforts at restoration. There are many new stressors along the newly configured coast, not least of which is increasing access to pedestrian and vehicular traffic that was formerly limited by high tides. Management initiatives will have to take account of the multiple values of this coast, the potential for delayed recovery because of access and over-use, as well as increased fishing pressure on formerly isolated areas. We trust that providing detailed scientific information will be a useful addition both to understanding the marine ecology of the area and in helping to preserve it for our children and future generations.

***Project funded by the Ministry of Primary Industry**: For more information,* *contact Prof D R Schiel: david.schiel@canterbury.ac.nz; Shawn Gerrity: shawn.gerrity@canterbury.ac.nz; or Tommaso Alestra: tommaso.alestra@canterbury.ac.nz*

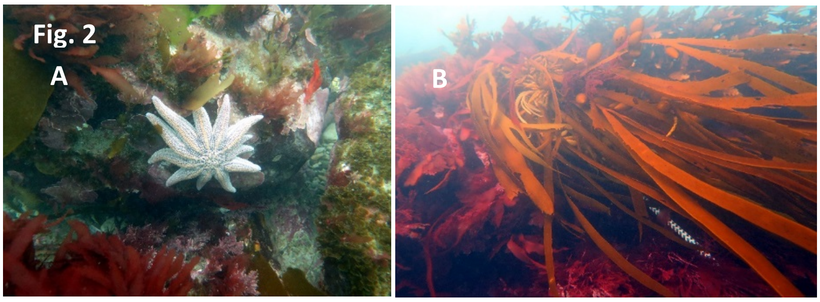
Rocky reef impact quantification and monitoring for the Kaikōura earthquake: *Gauging impacts on biogenic habitats and key invertebrates in the nearshore subtidal zone.*

Objective: to gauge the status of shallow subtidal reefs, the biogenic habitat that remains, the presence of subtidal habitat suitable for pāua settlement and recruitment, and the abundances of key species.

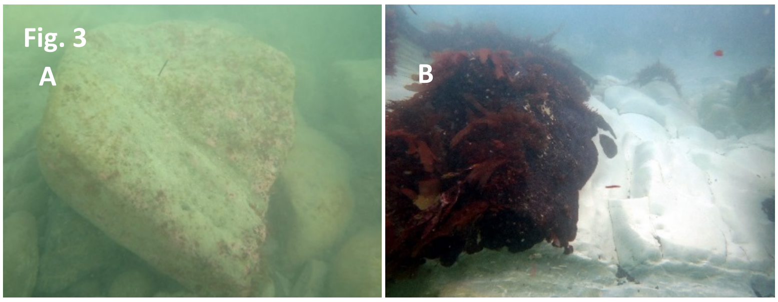


Methods: We surveyed 10 locations along the Kaikoura coastline, between Cape Campbell and Oaro (Fig 1). Five of these locations were surveyed twice (Fig 1, red circles). Sites were allocated Uplift levels according to values determined by GNS Science: C = control, L = low, M = medium, H = high. At each location there were 2 sites, and 3 transects were surveyed at each site. The transects were 50 m perpendicular to the shore, starting from the low tidal zone. Along each transect, substrate type, seaweed and sessile invertebrate percentage covers, and numbers of mobile invertebrates and fish were recorded, pāua were measured, and video footage and photos were taken.

Main results and discussion: The degree of uplift was reflected in the amount of habitat disturbance. Most disturbance was at Waipapa Bay (high uplift), minor - medium disturbance was at medium levels of uplift, and no obvious effects were at no - low uplift sites (Oaro, Kaikoura Peninsula, Cape Campbell).

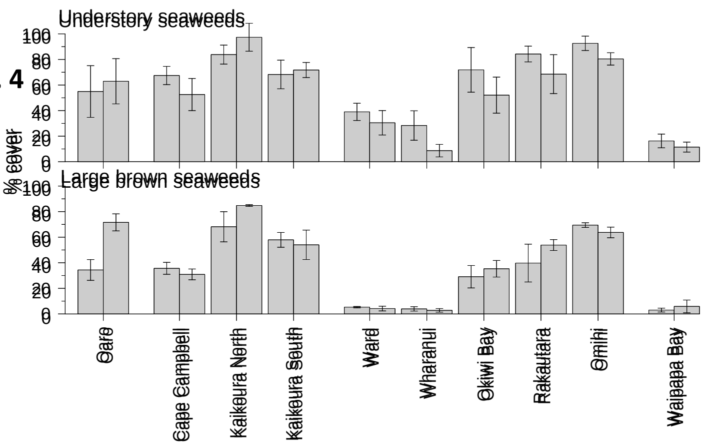


Sites with no - low uplift, and Rakautara and Okiwi Bay sites (medium uplift) appeared largely unaffected and were characterised by a diverse array of seaweeds, and sessile and mobile invertebrates such as sponges, anemones, ascidians and sea stars (Fig 2 A&B).

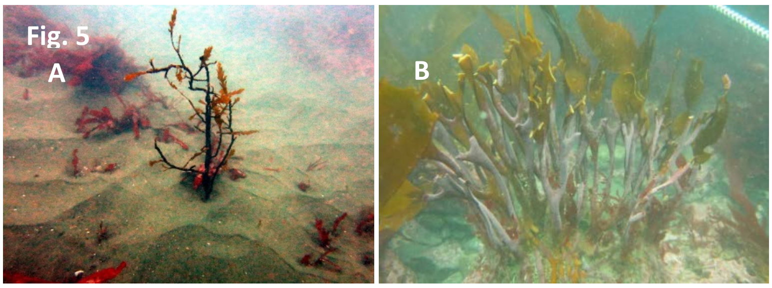


Waipapa Bay had large bare areas that had been pushed up through sand and gravel, and some sites with medium uplift (Ward and Wharanui) had smaller bare patches (Fig 3 A&B). These three locations had less understory seaweeds (corallines and encrusting reds) and large brown seaweeds than other sites (Fig 4).

Fig. 4



Some shifts in sand distribution were observed, with some seaweed habitat covered in sand (Fig 5 A). We also observed the results of intense grazing by the herbivorous butterfish (*Odax pullus*) on brown seaweeds, even at low uplift sites (Fig 5 B). With the decline in bull kelp (*Duvillaea* spp.) in the intertidal zone, stronger grazing pressure on other brown seaweed species may occur.



Acknowledgements: We are grateful to the many Kaikōura locals who have assisted us in many aspects of this work, from site knowledge, access, boat launching, dive tank refills and accommodation. Thanks to Marlborough Commercial Diving Services and Diving Services New Zealand for assisting the Cawthron dive team.

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Estimating biomass and monitoring paua populations affected by the 2016 Kaikoura Earthquake

Dr Tom McCowan – Paua Industry Council Ltd.
Dr Phil Neubauer – Dragonfly Data Science

The seabed uplift caused by the November 2016 Kaikoura Earthquake resulted in extensive paua mortality and loss of critical paua habitats. Initial estimates were that 21% of the previously fished habitats were exposed as a result of the uplift. The primary response to this has been the ongoing closure of the fishery for this locally valuable resource until stocks have fully recovered.

The objectives of this research were to estimate the biomass and to monitor paua populations in the earthquake-affected area. Survey sites were randomly selected from areas with high, medium and low fishery utilisation strata constructed from industry data logger information. Biomass estimates at each site were made employing recently developed methodologies using underwater electronic callipers to measure paua and GPS dive units to delimit the exact areas surveyed. Within survey sites, discrete paua aggregations were marked and measured, so they could be monitored over time.

43 sites spanning from Spyglass Point in the south to Cape Campbell in the north were surveyed, and 83 individual monitoring points were established within these sites. Over 14,000 paua were measured across all sites with an average size of close to 130mm. Observationally, high paua abundance was seen in areas of previous high-utilisation that were less affected by the uplift, however little or no recovery was observed in several high-impact areas. Continual loss of habitat has been observed in some locations where ongoing sediment movement and deposition has covered monitored paua habitat.

Data collected from these surveys was used to calculate a relative estimate of abundance that can be treated as a baseline for ongoing monitoring and paua population recovery at a regional and site-specific level. Discrete monitoring points will also enable recruitment into the spawning biomass to be detected. This information will help to inform Fisheries New Zealand management decisions around when and at what level the paua fishery may be re-opened.

Additional projects have also commenced to investigate paua recruitment monitoring and stock enhancement. NIWA and the Paua Industry Council are working in conjunction to test the utility of artificial concrete habitats as a standardised means of monitoring juvenile paua abundance, and as a means of improving reseeding survival rates. PauaMAC3 has also commenced a reseeding program targeting the worst affected areas. To date, 176,000 hatchery-reared juveniles (between 10-20mm in size) have been reseeded, spanning sites from Omihi to Paparoa Point.

Status of blue cod off Kaikōura in 2017 following the 2016 earthquake

Blue cod (*Parapercis colias*) is a target species most frequently landed by recreational fishers off the South Island, and in north Canterbury the two key recreational fishing areas are Kaikōura and Motunau about 90 km to the south. Kaikōura offers substantial and varied blue cod habitat with a wide range of depths and a narrow continental shelf. South Island recreational blue cod stocks, including Kaikōura are monitored using Ministry for Primary Industries (MPI) potting surveys carried out every three to four years. The surveys are used to evaluate the response of populations to changes in fishing pressure, the daily bag limit, minimum legal size, and area closures. They can also be useful for determining impacts on the local population to major environmental events such as the 2016 earthquake.

This summary describes the results of a random-site design blue cod potting survey off Kaikōura in December 2017, with the aim of assessing whether the November 2016 earthquake has had any impact on the blue cod population. Blue cod potting surveys provide estimates of population abundance, size and age structure, sex ratio, and mortality. This is the third MPI survey in the Kaikōura random-site survey time series, following routine surveys in 2011 and 2015. A fixed-site survey design was used from 2004 to 2015, but these are no longer carried out and cannot be validly compared to random-site surveys.

In December 2017, blue cod pots were set at twenty-nine random sites (6 pots per site, 174 pot lifts) at depths of 11–121 m from Kaikōura Peninsula south to Bushett Shoal. Pots were left to fish for one hour and then hauled. The catch was weighed and individual blue cod measured for length and weight, sex determined from visual examination of the gonads, and otoliths (= ear bones) removed for ageing.

The key results are summarised below:

- There was no trend in abundance of all blue cod or recruited blue cod (33 cm and over = the minimum legal size) overall off Kaikōura in the three surveys (2011, 2015 and 2017).
- Blue cod were most abundant off Kaikōura Peninsula, and least abundant between South Bay and Haumuri Bluffs in the three surveys (2011, 2015 and 2017).
- Mean length was consistently about 29 cm (range 18 to 50 cm) for both males and females, with no trend in the three surveys (2011, 2015 and 2017).
- Blue cod minimum legal size in the Kaikōura Marine Area is 33 cm, corresponding to ages of about 6 years for males and 8 years for females.
- Strong recruitment of juvenile 3-year-old blue cod in 2015, progressed through and dominated the age composition in 2017 as 5-year-old blue cod.
- The sex ratio has been consistently balanced at around 50% male in the three surveys (2011, 2015 and 2017).

There were no observed changes in blue cod abundance, size and age composition, and sex ratio in 2017 that could be attributed to the 2016 earthquake.

CRA 5 Rock Lobster Emergency Survey & Post Earthquake-Survey Research

Immediately after the November 2016 earthquake all fishing was stopped for three months until research could be conducted to show that a fishery could be opened for harvesting. This was a big issue for the commercial sector, the lobster fishermen plan their years harvesting based on market values, over $10 million dollars of lobster was still sitting in the ocean ready for the Chinese New Year market. The fishery needed to be opened with in six weeks.

The Minister agreed if we could provide evidence that the lobster fishery was still in good shape he would look at removing the fishery from the closure. To obtain the data required MPI arranged 6 vessels that had at least three years of harvesting history across the closed area. MPI, NIWA and commercial established the survey protocols, the survey would run for two weeks, an observer on each vessel to count, sex lobster, measure every lobster, each vessel used 50 pots, 1,000 lobsters to be tagged during the survey, a team of fishery stock scientists ready in Wellington to assess and compare historical data to the survey data.

After several days harvesting it became very clear that the fishery was still in good health, we still need to complete the survey in the time frame agreed to. As each day went by and each day's data was sent up to Wellington to be analysed and compared with three months of historical logbook and CELR data. After six days the results were overwhelming in showing the lobster resource had not been affected by the earthquake. The data collected was so convincing that the survey stopped after one week, MPI went about generating a report for the Minister so he had confidence in making the right decision.

When the completed report took account of the historical data from the Logbook which has been running since 1997 provide good length frequencies, sex, and maturity. Sitting that data alongside the CELR (Catch Effort Landing Report) which is generated at the completion of every commercial day fished provides CPUE data (Catch Per Unit Effort) which relates to kilograms per pot lift. Compared against the survey data both sets showed that the earthquake had no influence on the abundance of lobster harvested during the survey period.

Historical tag recapture data was used to sit alongside the length frequency data gathered during the survey, the male lobster were in line with the historical data, there was a sign with the female lobster that were captured in the survey were of a slightly smaller size, the difference could easily been seen as a seasonal occurrence or the period in which the survey was being conducted, the female lobster were entering a period of molting which took them off shore and they also become pot shy until their shell hardens.

The survey was robust, the historical data had value to be able to bench mark the performance of the fishery at that same period as the survey. Since the opening of the fishery an offset year assessment has been conducted, the lobster resource by using CPUE as in indices of abundance has gone from 1.570 kilograms per pot lift to 2.010 kilograms per pot lift. The lobster fishery was reopened one month after the earthquake, CRA 5 is a very healthy fishery.

Evaluating the impact of the 2016 Kaikoura earthquake on the population of Hutton's shearwater.

Background

The Hutton's shearwater is an endangered seabird, unique to Kaikoura and a taonga/treasured species its people. Changes in land use and predominantly predation by feral pigs has led to the species surviving in only two alpine colonies (Kowhai River and Shearwater Stream) in the Kaikoura Ranges, and in one small artificial colony established on the Kaikoura peninsula. Hutton's shearwaters are migratory, spending the winter away from Kaikoura's waters, and return to breed from September to April. They are burrow breeders and active at their colonies at night. Like other seabirds they are slow reproducing. They start breeding at about 4 years of age, raising 1 chick per year. These birds have a long reproductive life, meaning that any loss of breeding adults has a considerable impact on the population. Pre - earthquake population estimates indicated a positive trend in Hutton's shearwater numbers.

The Kaikoura earthquake hit at the time of year when birds were incubating eggs, with at least one breeding adult present in every active burrow that night. Moreover, we had to assume that non-breeding but prospecting birds as well as mates of breeders were present to some extent, and that landslides and collapsing burrows had caused severe loss of lives.

How hard were they hit? Was there potential for their recovery?

The Hutton's Shearwater Charitable Trust received funding from the Ministry for Primary Industries as part of the Kaikoura marine recovery package to assess the magnitude of the impact.

Objectives

- Conduct aerial surveys and revisit wild colonies to assess available breeding habitat (area loss, burrow collapse) and number of remaining breeding pairs.
- Assess threat levels, e.g. altered risk of predation or other limitations to recovery.
- Assess overall population numbers / magnitude of population effects.
- Assess potential new colony/breeding sites to build up future capacity.

First results

- Artificial colony on peninsula unharmed; Shearwater Stream colony inaccessible.
- Aerial imagery and on-the-ground surveys revealed:
  - Landslides causing 13% loss of colony area in Kowhai Valley and 2% in Shearwater Stream.
  - Reduction in burrow density by 33% and decline in breeding numbers by 39% in Kowhai Valley.
  - Revised breeding population estimates resulted in numbers presumed large enough to compensate for sustained losses.
  - Kowhai colony active and vibrant; signs of recovery in progress.
  - Accessibility to pigs not altered; control measures continue.
  - 2 potential new colony sites identified; extension of existing colony in Kowhai Valley possible.
- Mark-recapture study to assess post-EQ total population numbers postponed till September 2018.

Hector’s dolphin survey after the Kaikōura Earthquake

Dr Jody Weir[1] and Dr Darryl MacKenzie[2]

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Since 2013, the Kaikōura Ocean Research Institute (KORI), has conducted boat-based surveys for Hector’s dolphins along the Kaikōura coastline between Hapuku River and Haumuri Bluffs. Surveys were being undertaken during the 2016/2017 summer that coincided with the November 14, 2016 earthquake. For this project we conducted surveys in the 2017/2018 summer and used the new and previously collected survey data to assess potential impacts of the earthquake on the abundance and distribution of Hector’s dolphin in the Kaikōura region. A total of 69 and 43 surveys were conducted pre and post earthquake respectively. In total, 372 encounters with Hector’s dolphin groups were recorded on survey from January 2013 through March 2018.

Some Hector’s dolphins can be individually identified through unique scaring patterns on their dorsal fin. During surveys, photographs are taken of marked individuals enabling an encounter history to be developed of the sighting frequency of such individuals. In addition, sightings of unmarked individuals along the survey route are recorded. From photographs collected 2013 – 2018 a catalogue of 80 individuals with distinct markings was compiled. Dolphin abundance can be estimated from both the sighting frequency of marked individuals and number of sightings of unmarked individuals using a mark-resight model. A binomial mark-resight model was used to estimate the abundance of adult Hector’s dolphins during periods of surveying between January 2013 and March 2018. The estimates varied depending on which survey periods were used but were consistently in the range of 250 – 450 adults for most survey periods, except for early 2013 which tended to produce higher estimates. There was no statistically discernible difference in abundance during the two summers after the earthquake.

Potential changes in the spatial distribution of Hector’s dolphin were evaluated by analysing the number of sightings of adult dolphins per survey in six distinct regions. A generalised linear model assuming Poison distributed counts was used to evaluate how the expected number of adults sighted per survey varied spatially and temporally. In particular, survey region, pre/post earthquake and survey period were used as potential predictor variables. Different combinations of these variables (including interactions) were used to define models to fit to the data. AIC was used to evaluate the level of support for each model. As the pre/post earthquake and survey period variables are partially confounded, they were not both included in the same model. The model with greatest support included an interaction between the survey region and survey period variable, suggesting that there are localised changes in the distribution of dolphins between survey periods, which is operating at a finer time scale than pre/post earthquake. Further separation of these effects is not possible with the short time series available. There are some areas along the coastline that consistently have a greater proportion of the sightings, but there is no obvious, consistent change in the level of use post earthquake.

In summary, the survey results do not indicate there has been a substantial change in the number of Hector’s dolphins using the study area, and while there may have been some distributional changes (based on the expected number of adult sightings), it is difficult to identify any lasting effect of the earthquake from more general annual variation at this point. One should also be mindful of the potential for changes in other environmental factors that are confounded with the timing of the 2016 earthquake.

Kaikōura Canyon – submarine landslides, erosion and deposition by turbidity currents, carbon transfer, and impacts on biological communities of the deep seafloor

Kaikōura Canyon lies seaward of the of the south shores of Kaikōura Pensinsula. Like an underwater Grand Canyon, its steep sides cut deep into the continental shelf. From its head, less than 1000 m off-shore from Goose Bay, its sheer walls drop from the shallow 30 m deep continental shelf to over 600 m deep over a space of a kilometre. The canyon acts as a conduit carrying material from the coast to the southernmost reaches of the Hikurangi Channel system at over 2000 m depth at the base of the continental slope. This channel runs for a further 1500 km northwards.

To address the need for a better understanding of the wider effects of the Kaikōura Earthquake on the seafloor, NIWA and its scientific collaborators have conducted several surveys and studies of the Kaikōura Canyon, and the adjacent seafloor

Early post-earthquake surveys indicated that, just like on land, the Kaikōura Earthquake caused slope slides within the Kaikōura Canyon. The surveys revealed that submarine slides occurred over almost the entire upper end of the canyon, and a swath of about 30 km had failed. Turbidity currents triggered by these slope failures moved sediment down the canyon and into the Hikurangi Channel. Sediment travelled at least 680 km from the canyon, off Hawke's Bay, and formed deposits up to 65 cm thick on the seafloor. By comparing bathymetry data from before and after the earthquake, it was possible to estimate the volumes of sediment stripped from the canyon walls and floor by the slope failures and the turbidity current. The total erosion of the canyon caused by the earthquake is estimated to be 9.4×10^8 m^3. At the canyon floor, up to 50 m of sediment was mobilised and flowed down the canyon. Further down the canyon, huge sediment waves were re-worked and moved downstream up to 560 m.

A pre-earthquake survey of Kaikōura Canyon showed that the animal communities of parts of the deep-seafloor of the canyon are amongst the most productive in the world. A repeat survey of the same sites less than 3 months after the earthquake revealed no evidence of invertebrate organisms living on or in the seabed. Erosion of the seabed caused by the slides and turbidity current means that the biomass of organisms once living in the sediment is exported, with around 39×10^6 kg of biomass (equivalent to 2.67×10^6 kg of carbon) estimated to have been swept down the canyon. A survey nearly 1 year after the earthquake has revealed that recolonization by seafloor animals has begun. In some areas juveniles of the same species that occurred before the earthquake have been found, while in other areas different species are opportunistically filling niches created by the impact of the earthquake. The survey included areas of the canyon not previously sampled, and here some of the animal communities were apparently unaffected by the earthquake.

The Kaikōura Earthquake and subsequent submarine landslides and turbidity currents that flushed through the canyon are not a unique occurrence. They are just another event in a regular, geologic-scaled routine on the Earth - that is responsible for shaping the canyon morphology and regulating the structure and function of seafloor communities in the canyon and beyond.

This text is extracted and modified from Lane et al. (2018) Submarine landslides and turbidity currents. In: Shaky Shores – Coastal impacts and responses to the 2016 Kaikōura earthquakes. Hendtlass et al. (eds). New Zealand Coastal Society.

Effects of the Kaikōura earthquake on sperm whales – summary

The Kaikōura Canyon is an important foraging ground for male sperm whales, whose abundance in the area has declined over the last two decades. In November 2016, a 7.8 magnitude earthquake affected Kaikōura, triggering powerful mud-slips and sediment flows in the canyon. Using a multi-year dataset, we investigated whether there were differences in sperm whale abundance, behaviour, distribution and use of food resources in the periods before and after the earthquake. Boat-based surveys were carried out to record the individual identities, locations and behaviour of sperm whales from January 2014 to January 2018, and samples of sloughed skin were collected for stable isotope analyses. In addition, previous sighting histories were used in a 'capture-recapture robust design' analysis to estimate seasonal abundance from 1990 to 2018. We modelled the variation in surface intervals between dives, ventilation rates, echolocation behaviour and stable isotope signatures of sperm whales. Spatial analyses were used to assess changes in foraging distribution. The number of whales within the study area in the first post-earthquake summer was very low but within the range previously recorded, while abundances in the following winter and second summer after the earthquake were similar to pre-earthquake levels. This suggested the potential for a temporary influence on sperm whale abundance, while demonstrating a lack of permanent displacement away from Kaikōura. A 25% increase in the duration of whales' surface intervals post-earthquake suggested changes in diving behaviour, potentially reflecting increased effort searching for prey. A return of surface intervals to pre-earthquake durations after one year suggested that the impact on foraging behaviour was temporary. We found no significant changes in the whales' isotopic signatures, suggesting that sperm whales were not targeting different prey after the earthquake. However, noticeable changes in the distribution of high-use areas indicated shifts in habitat use during the year after the earthquake, potentially driven by changes in prey availability. Following the earthquake, sperm whales moved away from the upper canyon, an area where sediment flushing had caused the strongest erosion and extensive removal of benthic invertebrate communities. We suggest that the observed shifts in the whales' high-use areas could have been caused by changes in the distribution and abundance of their prey, resulting from the canyon-flushing event. Overall, our results suggested that the earthquake had an impact on the habitat use and foraging patterns of sperm whales over time scales of one month to at least 14 months. In the context of the long-term decline in abundance at Kaikōura, sperm whales may be particularly vulnerable to impacts on their habitat. This highlights the need for continued population monitoring and precautionary management of anthropogenic activities affecting the whales.