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Article *in* New Zealand Journal of Marine and Freshwater Research · January 2015

DOI: 10.1080/00288330.2014.984728

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New Zealand Journal of Marine and Freshwater Research, 2015
http://dx.doi.org/10.1080/00288330.2014.984728

SHORT COMMUNICATION

Photo-identification of bottlenose dolphins in the far south of New Zealand indicates a 'new', previously unstudied population

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(*Received 7 July 2014; accepted 2 November 2014*)

Abstract Declines in the abundance of bottlenose dolphins in the Bay of Islands and in Doubtful Sound have contributed to the species being classified as Nationally Endangered in New Zealand waters. Updated information on distribution and abundance nationwide is therefore a high priority. This study presents data from the first photo-identification surveys of Paterson Inlet, Stewart Island, conducted to document bottlenose dolphin presence, abundance and residency. Open-population mark-recapture models indicate that 18 (95%CI = 15–20) dolphins regularly use Paterson Inlet. Photo-identification of dolphins from unknown populations during two chance encounters in Otago Harbour and Dusky Sound included 11 individuals previously identified at Stewart Island. These results indicate that dolphins found regularly at Stewart Island are part of a larger, wide ranging southern population with a minimum population abundance of 92 (95%CI = 80–111) individuals.

Keywords: abundance; bottlenose dolphin; distribution; New Zealand; photo identification

Introduction

Bottlenose dolphins are found in three distinct, resident populations along the mainland New Zealand coast (Tezanos-Pinto et al. 2009). The northern population inhabits the northeast of the North Island, from approximately North Cape in the north to the Bay of Plenty in the south (Constantine et al. 2004; Tezanos-Pinto et al. 2013). Another population is found at the north of the South Island, centred around the Marlborough Sounds (Merriman et al. 2009). The southernmost population is found in Fiordland, on the southwest of the South Island (Williams et al. 1993; Lusseau 2005; Currey et al. 2008). Extensive photo-identification (photo-ID) surveys (Currey et al. 2007, 2008; Merriman et al. 2009; Tezanos-Pinto et al. 2013), as well as genetic analysis (Tezanos-Pinto et al. 2009), show that the three coastal populations are discrete, apparently with no mixing. In addition to the coastal populations, an 'oceanic ecotype' (Baker et al. 2010) is found around the New Zealand coast with a more offshore distribution (Zaeschmar et al. 2013).

Long-term monitoring of the northern and Dusky and Doubtful Sound subpopulations within the greater Fiordland population has indicated a decline in abundance (Currey et al. 2007; Tezanos-Pinto et al. 2013; Brough 2013). Based on the isolation of the populations, history of decline, and a total national abundance estimated at fewer than 1000 animals, New Zealand bottlenose dolphins are classified as Nationally Endangered (Baker et al. 2010).

Historically, there have been frequent reports of bottlenose dolphins along the south coast of the South Island. Such reports are most common from the inshore waters of Stewart Island, but encompass Preservation Inlet in the west and Taiaroa Head in the east (Fig. 1). Strandings of bottlenose dolphins in the south of the South Island include: 17 individuals stranding in Bluff Harbour in 1980; two individuals stranding at Awarua Bay in 2008;

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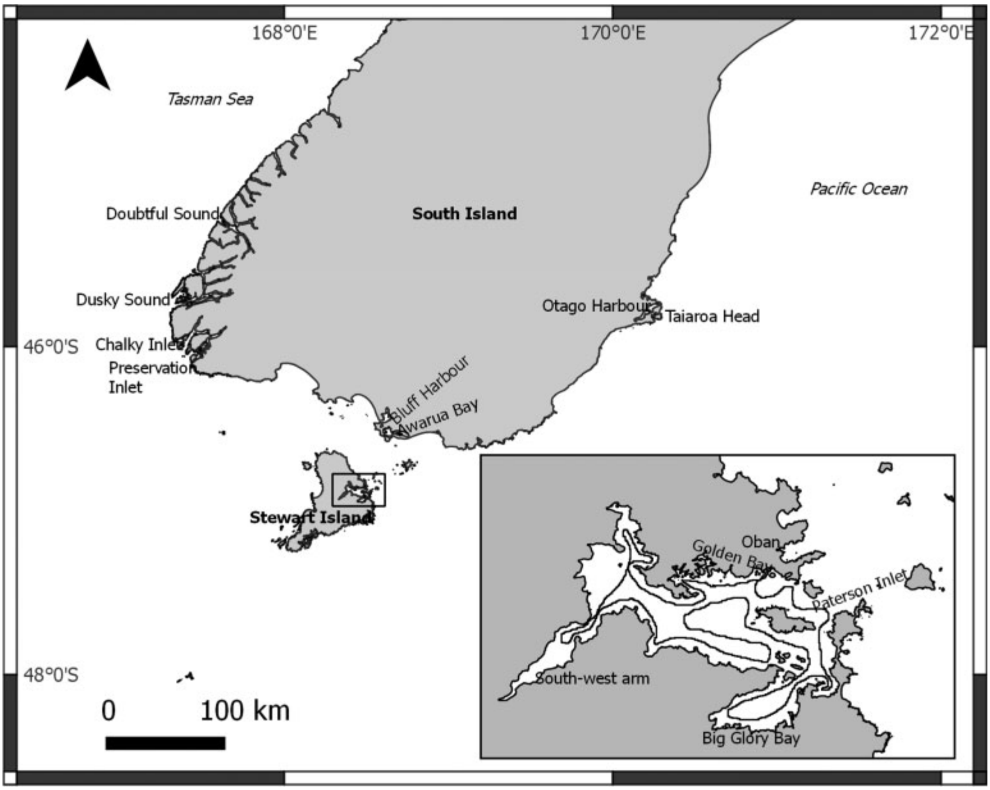

Figure 1 Map of the lower South Island of New Zealand depicting the location of systematic surveys, Paterson Inlet (inset) and the location of opportunistic sightings of the southern population, Otago Harbour and Dusky Sound. The standard Paterson Inlet survey route used for searching for dolphin groups is overlaid on the Paterson Inlet inset.

and a single dolphin stranding at Awarua Bay in 2011 (Department of Conservation 2012). The stranding events and sighting reports suggest the presence of a previously unstudied population of bottlenose dolphins in the south of the South Island.

Assessing the presence of bottlenose dolphins in the south of New Zealand is important, as the existence of a population in the area would provide valuable new information regarding the national distribution and abundance of this threatened species. Whether a population is 'new' can be determined by assessing any overlap of individuals between dolphins encountered at Stewart Island with two distinct, well monitored populations in nearby Fiordland. Additionally, determining any overlap with the nearby Fiordland populations could provide useful information about the connectivity of populations which are currently managed as separate (Currey et al. 2007, 2008)

Primarily, this study aimed to document the presence and abundance of bottlenose dolphins in Paterson Inlet, Stewart Island, and to compare dolphins identified in this area with nearby populations to assess if they form a separate 'new' population. Additionally, we utilise opportunistic encounters of bottlenose in southern areas to provide further information on the distribution and abundance of the southern population.

Methods

Systematic surveys

Three trips were made to Stewart Island to conduct surveys for bottlenose dolphins. The trips took place during April 2012 (7 days), September 2012 (7 days) and December 2012 (10 days). Daily surveys were conducted from Golden Bay, Paterson Inlet, using either a 6.8 m rigid-hulled inflatable powered by a 200 hp four-stroke outboard, or a 5 m aluminium-hulled vessel powered by a 70 hp four-stroke outboard. The survey route was established so that the entire inlet would be covered once each day (Fig. 1). Surveys were carried out during daylight hours in Beaufort 3 or less and no rain. Search effort was recorded every 30 s using a Lowrance HDS-5 GPS chart plotter linked into an HP 200LX palmtop computer. During encounters with groups of dolphins, scanning for additional groups was maintained, thus total time 'on effort' includes time spent with dolphin groups.

When dolphin groups were sighted, we recorded the time, location, group size and group composition (individuals recorded as adult, juvenile or calf; Williams et al. 1993). Daily surveys covered all potential dolphin habitat within Paterson Inlet, those being the areas with water depths > 2 m (see Fig. 1 for the survey track). Especially during calm weather, it was likely that the majority of dolphins inside the inlet on a given survey day were encountered.

Photo-identification

Photo-ID of natural marks is a well established method for identifying individual dolphins in a population (Würsig & Würsig 1977). For bottlenose dolphins, natural marks on the dorsal fin are typically used for photo-ID and are classified into two categories: nicks; and temporary marks (Würsig & Würsig 1977; Würsig & Jefferson 1990). For the present study, only the long-lasting 'nicks' were used for identification.

When dolphin groups were sighted, individuals were photographed using Nikon D90, D2H and D3 cameras equipped with Nikor 80–200 mm f2.8 or 300 mm f2.8 lenses. Photo-ID sampling was continued until we had taken at least three times the number of photographs as the number of dolphins present. This rule of thumb provides a high likelihood that each dolphin is photographed at least once. Photos were graded in terms of focus, exposure, interference (i.e. water splashing) and fin orientation (Currey et al. 2007), with only the best quality photos (frames that were in focus, well exposed, with minimal splashing or reflection and with fins that were approximately parallel with the optical axis) being retained for analysis. A catalogue of good quality dorsal fin photographs was produced using photographs of each side of the dorsal fin. In some studies, two different catalogues are produced, one for each side of the dorsal fin, and abundance estimates are generated using each catalogue separately. This minimises biases associated with misidentification of individuals, which can be an issue if individuals are identifiable from one side only. In this study we used fin nicks, meaning that individuals could be uniquely identified from photographs of either side of the dorsal fin. Subsequent photographs were matched against the catalogue, and the catalogue pictures updated if a new picture showed a marked change or was better quality. Capture histories were created in Microsoft Excel, describing whether a particular dolphin was seen (1) or not (0) on a given day.

The catalogue generated from photo-ID of dolphins in this study was compared with two separate catalogues, one from Dusky Sound and one from Doubtful Sound, to establish if there is any overlap in individuals among these neighbouring populations. These two Fiordland populations are discrete, and routinely monitored via a collaboration between the Department of Conservation and the University of Otago (Currey et al. 2007, 2008). Failing to encounter individuals already catalogued in either the Doubtful or Dusky Sound populations would provide evidence that the dolphins identified in this study form a new, previously unstudied population.

Abundance estimation

We used a version of the Jolly-Seber (J-S) open-population abundance estimation (POPAN) to provide an estimate of the total number of dolphins regularly found in Paterson Inlet, as well as a minimum abundance estimate for the entire southern population. Using an open model is necessary as currently there is no information regarding residency patterns or birth/death rates for this population.

The core parameters of POPAN are the same as the traditional J-S model:

ϕ – Probability of survival between recapture periods
p – Capture probability
β – Probability of entry into the population between recapture periods
N – Population abundance

The assumptions of the POPAN model are also the same as for the J-S model, the main ones being homogeneity of survival among individuals from one capture period to the next and equal probability of capture among individuals (Cooch & White 2011).

POPAN modelling was undertaken in the program MARK (version 6.1, Colorado State University; White & Burnham 1999). MARK allows all parameters to be either time constrained (.) or temporally variable (t), and thus a number of different models are formulated (White & Burnham 1999). The 'best' models were determined by the lowest AICc value (Akaike 1973; Hurvich & Tsai 1989).

As this study used pictures from dolphins exhibiting 'nicked' marks only, the final population abundance estimate will reflect an estimate for 'nicked' individuals. This estimate is then scaled by a mark rate, to account for the number of unmarked individuals in the population:

$$MRa = \frac{N}{nN}$$

where N is the total number of photographs of 'nicked' individuals and nN is the total number of photographs of both 'nicked' and 'non-nicked' individuals (Williams et al. 1993; Bejder & Dawson 2001). The effect of uncertainty in *MRa* was accounted for by incorporating the CV of this proportion into the calculation of a log-normal 95% confidence interval for the scaled estimate (Williams et al. 1993; Currey et al. 2007).

The abundance estimate was carried out using data from all demographic groups (i.e. calves, juveniles, adults) photographed during encounters. Calves (< 1 year, presence of foetal folds, and in close association with an adult) and juveniles (c. 1/3 size of an adult) were generally unmarked and so were excluded from the abundance estimation of marked individuals. However, data from these unmarked individuals were used to produce mark rate and so the scaled estimate of abundance includes these animals.

Goodness of fit testing

It is important to assess how well a MR model fits the data in order to confirm the accuracy of the final population abundance estimate (Cooch & White 2011). The present study utilised software U-CARE (Choquet et al. 2009) to determine the model's goodness of fit by assessing the validity of model assumptions and data dispersion. U-CARE incorporates tests for transience or trap happy/shy behavioural responses that would undermine model assumptions and generates a $\hat{c}$ value to assess dispersion (Choquet et al. 2009). For a similar approach, see Oremus et al. (2012) and Tezanos-Pinto et al. (2013).

Results

Survey effort

Twenty-four days were spent at Stewart Island over the three approximately week-long research trips. However, weather constraints resulted in surveys being carried out on only 17 of the 24 days. A total of 81 h were spent on the water looking for dolphins, covering 1088 nautical miles.

Encounters

Ten groups of dolphins were encountered on 8 days at Paterson Inlet, with no dolphin group sightings occurring on 9 survey days. Average group size was 10 individuals, minimum groups size was five and maximum 15 individuals. Groups consisted of adults, apart from one group, observed in April, which contained one juvenile. Most sightings (n = 7) were made in Big Glory Bay (Fig. 1). Group sightings were most frequent on the September trip (five), with four sightings made in December and a single sighting in April.

We also had two opportunistic encounters: in Otago Harbour on 10 December 2012 and in Dusky Sound on 1 September 2013. Both of these groups were large (> 50 individuals) and consisted of adults, juveniles and calves. The encounter in Dusky Sound took place during a routine monitoring trip for the Dusky Sound bottlenose dolphin population. This population receives three approximately 10-day-long photo-id trips each year to determine population trends. The encounter with dolphins identified in this study in Dusky Sound was novel; no 'new' individuals other than those born into the population to known adults have been observed in Dusky Sound since the initial population surveys in 2007 (Henderson 2013). No interaction between the southern dolphins and dolphins from the Dusky Sound population was observed during the encounter. In fact, the behaviour of the southern dolphins in Dusky Sound, travelling at very high speeds (sustaining 18 km/h) towards the open coast, suggests they were attempting to avoid contact with the Dusky Sound population. This lack of interaction, and lack of overlap of individuals (see below) indicates that the southern and Dusky Sound populations are distinct.

Photo-identification

A total of 1649 good-quality photographs of 17 individually recognisable dolphins were taken at Paterson Inlet. The total number of photographs includes both sides of the dorsal fin. The April survey trip resulted in 242 photographs of five individuals; the September trip, 806 photographs of 14 individuals; and, in November, 601 photographs were taken of 11 individuals. Forty good-quality photographs were taken of an 'unmarked' individual(s). Mark rate (*MRa*) was calculated at 0.98.

New individuals were encountered during the first 4 days during which dolphins were observed at Paterson Inlet (Fig. 2), but not thereafter, suggesting that all dolphins that use Paterson Inlet on a regular basis were photographed and identified.

The opportunistic encounters of southern dolphins in Dusky Sound and Otago Harbour together provided 891 photographs of 68 uniquely marked individuals. Eleven of these were previously identified at Paterson Inlet during systematic surveys. Twenty-seven marked individuals were sighted at

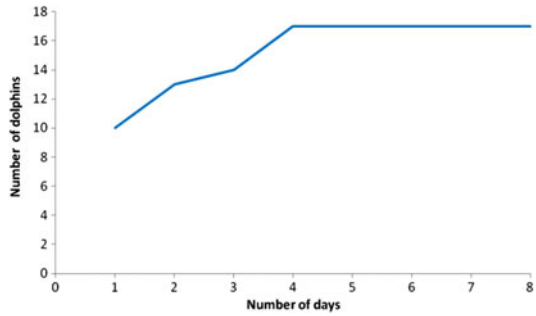

Figure 2 Discovery curve showing the total number of marked dolphins encountered during surveys of Paterson Inlet, Stewart Island, as a function of the number of days observing dolphins in the field.

both opportunistic encounters. Ninety-five photographs were taken of 'unmarked' individuals. The total *MRa* (using all sightings) is given as 0.95.

No individuals we photographed in Paterson Inlet or in the two opportunistic sightings could be matched to the extensive photo-ID catalogues we have from the separate Fiordland populations of Doubtful and Dusky Sound (e.g. Currey et al. 2008). Every individual in these populations is known and is typically encountered on every monitoring trip, thus we are confident the catalogues are accurate. The absence of an overlap of individuals between the southern population and either of the two Fiordland populations suggests that dolphins identified in this study form part of a previously unstudied population.

Abundance estimates

POPAN modelling of photo-ID data across the three Stewart Island trips indicated that 17 marked individuals (95% CI = 15, 20) regularly used Paterson Inlet (Table 1). This estimate agreed with the census value of 17 marked dolphins. Correction for mark rate resulted in a total abundance of 18 (95% CI = 16, 21) individuals.

The best model for abundance of dolphins using Paterson Inlet was Phi(t) p(.) pent(.) N(.), which has survival (Phi) temporally variable and the other parameters (capture probability, probability of entry and population abundance, respectively) temporally fixed.

POPAN modelling using photo-ID data from all sightings (including opportunistic encounters) estimated a population abundance of 87 (95% CI = 81–94) marked individuals for the southern population. Correction for mark rate resulted in a population estimate of 92 (95% CI = 80–111).

The best model to estimate abundance of the southern population was Phi(.) p(.) pent(.) N(.), which has all parameters (survival, capture probability, probability of entry and population abundance) temporally fixed.

Goodness of fit testing using U-CARE suggested no violation of MR assumptions for either of the abundance estimates (Paterson Inlet or southern population). However, a test for data dispersion indicated data for both models was under-dispersed ($\hat{c}$ of 0.5 and 0.4, respectively). There is some debate about whether or not to utilise an under-dispersed $\hat{c}$ to adjust MR models (Cooch & White 2011). In this study the new $\hat{c}$ values were used to adjust the models using a function in MARK (Cooch & White 2011). The adjusted parameter estimates were more precise, as indicated by narrower confidence intervals (Tables 1–2).

Discussion

This study reports on the results of photo-ID surveys for bottlenose dolphins in Paterson Inlet and opportunistic sightings in Otago Harbour and Dusky Sound. Seventeen marked individuals were catalogued at Stewart Island using both left and right dorsal fin photographs. According to our abundance estimate, 18 individuals regularly used Paterson Inlet, and all were re-sighted at least once after initial identification. The POPAN abundance estimate matches exactly with the photo-ID census over the same period. Eleven of these individuals were seen in much larger groups of dolphins in Otago Harbour and Dusky Sound; hence, it is assumed that the Paterson Inlet animals are part of a larger ‘southern’ population of about 90 individuals which roams over a much larger area.

Table 1 Parameter estimates for the top ranked model used to estimate the abundance of dolphins that regularly use Paterson Inlet as provided by MARK. Two estimates of survival (Phi) are provided as Phi was temporally variable for the top model. N ($\hat{c}$) is the final abundance estimate (adjusted by a $\hat{c}$ of 0.5).

Parameter	Estimate	SE	CI low	CI high
Phi	0.89	0.10	0.52	0.98
Phi	1.00	0.00	1.00	1.00
p	0.63	0.08	0.48	0.77
pent	0.02	0.07	0.00	0.89
N	17.52	1.42	17.03	26.12
N ($\hat{c}$)	17.65	1.13	15.44	19.86

Table 2 Parameter estimates for the top ranked model used to estimate the minimum abundance of the southern population as provided by MARK. N ($\hat{c}$) is the final abundance estimate (adjusted by a $\hat{c}$ of 0.4).

Parameter	Estimate	SE	CI low	CI high
Phi	0.97	0.03	0.76	1.00
P	0.52	0.07	0.39	0.65
pent	0.17	0.01	0.15	0.19
N	87.32	5.49	79.93	102.57
N ($\hat{c}$)	87.32	3.48	80.52	94.12

The abundance estimate for the southern population using the opportunistic sightings is likely to be biased low. Without exhaustive photo-ID surveys of a significant proportion of the population’s range, it is likely some individuals are not yet identified and catalogued. Moreover, it seems that some individuals in this population prefer particular areas (i.e. Paterson Inlet). This may bias abundance estimates due to unequal capture probability among individuals, even though this bias was undetected by U-CARE. Despite these limitations, the present estimate provides a useful preliminary estimate of minimum population abundance.

It is interesting to consider why only a small, mainly adult proportion of this population regularly uses Paterson Inlet. Explanations could include: (1) only those dolphins which have habituated to the habitat modification caused by the large-scale aquaculture operations in Big Glory Bay are able to use this area; (2) the regular presence of great white sharks (*Carcharodon* *carcharias*) around Stewart Island (Duffy et al. 2012; Francis et al. 2012) may prevent the use of Paterson Inlet by more vulnerable individuals (e.g. juveniles/calves); and (3) habitat other than Paterson Inlet may be more important to the demographic groups notably absent from the study area (i.e. females and calves).

It has been noted that certain members of a dolphin population can become habituated to forms of disturbance whilst others may choose to avoid the same area (Connor & Smolker 1985; Bejder et al. 2006). In the context of aquaculture, a previous study has shown that female dolphins avoid aquaculture infrastructure in favour of other areas (Watson-Capps & Mann 2005). This may explain why only a few individuals were observed within Paterson Inlet in the present study. The majority of the sightings at Paterson Inlet were made in Big Glory Bay (Fig. 1), where a substantial aquaculture industry is present. From this we may infer that dolphins regularly found at Paterson Inlet are not only habituated to, but favour, areas dominated by aquaculture.

Shark presence is an important influence on dolphin behaviour, group size and habitat use (Heithaus 2001; Heithaus & Dill 2006). Evidence of unsuccessful shark attacks was observed on two dolphins at Paterson Inlet. These individuals exhibited scars characteristic of attack by a large shark (Fig. 3): ragged or coarsely serrated bite marks with parallel slashes that differ substantially from scars originating from conspecifics (Heithaus 2001; Gibson 2006). Shark predation is likely to be a higher risk for younger, smaller animals and these animals may avoid areas with high shark densities (Mann & Watson-Capps 2005). This could account for why the vast majority of dolphins seen in Paterson Inlet were adults. There is some indication that white sharks move away from temperate oceans towards the tropics around April (Duffy et al. 2012), which may explain why the only juvenile dolphin was seen at Paterson Inlet in April.

Comparison of the marked dolphins identified in this study with the Fiordland bottlenose dolphin catalogues resulted in no overlap of individuals among these populations. The two Fiordland populations of Doubtful and Dusky Sounds are essentially closed to immigration; no new dolphins other than calves born to known adults have been observed in either population since initial surveys (Brough 2013; Henderson et al. 2013). Yet, as in any population, individuals are from time to time no longer encountered; in the case of the Fiordland populations these individuals are assumed to have died. Conceivably, missing dolphins may have emigrated to neighbouring populations; however, as dolphins from the Fiordland populations have not been found in other southern areas, this seems unlikely. Interestingly, the sighting of the southern dolphins in Dusky Sound suggests there may be some overlap in home range with the Dusky Sound population. Seemingly, this overlap is rare, as the Dusky Sound population has been monitored three times a year since 2007 without a single sighting of individuals beyond those in the Dusky Sound catalogue until now. The ‘southern’ dolphins also lacked the physical characteristics of ‘offshore’ New Zealand bottlenose dolphins (notably the absence of cookie-cutter shark [*Isistius* sp.] scars; Zaeschmar et al 2013). Because of this, and the lack of overlap with individuals from neighbouring populations, we can assume that the dolphins identified in this study form a separate, previously unstudied population.

Figure 3 A marked dolphin (SWI016) exhibiting scarring typical of shark attack to the trunk below the dorsal fin.

Our results suggest a small proportion of a larger population of at least 92 (95% CI = 80–111) bottlenose dolphins regularly use Paterson Inlet. This extends the known coastal distribution of the species in New Zealand waters and provides information to update the national abundance estimate. Given the indication of a more wide-ranging home range, a reliable population-wide abundance estimate would require surveys of other potentially important habitats in the south of the South Island.

Acknowledgements

Funding for this study was generously provided by the New Zealand Whale and Dolphin Trust and the Department of Marine Science at the University of Otago. We would like to thank the following people for assistance in the field: Ian Brough, Maddalena Fumagalli, Anthea Ibell, Dave Johnson, Liz Slooten and Ken MacAnergney. Thanks to Rakiura shipping and Real Journeys for transportation of the research vessel and survey team across Foveaux Straight.

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