


Genetic and demographic assessment of dolphins taken in live-capture and traditional drive-hunt in the Solomon Islands

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EXECUTIVE SUMMARY

In 2009, a Memorandum of Understanding was developed and a collaborative project was initiated between the South Pacific Whale Research Consortium, the Solomon Islands Ministry of Fisheries and Marine Resources and the Solomon Islands Ministry of Environment, Climate Change, Disaster Management and Meteorology. The aim of the collaborative project was to provide scientific advice to help inform management decisions relating to the removal of dolphins from wild populations in Solomon Islands. Here, we report primarily on research and conservation issues related to the live-capture of Indo-Pacific bottlenose dolphins, *Tursiops aduncus*, combining demographic and genetic tools. However, we also present preliminary results on *Stenella longirostris* and *S. attenuata,* which are the primary species targeted by traditional drive-hunters.

<u>Small boat surveys and Dolphin holding facilities</u>

Small boat surveys (n_{TOT} = 62) were conducted in November 2009, November 2010 and July 2011. Total research effort was 5,197 kilometers (km) in coastal waters of Guadalcanal, Florida Islands, Santa Isabel and Malaita, and 1,930 nm covered in offshore waters. The choice for this area was made on the basis that most dolphin removals, past and present, happened around or near these islands. A total of 123 groups of marine mammals were encountered during boat surveys, representing nine different species. Biopsy samples were collected from 71 individuals of five species for the purposes of genetic analysis.

Groups of *T. aduncus* (n = 45) were the most-commonly encountered after *S.longirostris* (n = 55). Both species were typically found in coastal habitat (< 1 km) and shallow waters (< 100 m depth). Rate of group encounters varied according to islands but not according to surveys or seasons. Five groups of *S. attenuata* were observed in offshore waters.

Two dolphin exporters allowed access to captive dolphins to collect skin samples for DNA analyses (n = 33) and photographs in November 2009 and 2010.

<u>Visits to drive-hunting communities and market surveys</u>

During surveys around Malaita, we visited three communities of dolphin drive hunters: Fanalei, Bita'ama and Taeloa. Fanalei was visit a second time in March 2013 to document recent catches. A total of 285 teeth originating from drive-hunted dolphins were collected from markets, handicraft shops and drive-hunting communities. We also collected 18 meat samples during our 2013 visit to Fanalei.

Molecular identification of captive and drive-hunted dolphins

Molecular analyses were used to confirm the taxonomic status of the dolphins targeted for live-capture and export as being *T. aduncus*. DNA extracted from teeth and meat samples confirmed that the primary species targeted by traditional drive-hunters are the spinner dolphin and pantropical spotted dolphin. Surprisingly, one tooth was identified as a pygmy killer whale, as species not reported in the Solomon Islands before.

Genetic diversity and regional population structure

Genetic diversity was investigated for *T. aduncus*, *S. longirostris* and *S. attenuata* using mitochondrial DNA sequences. These analyses revealed that the three species in the Solomon Islands retain a relatively high level of diversity in comparison to other populations in the Pacific Ocean. We found that *T. aduncus* and *S. longirostris* are highly differentiated from neighbour populations such as New Caledonia.

Photo-identification and site fidelity of T. aduncus

Photographs were obtained from most encountered groups and a particular effort was made to document groups of *T. aduncus* (44 groups were photographed). Photographs of *T. aduncus* identified 225 unique individuals in the wild. Twenty individuals were re-sighted within the same year while 46 individuals were re-sighted between different years. All resightings but one (Florida Islands to Guadalcanal) were within one of the island study sites, indicating a high degree of site fidelity and suggesting a demographic partitioning between the study sites, as further supported by likelihood analyses. Therefore, the four islands or group of islands appear to shelter distinct populations, most likely isolated demographically from each other.

A total of 28 captive dolphins were photographically identified during visits to holding facilities in 2009. Knowing that some were released in Guadalcanal and Florida Islands in 2010 (about 14 individuals), we look for matches with dolphins photographed in the wild in 2010 and 2011. Only one of the 2009 captive animals was re-identified on the North Coast of Guadalcanal, in July 2011.

T. aduncus *abundance estimates*

Given the evidence for localised populations of *T. aduncus,* abundance was estimated independently for each of the four study sites. We used closed-population models for comparison, and found that they all yield consistent results. After correcting the abundance estimates for the proportion of unmarked individuals in the population, we found that north-west Guadalcanal, Florida Islands and south Santa Isabel shelter populations of around 100 *T. aduncus* for the former and 300 for the latter. Abundance estimates for west Malaita were considered to be less reliable because of insufficient data from this site. However, population size around this island is probably also in the low hundreds. Summing of the four *T. aduncus* populations abundance estimates suggest a total abundance of around 700-1,300 dolphins in the area.

Potential Biological Removal for T. aduncus *under live-capture pressure*

Calculations of the Potential Biological Removal (PBR), a management tool used to set anthropogenic removals, show that the authorized export quota (50 dolphins per year) and the effective number of dolphins exported since 2003 (average 12 dolphins per year) are unsustainable, even considering the combined abundance estimates. For management purposes, the sustainable level of removals should be assessed for each distinct population and using conservative PBR values ($F_r = 0.1$). Doing so, it was found that no more than one dolphin every five years should be removed from north-west Guadalcanal and Florida Islands, while no more than one dolphin every 2.5 years should be removed from south Santa Isabel and west Malaita. Considering that most captures happened along the north-west coast of Guadalcanal, it is likely that the local population has been depleted since the beginning of the trade. It is also likely that the population in Malaita has been depleted, although it is harder to assess because of uncertainties in population abundance.

Recommendation

In order to ensure the persistence of Solomon Islands *T. aduncus* in the long term, it is recommended that new management takes into account the PBR and past exploitation. Furthermore, no removal should be allowed outside the study area without further biological assessment. Future quotas should be species-specific and refer to the number of captures rather than the number of export because the last does not account for mortality during local captivity. Considering the past impact on Guadalcanal population (potentially as much as half of the population was removed), a capture ban and future monitoring of abundance is recommended. Finally, a 'DNA register' of all dolphins taken for trade, including those now held overseas, should be developed.

Previous results from components of this work have been reported in SC/64/SM23, SC/65a/Forinfo32 and SC/65a/SM08.

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BACKGROUND OF THE PROJECT

Despite a long history of traditional dolphin drive-hunt, little attention has been given to marine mammal conservation management in the Solomon Islands until recently. The situation changed in 2003 with the development of a live-capture dolphin trade. This new enterprise received large media coverage followed by numerous critisisms from wildlife activists, environmental agencies and foreign governments. Concern was expressed by major intergovernmental groups, including CITES (Convention on International Trade in Endangered Species), CMS (Convention on Migratory Species) and IUCN (International Union for Conservation of Nature), about the potential conservation implications of dolphin removals in the Solomon Islands (Reeves & Brownell Jr. 2009). An assessment of dolphin removals has also been recognized as a priority under the SPREP (South Pacific Regional Environment Program) Whale and Dolphin Action Plan 2008-2012 and the CMS Pacific Cetacean Memorandum of Understanding (MoU).

The export of dolphins was banned by the Solomon Islands Government after the controversial shipment of 28 dolphins to Mexico in 2003. However, the export ban was later challenged and overturned in court, resuming the live-capture and export trade. Nevertheless, the Government decided to set a quota of 100 dolphins, of any species, to be exported per year, which was later reduced to 50 dolphins per year (UNEP-WCMC 2012). Despite these new regulations, International agencies and Governments still failed to achieve consensus on a way to manage dolphin populations in the Solomon Islands (Parsons et al. 2010). In August 2008, a workshop was held in Samoa by IUCN-Cetacean Specialist Group, focusing on the status and potential implications of *T. aduncus* removals from wild populations (Solomon Islands was a study case). Discussions focused on the status of *T. aduncus* populations and on how to conduct a research program that could provide decision makers with the robust data needed to help in management decisions involving the removal of dolphins from wild populations. This workshop was attented by dolphin experts from around the world, including four representatives from South Pacific Whale Research Consortium, SPWRC (M. Oremus, C. Garrigue, S. Taei and S. Childerhouse). It provided the opportunity to initiate communication between the SPWRC and representatives of the

Solomon Islands Government (Mr. John Leqata and Mr. Joe Horokou). Following this initial contact, the Solomon Islands Government was invited to attend the next SPWRC annual meeting in February 2009 to further discuss dolphin removal issues and the potential for collaborative effort that could take advantage of the SPWRC expertise in the assessment of cetacean populations' status (SPWRC 2009). This has resulted in the joint development of a research proposal between the SPWRC, the Solomon Islands' Ministry of Fisheries and Marine Resources (MFMR) and Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM), taking into account recommendations made at the population assessment workshop organised by IUCN in August 2008 (Reeves and Brownell 2008). The main aim of this collaborative effort was to overcome disagreements surrounding the use and associated conservation and management issues for dolphin populations in the Solomon Islands. This would be accomplished by developing an independent research project that would provide the Government with local scientific knowledge to help in management decisions involving the removal of dolphins.

In May 2009, a National Dolphin Technical Committee (NDTC) was formed by the Solomon Islands government to ensure the finalisation and endorsement of a National Dolphin Management Plan of the Solomon Islands. The Committee is composed of relevant government agencies and NGOs. One of the key objectives of the committee is to oversee the development and implementation of biological surveys to investigate the status of dolphin populations in the waters of Solomon Islands. In June 2009, a researcher from the SPWRC (M. Oremus) travelled to the Solomon Islands to meet decision makers and to further discuss the research proposal written in February 2009 and the feasibility of such biological surveys. This resulted in the development of a MoU. The MoU was completed in November 2009 and signed in February 2010 by the SPWRC, the Solomon Islands MFMR and the Solomon Islands MECDM. The first biological surveys started in November 2009, followed by second survey conducted in November 2010 and a final survey in July 2011. One researcher (M. Oremus) from the SPWRC has led the surveys, working in direct collaboration with officers from the MFMR and MECDM.

Meanwhile, in an unrelated development, traditional drive-hunts in the Solomon Islands took a new turn under the influence of the non-governmental organisation (NGO), the Earth Islands Institute (EII). In 2010, this NGO offered financial support to develop alternatives activities in exchange for stopping the hunt (Solomon Star News, 10 Apr. 2010). The EEI signed a MoU with Fanalei representatives (last community to hunt every year) but also with the former hunting communities of Bita'ama and Walande. These were also offered some financial support although they had already stopped hunting for numerous years. However, in December 2012, local newspaper reported that 134 dolphins (identified in the reports as "bottlenose dolphins") were just killed by the community of Ata'a, on the north east of Malaita, using traditional methods. This community had no agreement with EII but is formally known to be a village of traditional dolphin drive-hunter (Takekawa 1996a). Soon after, the Fanalei people decided to go back hunting presumably because of financial dispute with EII. On 22nd January 2013, local newspaper, the Solomon Star News, confirmed that the Fanalei community resumed hunting with a massive catch of 700 more dolphins. According to subsequent newspaper reports, this was soon followed by another hunt of 300 dolphins (Solomon Star News, 25 Jan. 2013). These hunts raised welfare concerns but also questions onto the exact numbers taken and the species targeted.

INTRODUCTION

Top predators such as dolphins and other small cetaceans have a fundamental influence on the biological structure and function of marine communities (Heithaus et al. 2008). As 'keystone species', the consequences of their removal by hunting, capturing or incidental mortality can vary, but an increasing number of studies show evidence of large-scale deleterious cascading effects (e.g., Myers et al. 2007). They are also 'umbrella species' because conservation actions that mitigate threats to them are likely to improve the prospects for the protection of other organisms, as well as the ecosystem itself (Mann et al. 2000, Roberge & Angelstam 2004). A third aspect particularly relevant to the South Pacific, is that these charismatic megafauna play an important role in human culture. Indeed, many Pacific island cultures have myths, legends and traditional uses of cetaceans, indicating the importance of these species in the identities of people, their way of life and their heritage (SPREP 2008). For all these reasons, it is increasingly recognized that there is a need to improve their managment and conservation (Garibaldi & Turner 2004, Roberge & Angelstam 2004, Hoyt 2005), and in particular, it is a priority to assess and ensure the sustainability of any kind of removals through by-catch, direct kill or live-capture.

The removal of dolphins in the Solomon Islands has long been seen as one of the primary direct threat to marine mammals in the South Pacific, first through traditional drive-hunts and more recently through live-captures for the captive industry. These two forms of removals are independant from one another as the techniques used, the people involved and the finality of the removals are different.

Traditional drive-hunts in the Solomon Islands

The Solomon Islands are well known for their practice of dolphin hunting, in which fishermen use traditional techniques to drive entire schools from the open ocean to coastal shallow waters (Dawbin 1966, Takekawa 1996a). The main objective of this hunt is to obtain teeth that are used as traditional currency, bride price and adornment. However, the meat from the carcasses is also consumed either within the hunting villages or after being sold locally. This practice was first reported long ago (Ivens 1902), but it remains unclear when and where the hunt was initiated or introduced. Based on oral history, it most likely pre-dates the arrival of the first missionary in the mid-19th Century (Takekawa 1996b). However, it could potentially be much older.

Only a few villages in the Solomon Islands are specialized in dolphin hunting, and most of them are located on the island of Malaita (only Lau-speaking), although it seems that this practice also occurred at time on other islands such as Makira. The dynamic of the hunt through history is not clear (e.g., which village went hunting and when?) but previous reports seems to indicate that it varied substantially over the years. Oral history from Fanalei village, as reported by Takekawa (1996b), indicates that dolphin hunt might have stopped around the mid-19th Century, maybe in relation to Christianity, before being resurrected at Fanalei and introduced to new Lau villages in 1948. Boyd (no date, as cited in Reeves et al. 1999) also reported that dolphin hunting stopped some time before World War II. Dolphin hunts used to be widely spaced out, with probably some years between the hunts. However, in 1964, the scale of hunting increased enormously, resulting in catches of several thousand animals per year (Dawbin 1966). At that time, some of the villages had stopped the hunt while others continued, including Lau-people from North and South of Malaita (Reeves et al. 1999 and references therein). According to Takekawa (1996b), Fanalei was the last village to still hunt in a regular basis in more recent years. In 2004, it was confirmed that the Bita 'ama community (thought to be one of the primary hunting community in the past) has not been hunting for reasons that are unclear (Kahn 2006). During his interview, Kahn (2006) was told by elders from this community that they should resume hunting soon but apparently they did not, apart maybe for a couple of events as reported to us by Bita'ama elders during a visit in July 2011. Note that these last hunts might have been motivated by the recent development of the dolphin live-capture and export business in the country, that aroused interest for economical benefits through dolphin capture (Solomon Star News, 5 june 2009).

Tursiops aduncus *live-capture in the Solomon Islands*

In 2003, live-capture export trade was initiated, representing a new form of dolphin exploitation in the Solomon Islands. For this, dolphins are captured in the wild, held locally in captivity for training and exported overseas for the purpose of public display (some are kept in the Solomon Islands for display and breeding program). Attempts to maintain captive dolphins were made with several species, including pantropical spotted dolphins (*Stenella attenuata*), spinner dolphins (*Stenella longirostris*) and Risso's dolphins (*Grampus griseus*). These were not successful, probably because of the difficulties to train and keep these species alive. Therefore, the capture for export trade has concentrated on Indo-Pacific bottlenose dolphins, *Tursiops aduncus*, which are usually considered to adapt better to captivity, have better temperaments and are less susceptible to disease and stress than other species of dolphins (Reeves et al. 1994). To date, *T. aduncus* is the only species that has been exported from Solomon to overseas, according to official export records.

According to Solomon Islands CITES Authorities, a total of 108 Indo-Pacific bottlenose dolphins have been exported since 2003 (UNEP-WCMC 2012). This represents the minimum number of dolphins that was removed from the wild since the beginning of the trade. Note, however, that the real number of dolphins removed is unclear and could be much larger than 108. Some individuals are still currently in captivity in Solomon Islands (therefore not included in total export number), and there is no official record of accidental deaths during capture or during captivity. However, anecdotal accounts and media reports suggest that such loss happened multiple times (Parsons et al. 2010). Furthermore, it appears that, in 2010, a minimum of 14 dolphins were released from two facilities into the wild after an unknown period of captivity. The fate of these dolphins is unknown but release of captive animals into the wild has proven very difficult and unsuccessful elsewhere (Rose et al. 2009). The large majority of dolphins were captured on the north-west coast of Guadalcanal, but the last capture event around this island appears to have happened in 2009. The last export of 25 dolphins in 2011 was composed of animals captured around Malaita, probably in 2010. To our knowledge, there was no live-capture of dolphins anywhere else in Solomon Islands.

The Government of Solomon Islands currently permits up to 50 dolphins to be exported per year. However, based on the current state of knowledge of Indo-Pacific bottlenose dolphins throughout their range, international experts have expressed concerns that this level of removal is unlikely to be sustainable (Reeves & Brownell Jr. 2009).

Investigating dolphin removals in the Solomon Islands

To investigate these issues on the basis of scientific data, we developed a project that aimed to improve knowledge of the local population status of the targeted species and to specifically assess the sustainability of *T. aduncus* live-capture. In regards to the live-capture issue, our primary objectives were: 1) to confirm the species identity of captured dolphins; 2) to describe community structure of *T. aduncus* around the primary islands of Guadalcanal, Florida Islands, Santa Isabel and Malaita; 3) to estimate the abundance of *T. aduncus* at these study sites; and 4) to calculate Potential Biological Removal as a tool for management of any future anthropogenic removals (Wade 1998). In regards to the traditional drive-hunt, which resumed during the course of our collaborative research, we aimed at providing preliminary information on the identity and population status of the primary targeted species.

In this report, we first present the results of boat surveys, dolphin facilities surveys, market surveys and drive-hunter villages surveys. For boat surveys, we describe research effort, marine mammal encounters and data collection. We then investigate the taxonomic status of captive dolphins as well as of drive-hunted dolphins using molecular techniques to confirm the species to which they belong. Captive dolphins were previously reported to be *T. aduncus* but species identification was based on external morphological characteristics such as the total body length of adults, the shape of the beak or the presence of spots (Ross et al. 2003a). However, the taxonomy of *Tursiops* sp. is rather complex and still not fully resolved, particularly in the Indo-Pacific Region. At least two species of *Tursiops* are thought to occur in the Solomon Islands (*T. aduncus* and *T. truncatus*), and recent studies also suggest the existence of a third species, described in nearby Australia (Charlton-Robb et al. 2011). Therefore, the question of the taxonomic status of the captured dolphins needed to be clarified. Here we confirmed that live-capture dolphins are indeed *T. aduncus*. Taxonomy of the drive-hunted species was investigated by extracting and sequencing DNA from teeth and meat that came from hunted specimens.

We also present results of a regional analysis of population genetic structure to investigate long-term connectivity between Solomon Islands dolphins and populations from neighbouring areas (e.g. New Caledonia). These analyses focused *T. aduncus* which are captured for export as well as the main species targetted by traditional drive-hunters, i.e. *S. longirostris* and *S. attenuata*.

Using photo-identification and capture-recapture techniques, we investigated *T. aduncus* individual movements and patterns of site fidelity between islands or groups of islands. Such analyses can help to determine if *T. aduncus* found around different islands are isolated from their neighbours or belong to the same population, which has important implications in regards to the scale at which management decisions should be applied. We also search for resightings of captive dolphins in the wild, knowing that a number of individuals were released at Guadalcanal and Florida Islands in 2010.

Capture-recapture analyses were then used to provide population size estimates. Estimating cetacean abundance is not an easy task. Several types of survey methods can be used but some are not ideal or practical for this study. For instance, airplane line-transect studies can be useful but species identification of dolphins can be difficult from the air. It is particularly true in the case of *T. aduncus* that cannot be easily differentiated from other species such as the common bottlenose dolphin, *T. truncatus*. Therefore, we choose to conduct small-vessel surveys for photo-identification work (i.e. individual recognition using unique markings on dorsal fin) using mark-recapture analysis techniques. This method is the most appropriate technique in our case and is likely to provide the more precise estimates of abundance, especially given the relatively low encounter rates for this species. Also, the studied species is known to show a high level of individual distinctiveness in other areas near Solomon Islands (e.g. 70% in New Caledonia, Oremus et al. 2009), so the majority of the dolphins can be photo-identified. Photo-identification surveys also have the advantage of providing valuable data on population structure by investigating whether individual animals move between islands or, alternatively, show a pattern of site fidelity.

Finally, the latter results served to assess the sustainability of dolphin removals in the Solomon Islands, on the basis of the current quota of export as well as on the official number of dolphins exported since 2003. Once information is available on population structure and abundance, sustainability of takes (removals) from marine mammal populations can be assessed in a variety of ways (see Reeves & Brownell (2009) for a review). Here, we decided to apply an internationally recognized management tool used to set limits for anthropogenic removals under the US Marine Mammal Protection Act and elsewhere, referred to as the "Potential Biological Removal" (PBR). The intent of the PBR is to ensure that human-caused removals are below levels that could lead to population depletion (Wade 1998). The PBR effectively sets take-limits where the mortalities occur at particular locations and times and are, at least in principle, directly observable (Lonergan 2011). The main advantage of PBR is its simplicity: a value can be calculated from a single abundance estimate and without any direct estimation of population trends. The development of this method was a deliberate response to the difficulty of collecting data on the marine mammal populations (Taylor et al. 2006).

METHODS

Boat surveys

<u>Study area</u>

The Solomon Islands is an island nation located in Melanesia, Oceania (South West Pacific, 8°00’S and 159°00’W), between Papua New Guinea and Vanuatu. It consists of nearly 1,000 islands, representing over 5,000 km of coastline (Figure 1). The continental shelf around these islands is usually narrow, and the ocean floor quickly falls to several hundred meters depth. The Solomon Islands are part of the Coral Triangle which is recognized as the global centre of marine biodiversity (Allen 2008) and a global priority for conservation (Briggs 2005). The climate is typical of a tropical area being characterised by high and rather uniform temperature and humidity and, in most areas, abundant rainfall in all months (http://www.met.gov.sb/). East to southeast winds prevail from May to October, although not usually as strong as in other Pacific regions further south or east. West to northwest winds prevail from about November to April and are usually lighter than the southeast trades and much less persistent.

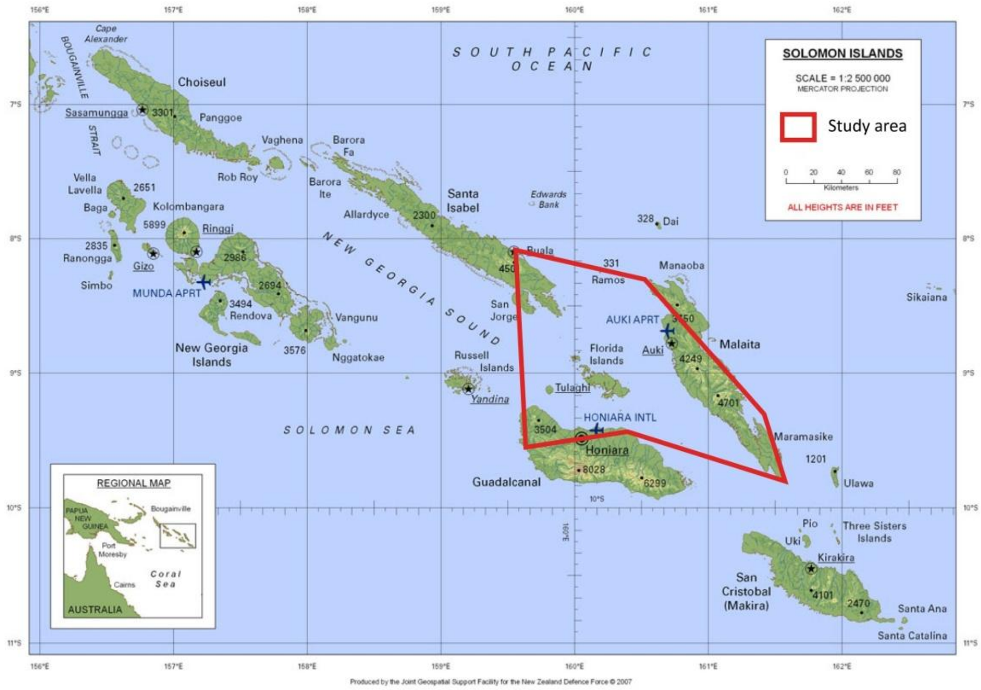

Figure 1 : Map of the studied area in the Solomon Islands

Surveys effort

From November 2009 to July 2011, three series of small-boat surveys were conducted over one month each. In total, we conducted 62 surveys: 19 in November 2009, 20 in November 2010 and 23 in July 2011. The research vessel (6 m) was purchased by the MFMR specifically for this project (Figure 2).

In order to answer our research questions, it was decided that the effort would primarily focus on four islands or groups of islands of the eastern part of Solomon Islands: Santa Isabel, Malaita, Guadalcanal and the Florida Islands (Figure 1). The choice for this area was made on the basis that most dolphin removals, past and present, occurred around or near these islands. Indeed, captures of *T. aduncus* were primarily made on the north-west coast of Guadalcanal and west coast of Malaita, while traditional drive-hunt occurs exclusively around Malaita (although it also occurred around the island of Makira in the past). Logistical constraints mean that it was not possible to cover the entire coastline of these islands during the surveys, except for the Florida Islands. Therefore, for the other sites, we choose to work where *T. aduncus* captures occurred, as well as south of Santa Isabel, which is the closest part to the former two islands (Figure 1).

Figure 2: Research vessel for dolphin surveys in Solomon Islands

Effort was primarily concentrated in 'coastal habitat', looking for *T. aduncus*. Here, 'coastal habitat' is defined as the stretch of water extending from the coastline to 1 nautical mile (nm) offshore. Indeed, throughout their range, Indo-Pacific bottlenose dolphins appear to prefer near-shore continental shelf waters and areas with rocky and coral reefs, sandy bottom, or sea grass beds (Reeves & Brownell Jr. 2009). They can be found in waters more than 200 m deep but are much more common in water less than 100 m deep (Wang & Yang 2009). Initial studies in the Solomon Islands by R.H. Defran have found this to be true for this area as well (Reeves and Brownell 2009). However, substantial search effort was also made offshore, including multiple crossings between islands, providing opportunity for encounters with deep water species.

The research team was usually composed of a boat driver from MFMR, one or two photographers from MFMR and/or MECDM and one cetacean expert from SPWRC that recorded data on tape recorder and collected biopsy samples and photographs.

Data collection

We recorded the geographic positions of each group of marine mammals encountered during the surveys with a GPS devise (Global Positioning System). In this study, a "group" is defined as a spatial aggregation of dolphins that appears to be involved in a similar activity (e.g., foraging, socialising, resting or travelling, Shane et al. 1986). For each encounter, group size was estimated by visual counts, recording the minimum, maximum and best estimates. Dorsal fin photographs were taken of as many individuals as possible, regardless of distinctive marks or vicinity to the boat, using digital SLR cameras equipped with telephoto-zoom lens. For each group, we measured the closest distance to shore using the Google Earth ruler tool. Approximated depth where groups were found was estimated using a nautical chart of the area with bathymetric information. Depth classes were as follow: less than 10 m; between 10 m and 20 m; between 20 m and 50 m; between 50 m and 100 m; more than 100 m.

Skin biopsy samples were obtained using a minimally invasive biopsy dart and a modified 22-caliber veterinary rifle equipped with a variable pressure valve (Figure 3), as described by

Krützen et al. (2002). This type of system was shown to have minimal impact on small cetaceans (Noren & Mocklin 2012, Tezanos Pinto & Baker 2012). Biopsies were only collected on individuals presumed to be mature. Samples were preserved in 70% ethanol and stored at -20°C for subsequent analyses, at the University of Auckland, New Zealand.

Figure 3: Biopsy system and dart.

Dolphin holding facilities surveys

Contact was initiated with the dolphin exporters holding dolphins in captivity in the Solomon Islands during the course of our project in order to gather information on the species and number of individuals in pens. An attempt was also made to collect dorsal fin photographs of captive dolphins as well as skin samples. For skin samples, the skin-swabbing technique (Harlin et al. 1999) was explained to the trainers so that they collect the samples themselves. This technique consists of using a sterilized nylon scrub pad that is swabbed on the dorsal or lateral surface of the dolphin to remove and retain epidermal cells. It has the advantage of being almost non-invasive but has the disadvantage of providing poorer quality genetic material (Harlin et al. 1999).

Market surveys

In parallel to the boat surveys, local markets, shops and communities were visited to purchase dolphin teeth from the traditional drive-hunt. DNA can be extracted from teeth providing an opportunity to investigate the taxonomic identity of hunted species. However, DNA obtained from teeth is generally more fragmented and in lower quantity than when extracted from skin biopsy.

Surveys of drive-hunting villages

During boat surveys around the island of Malaita, we took the opportunity to visit traditional drive-hunters' villages. We first visited the village of Fanalei in November 2009, and in July 2011 we visited the village of Bita'ama. That year, we also visited the village of Taeloa, just south of Bita'ama, which had recently been involved in the live-capture of Indo-Pacific bottlenose dolphins (MFMR pers. comm.).

Following the recent drive-hunts, a visit to the Fanalei community was organized in March 2013. A team travelled their by boat on the 22nd March 2013 with the main objectives of getting accurate numbers of dolphins hunted during this season and identifying the species that were caught. To do so, we met with representatives, hunters and elders of the village at the community house. We looked for artifacts of the recent hunts, in particular for teeth, meat and carcasses remains, in order to collect genetic samples for species identification. The meeting also provided with an opportunity to discuss the community future plans for hunting and conservation issues. One of us (J. Leqata, MFMR) acted as interpreter.

Laboratory procedures

<u>Genetic samples processing</u>

Total DNA was isolated from skin samples (including skin swabbing from exporters) by digestion with proteinase K followed by a standard phenol: chloroform extraction method (Sambrook et al. 1989) as modified by Baker et al. (1994) for small samples. Teeth samples and drive-hunt meat samples were extracted using the Qiagen DNeasy kit. A 700 base-pair (bp) fragment of the 5' end of the mtDNA control region (d-loop) was amplified via PCR using the primers light-strand, tPro-whale M13-Dlp-1.5 (5'-TCACCCAAAGCTGRATTCTA-3', Dalebout et al. 1998), and heavy strand, Dlp-8G (5'-GGAGTACTATGTCCTGTAACCA-3', as reported in Dalebout et al. 2005). Because DNA from teeth and cooked meat was expected to be highly degraded, we attempted to amplify a shorter fragment of 500 bp using a different set of primers: tPro-whale M13-Dlp-1.5 and Dlp 5 (5'-CCATCGWGATGTCTTATTTAAGRGG

AA-3', Dalebout et al. 1998). All amplification reactions were carried out in a total volume of 20 µl with 1 × Ampli-Taq buffer, 2.5 mM MgCl2, 0.4 µM of each primer, 0.2 mM deoxyribonucleotide triphosphate (dNTP) and 0.5 U of Ampli-Taq® DNA polymerase. To overcome inhibition of PCR, 1mg/mL bovine serum albumin (BSA) was added for reactions with DNA from teeth and meat samples. The PCR temperature profile was as follows: a preliminary denaturing period of 2 min at 94°C followed by 35 cycles of denaturation for 30 s at 94°C, primer annealing for 45 s at 55°C and polymerase extension for 40 s at 72°C. A final extension period of 10 min at 72°C was included at the end of the cycles. Sex of DNA samples was identified by co-amplification of the male-specific *sry* gene and the ZFX positive control gene, as described by Gilson et al. (1998).

T. aduncus *Photographs processing*

Individuals within each group were identified using notches on the dorsal fin, shape of the dorsal fin, scarring and skin pigmentation. For every individual within each group, the best left- and right-side photographs were selected and graded for quality using four parameters: focus, exposure, orientation and percentage visible (Oremus 2008). For each criterion, the photographs were assigned a grade from 1 (bad) to 5 (excellent). The final quality score of each dorsal fin was calculated as the average grade over the four criteria. All photographs ranking 1 for at least one criterion were excluded from subsequent analyses, along with the dorsal fin images that rated less than 3.5 on average. Cut-off values were chosen after an overall comparison of the photographs according to their marking. Each individual represented by at least one photograph of sufficient quality was given a distinctiveness rating, based on marks on the dorsal fin visible from either left- or right-side (Oremus 2008). Rating was as followed: (1) not distinctive, (2) slightly distinctive, (3) distinctive, and (4) very distinctive. Dorsal fins photographs from captive dolphins were assessed for quality and distinctiveness using the same protocol.

Every individual showing distinctive mark(s) (rated (2) to (4)) were compared to each other, to identify re-sightings. A catalogue of unique individuals was created and re-sighting events were classified as "within" or "between" islands and "within" or "between" years.

Furthermore, we compared distinctive dolphins held in captivity to the catalogue of distinctive dolphins from the wild.

Analytical treatment

Species identity of drive-hunted dolphins

The sequences of the mtDNA control region obtained from teeth and meat samples were implemented in the Web-based program www.DNA-surveillance (Ross et al. 2003b). This application assists in the identification of the species of unknown specimens by aligning user-submitted DNA sequences with a validated and curated data set of reference sequences for all know cetaceans. Phylogenetic analyses are performed and results are returned in tree and table format summarizing the evolutionary distances between the query and reference sequences.

Species identity of captive dolphins

A different approach was used to confirm the species identity of captive dolphins. Indeed, the genus *Tursiops* has been particularly challenging when it comes to assigning taxonomic units (Reeves *et al.* 2004). Therefore, a more comprehensive data set of reference sequences than the one offered by DNA-surveillance was needed to assign species identity in this genus. We compared the sequences of the mtDNA control region obtained from dolphins in captivity in the Solomon Islands to sequences published in GenBank and elsewhere from the two currently accepted species (*T. aduncus* and *T. truncatus*) and from the South-East Australia *Tursiops* population recently proposed as a new distinct species (*T. australis*, Charlton-Robb et al. 2011). Reference sequences are available from GenBank or from the authors (Appendix 1). For the purpose of this analysis, we used only sequences from animals sampled in the Indo-Pacific region. For *T. aduncus*, samples originated from China (Wang et al. 1999, Yang et al. 2005), East Australia (Möller & Beheregaray 2001, Möller et al. 2007, Wiszniewski et al. 2010), Hawaii (Martien et al. 2011), Indonesia (Wang et al. 1999), New Caledonia (Oremus et al. 2009) and South Africa (Natoli et al. 2008). For *T. truncatus*, samples came from China (Yang et al. 2005), East Australia (Charlton-Robb et al. 2011), French Polynesia (Tezanos-Pinto et al. 2009), Hawaii (Martien et al. 2011), Hong

Kong/Taiwan (Wang et al. 1999), Japan (Kita et al. Unpublished), Kiribati (Tezanos-Pinto et al. 2009), New Caledonia (Oremus & Garrigue, unpublished), New Zealand (Tezanos-Pinto et al. 2009) and Palmyra Atoll (Martien et al. 2011). Sequences of *T. australis* are all from South-East Australia (Bilgmann et al. 2007, Charlton-Robb et al. 2011)

Sequences were aligned using the MUSCLE alignment method (Edgar 2004) as implemented in the software GENEIOUS (Drummond et al. 2009). The maximum length of the sequences available varied according to the different sources and therefore, for the purpose of our analyses, sequences were truncated so that they all represent the same portion of the gene. Variable sites and unique haplotypes for Solomon Islands sequences were identified and confirmed by visual inspection of peak heights using GENEIOUS.

The phylogenetic relationships of the mtDNA haplotypes were reconstructed using neighbour-joining (NJ) and maximum-likelihood methods, as implemented in MEGA (Tamura et al. 2011), as well as the Bayesian method (BA) implemented in Mr BAYES (Ronquist et al. 2011). Homologous sequences from two closely-related species, short-finned pilot whale (*Globicephala melas*) and rough-toothed dolphin (*Steno bredanensis*) were used as outgroups. The robustness of phylogenetic groupings was assessed by bootstrap resampling (replicates: NJ, 5000; ML, 200) and posterior probabilities for the BA. Clades with bootstrap values > 70% or posterior probability > 0.95 were considered robust (Hillis & Bull 1993).

Genetic diversity and regional population structure

In addition to the taxonomic identification, we also used mtDNA control region sequences to investigate the level of genetic diversity and connectivity between *T. aduncus*, *S. longirostris* and *S. attenuata* in the Solomon Islands and the populations of the same species from surrounding areas. These analyses were restricted to these species as they are the primary targets of dolphin removal in the Solomon Islands: *T. aduncus* through live capture; *S. longirostris* and *S. attenuata* through traditional drive-hunt. For *T. aduncus*, we used the data set described above for species identification of live-capture dolphins but only with areas for which haplotype frequencies of samples were available and number of samples was large enough (> 10 samples). These were: New Caledonia, East-Australia and

China/Taiwan. For *S. longirostris*, we compiled available mtDNA sequences from previous studies. These were from the Society Islands of French Polynesia (Oremus et al. 2007), Occidental and American Samoa (Olavarría et al. 2004, Andrews et al. 2010), New Caledonia (Garrigue and Oremus, unpublished) and Hawaii (Andrews et al. 2010). Haplotype frequencies were not available for Hawaii, which prevent using this region for some analyses. For *S. attenuata*, haplotype sequences were only available from Hawaii (Courbis 2011), China/Taiwan (Yao et al. 2004) and eastern tropical Pacific or ETP (Escorza-Trevino et al. 2005). For those regions were haplotype frequencies were available, standard indices of genetic variation including nucleotide diversity and haplotype diversity were calculated using ARLEQUIN, v3.5 (Excoffier et al. 2005).

To test for genetic structure between geographic regions for each species, the exact test of population differentiation and analyses of molecular variance (AMOVA) were conducted as implemented in ARLEQUIN. For AMOVA, the differentiation was estimated using conventional F_{ST} (based on haplotype frequencies) and its nucleotide equivalent, Φ_{ST} (using Kimura 2-parameter), which incorporates information on the genetic distance between haplotypes. Significance was tested by 20,000 permutations of the original datasets. F_{ST} and Φ_{ST} are measures that indicate the extent of genetic differentiation among subpopulations and range from 0 (no differentiation) to 1 (complete differentiation). Again, these analyses were restricted to the regions for which haplotype frequencies were available.

T. aduncus *individual movements and site fidelity*

We used capture-recapture histories based on photo-identification to investigate individual movements and site fidelity within the studied area. In the case of fidelity to a particular site, it is expected that individuals observed multiple times will be recaptured within the area where they were captured in the first place. If dolphins do not show fidelity to a particular site, then there is equal chance of it being recaptured within a neighboring island.

To provide a statistical assessment of site fidelity, inter-annual site fidelity was investigated using a maximum likelihood method assessing the probability, *pt*, that an individual observed in one particular area moves to another area between sampling periods. This method allows the number of identifications to be used as a measure of effort, allowing the inclusion of all years with any individual identification (Whitehead 2001). Then the probability that an individual remains in a study area one sampling period later is one minus the sum of the transition probabilities to the other areas. This was assessed with the program SOCPROG (Whitehead 2009). The option allowing for an external area was used to account for individuals that are not found in any of the four study sites (e.g., *T. aduncus* from neighbour islands such as Makira or Russell Islands that were not covered during our study).

Population abundance estimates

In light of the results obtained on site fidelity analyses (see Results section), we chose to estimate abundance for each island/study site separately. Each of the three surveys (2009, 2010 and 2011) constitutes a sampling event for mark-recapture analyses. All surveys were conducted in similar fashion with effort being broadly similar at each study site. There were 11 and 7 months between sampling periods 1 and 2, and 2 and 3, which has left sufficient time to allow animals redistribute themselves between sites and also for movements between islands if they occur.

For population estimation using mark-recapture methods there are two primary classes of models in wide use. The first of these are the closed models, in which it is assumed there are no additions to (birth, immigration) or losses (death, emigration) from the population of interest over the period of study (i.e., the demographic closure assumption). The second are the open models that allow for additions or losses over the period of study. In cases where the closure assumption can be met, the closed models are preferred over the open models because it is possible to account for realistic sources of variation in detection probabilities, such as time variation, individual heterogeneity, or behavioral variation, thereby improving population estimates (i.e., decreased bias and increased precision, (Stanley & Richards 2005). However, one must be aware that violation of the closed assumption generally produces overestimation of population estimates (Pollock et al. 1990), since closed models assume that all animals are present in the study area, and available for sampling. Here, we considered that, because of the study design and life history parameters of the species of interest, violations of closed models assumptions were unlikely, as discussed by Bearzi et al.

(2008). The potential exception is the assumption of individual heterogeneity in capture probability, which is often violated in cetacean mark-recapture studies (Hammond 2001). However, this source of variation can be taken into account by some models and therefore, we favored closed models rather than open models for our analyses.

Analyses of abundance estimates were performed using the program CAPTURE (Rexstad & Burnham 1991), as implemented in program MARK (White & Burnham 1999). CAPTURE fits eight different closed population models to the data to produce abundance estimates. The program offers a model selection algorithm based on goodness of fit tests but this procedure needs to be used with caution, because the tests are not independent and often have a low power, especially for small populations and low recapture rates (Menkins and Anderson 1988). Therefore, in order to investigate the influence of model choice on final estimates, we choose to present and compare results from four different models that we think are biologically most relevant to our study case. These are:

- Mo: is the simpler mark-recapture estimator which assumes that all individuals have the same probability of capture on each sampling occasion.
- Mt (Chao 1989): is a model especially developed for sparse data where the probability of capturing the animal varied with time.
- Mh (Chao 1988): is also a model developed for sparse data but where the probability of capture varied between individuals.
- Mth (Chao et al. 1992): accounts for both variation of capture probability in time and between individual.

As these estimates relied on natural markings to identify individuals, they refer exclusively to the population of marked animals. To include the unmarked portion of the populations and obtain estimates of the total populations, the proportion of unmarked individuals (which also included younger individuals) was computed on the basis of the proportion of unmarked dorsal fins estimated for each study site (Williams et al. 1993). CVs were also adjusted according to Williams et al. (1993). Confidence intervals for total population size were calculated by assuming that the error distribution was the same as for the estimate of the number of distinctive individuals (Wilson et al. 1999).

Assessment of T. aduncus *removal sustainability*

Over the various methods employed to date around the world, threshold values used to evaluate sustainability or acceptability of takes or removals of marine mammals range from 0.1% to 2% of a best estimate of abundance, and that they are relatively consistent with one another. Here, we choose to use the PBR method, which explicitly takes into account uncertainty and potential biases in the available information. A PBR is calculated using the following simple formula (Wade 1998):

$$PBR = N_{min} \times 0.5\ R_{max} \times Fr$$

Where: $\mathbf{N_{min}}$ = 20th percentile of the population size estimate; $\mathbf{R_{max}}$ = Maximum annual population growth rate, and; **Fr** = Recovery factor.

The PBR uses the 20% confidence limit of the abundance estimate (equivalent to the lower 80% confidence limit) to account for imprecision in the abundance estimates, as quantified in the CV. In regards to R_{max}, nearly all small cetaceans are thought to have rates of growth no higher than about 4% per year (R_{max}=0.04) (Wade 1998, 2002). Certainly no dolphin population has been observed to increase at a faster rate, and aspects of their life history (such as their relatively high age of sexual maturity and low birth rate) make faster rates unlikely for dolphins (Wade 2002; Reilly and Barlow 1986). Therefore, we used a default growth rate value of 0.04. A recovery factor (Fr) of 0.5 is standard for unexploited populations and was shown to be robust under many situations (Wade 1998), including when estimates of abundance R_{max} are potentially biased or when there are uncertainties about population structure. However, for very small or endangered populations, an Fr of 0.1 is recommended (Wade, 1998; Slooten & Dawson 2008). Indeed, a small population is vulnerable because of environmental or demographic stochasticity and inbreeding (Lande 1999), even in the absence of human-induced mortality. Here, we conducted calculations sing Fr = 0.1 and Fr = 0.5 for comparison, as minimum and maximum values recommended by the literature.

RESULTS

Boat-survey effort and data collection

Effort

Effort was broadly similar between the three series of small-boat surveys (Table 1), representing over 350 h of observation at sea for a total of 7,126 kilometers (km) covered, including 5,197 km of coastal effort and 1,930 km of offshore effort (Table 1, Figure 4). The same areas were covered in 2009, 2010 and 2011, with the inclusion of the island of Savo during the 2010 and 2011 surveys (Appendix 2). Because of the geographic proximity of the two islands, data from dolphin encounters at Savo were combined with Guadalcanal for analyses hereafter. Overall, weather conditions were good for the three series of surveys. Daily expeditions were only undertaken at Beaufort Sea State (BSS) less than four. Search effort was ended when BSS reached four but this occurred only rarely.

Table 1: Summary of research effort for study sites in the Solomon Islands.

SITE	# Surveys				Time on water (hours:minutes)				Coastal effort (km)			
	2009	2010	2011	**all**	2009	2010	2011	**all**	2009	2010	2011	**all**
Guadalcanal	7	7	5	**19**	39:56	34:21	29:50	**104:07**	350	482	407	**1239**
Florida Islands	3	5	7	**15**	18:20	37:33	36:44	**92:37**	215	496	550	**1261**
Santa Isabel	5	4	6	**15**	26:15	25:05	27:50	**79:10**	383	335	511	**1230**
Malaita	4	4	5	**13**	26:24	20:35	28:40	**75:39**	465	435	567	**1467**
Total	19	20	23	**62**	110:55	117:34	123:04	**351:33**	1413	1748	2035	**5197**

Group encounters

A total of 126 groups of marine mammals were encountered, giving an overall marine mammal group encounter rate during this study of 1.77 groups per 100 km of effort. These encounters were composed of nine different species, including eight cetacean species and one sirenian (Table 2). Spinner dolphins, *S. longirostris* (n = 55 groups) and *T. aduncus* (n = 45 groups), were by far the most-commonly encountered species. *S. longirostris, T. aduncus* and *Balenoptera sp.* were the only species observed at each of the four study sites (Figure 5). Although the *Balenoptera* species was not conclusively identified, total estimated length (ranging from 6 to 10m), and photographs of the rostrum and back of the animals suggest that they were Omura's whales (*Balenoptera omurai*) (Appendix 3).

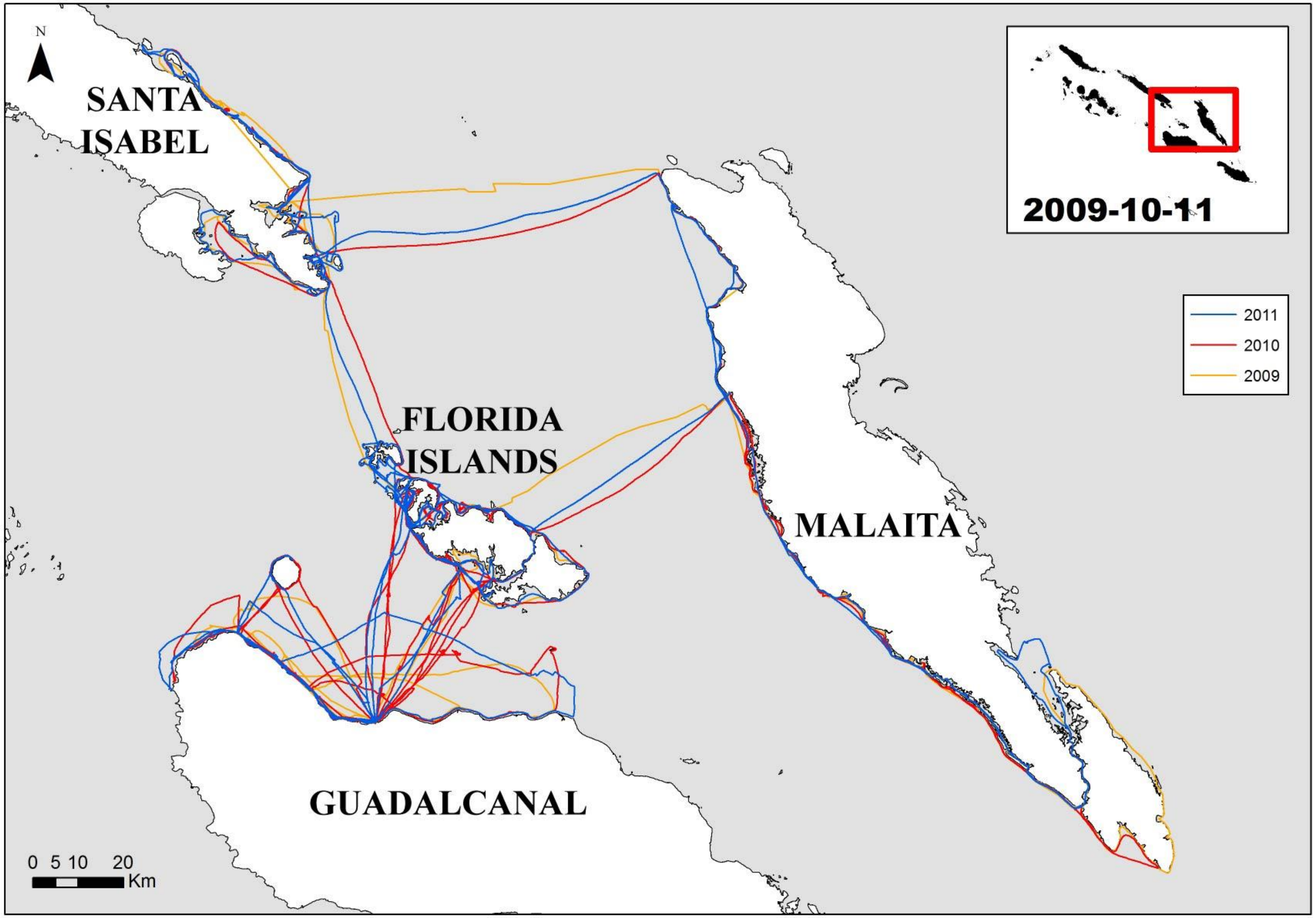

Figure 4: Track-lines of small-boat surveys in Solomon Islands during 2009, 2010 and 2011

The pantropical spotted dolphin was observed in five occasions and show the largest average group size overall (Table 2). *S. longirostris* average group size was smaller but still relatively large with almost 60 individuals per group (ranging from 1 to 60 individuals). Group size for *T. aduncus* was substantially smaller with an average of 10.6 dolphins, ranging from 1 to 60 individuals.

Table 2: List of marine mammals encountered in Solomon Islands across the study, including number of groups, biopsies and average group size.

Common name	**Latin name**	**# of groups encountered**			**# biopsies**	**Average group size**
		2009	**2010**	**2011**		
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	13	16	16	2	10.6 (SD=10.5)
Spinner dolphin	*Stenella longirostris*	17	18	20	34	57.6 (SD=58.7)
Baleen whale	*Balenoptera* sp.	1	2	3	0	1.2 (SD=0.4)
Pantropical spotted dolphin	*Stenella attenuata*	1	3	1	19	87.5 (SD=58.9)
Short-finned pilot whale	*Globicephala macrorhynchus*	2	1	0	3	36.7 (SD=17.6)
Dugong	*Dugong dugon*	0	3	0	0	1.0 (SD = 0)
Common bottlenose dolphin	*Tursiops truncatus*	2	0	0	7	60.0 (SD=14.1)
Risso's dolphin	*Grampus griseus*	1	1	0	0	4.0 (SD=2.8)
False killer whale	*Pseudorca crassidens*	0	1	0	0	9
Unidentified sp.		2	0	2	-	-

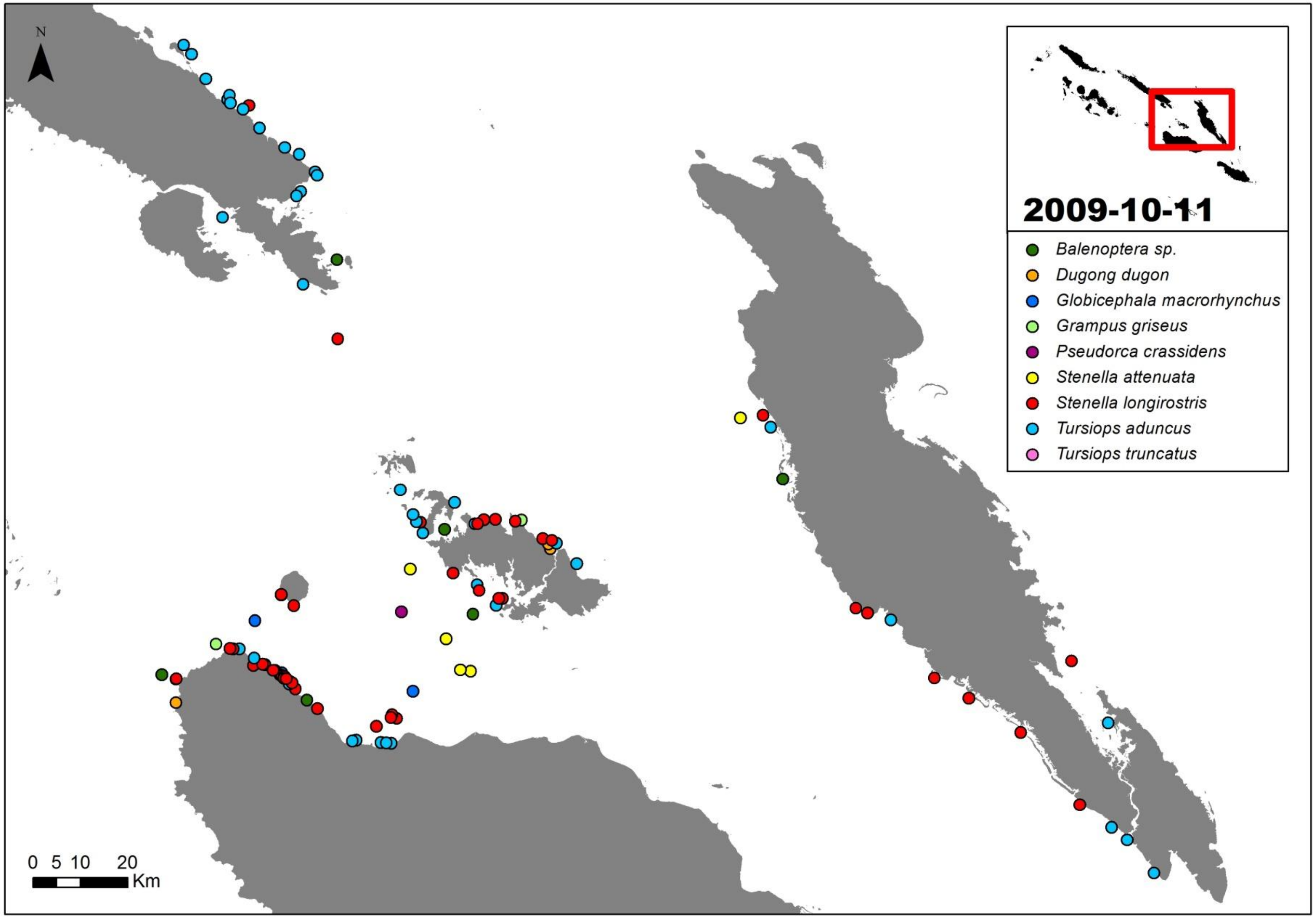

Figure 5: Geographic positions of marine mammal encounters in Solomon Islands during small boat surveys 2009, 2010 and 2011.

Mixed species group

T. aduncus was observed in mixed-species aggregations with *S. longirostris* during 11 encounters. In November 2009 at Guadalcanal, we observed a juvenile *S. longirostris* swimming along with a *T. aduncu*s on two instances, one day apart (Figure 6). On both encounters, the juvenile was the only *S. longirostris* in the group and on both encounters it was seen swimming with the same *T. aduncus*, as shown by distinctive marks on its dorsal fin. This particular *T. aduncus* was seen again in November 2010, with another Indo-Pacific bottlenose dolphin but mixed with a larger group of *S. longirostris*. The juvenile *S. longirostris* observed in November 2009 showed no distinctive marks and therefore, it is unknown if it was present again in this group.

Figure 6: Juvenile of *Stenella longirostris* accompanying an adult *Tursiops aduncus* at Guadalcanal

Biopsy sampling

A total of 71 biopsy samples were collected over the three years (32 in 2009, 32 in 2010 and 7 in 2011). Most of these came from two species: *S. longirostris* (n = 39) and *S. attenuata* (n = 20). Only two biopsy samples of *T. aduncus,* despite being the species with which we spent most time (total of 38h 57min). *T. aduncus* approached the boat very rarely and when they did, they usually did not surface. In addition, we collected seven biopsies from *T. truncatus* and three biopsies from *Globicephala macrorhynchus*.

Habitat use

T. aduncus groups were encountered at an average of 0.75km (SD = 0.49) from the coastline (Figure 5). In one occasion only, out of 45 encounters, a group was observed more than 1.5km offshore (it was 2.8km from coastline). The depth classes at which *T. aduncus* were encountered were distributed as follow: 5% at less than 10m; 26% at between 10m and 20m; 53% between 20m and 50m; 16% between 50m and 100m; 0% at more than 100m. *S. longirostris* were also typically found close to shore (mean = 0.90; SD = 1.09) although, in a few instances, groups were observed several kilometres offshore (maximum of 4.8 km offshore, Figure 5). However, as for *T. aduncus* they show a clear preference for shallow waters (< 100 m). The baleen whales observed in the Solomon Islands were also observed relatively close to coastline (mean = 2.05 km), sometimes at just a couple of hundred meters from shore (Appendix 3). Other species such as *S. attenuata*, *P. Crassidens*, *G. macrorhynchus* and *T. truncatus* were observed further offshore, typically > 5 km from coastline, and in deeper waters (> 500 m). On the two instances that they were observed, *G. griseus* was found relatively close to shore (< 2.5 km). Finally, and as expected, *D. dugong* was observed very close to shore in shallow waters (< 50 m).

T. aduncus *and* S. longirostris *encounter rates*

Considering the large number of encounters for *T. aduncus* and *S. longirostris*, we looked at encounter rates in more details for these two species. *T. aduncus* encounter rates were computed for both groups and individuals. Overall, the average group encounter rate was 0.9 group or 9.3 individuals per 100km of effort within coastal waters. There was no significant difference in the rate of group encounters or in group sizes between any of the three surveyed periods (group encounters: Kruskal-Wallis rank test $H = 0.346$, df = 2, p = 0.841; group sizes: Kruskal-Wallis rank test $H = 2.361$, df = 2, p = 0.307). The highest rates of group and individual encounters were around the island of Santa Isabel (Table 4). The lowest rate of group encounters was found in Malaita but it was at Guadalcanal that we found the lowest rate of individual encounters. The rate of group encounters varied significantly between study sites (Kruskal-Wallis rank test $H = 8.744$, df = 3, $p < 0.05$) but not the rates of individual encounters (Kruskal-Wallis rank test $H = 5.821$, df = 3, $p = 0.121$). To investigate a potential seasonal effect on the occurrence of *T. aduncus* in Solomon Islands, we combined November 2009 and November 2010 data and ran comparative tests with data collected in July 2011. We found that there was no significant difference in the rates of group encounters (Kruskal-Wallis rank test H = 0.259, df = 1, p = 0.610) or the rates of individual encounters (Kruskal-Wallis rank test H = 0.259, df = 1, p = 0.610) between the two putative seasons.

Table 3: Summary of group and individual *Tursiops aduncus* encounter rates at four study sites in Solomon Islands

SITE	*T. aduncus* groups/100km				*T. aduncus* individuals/100km			
	2009	2010	2011	**all**	2009	2010	2011	**all**
Guadalcanal	0.6	1.0	0.7	**0.8**	2.3	4.4	10.6	**5.8**
Florida Islands	0.9	1.0	0.7	**0.9**	12.6	10.5	6.7	**9.2**
Santa Isabel	1.6	1.5	1.2	**1.4**	17.7	14.3	11.7	**14.3**
Malaita	0.6	0.2	0.5	**0.5**	6.0	1.6	12.9	**7.4**
Total	0.9	0.9	0.8	**0.9**	9.3	7.3	10.5	**9.1**

Encounter rates with *S. longirostris* were computed for groups only as it was more difficult to get accurate estimates of group sizes. Overall, the average group encounter rate was 1.1 group per 100km of effort within coastal waters. There was no significant difference in the rate of group encounters between any of the three surveyed periods (group encounters: Kruskal-Wallis rank test H = 0.415, df = 2, p = 0.813). The highest rates of group encounters were around the island of Guadalcanal (Table 4). The lowest rate of group encounters was found in Santa Isabel. The rate of group encounters varied significantly between study sites (Kruskal-Wallis rank test H = 10.009, df = 3, $p < 0.05$).

Table 4: Summary of *Stenella longirostris* group encounter rates at four study sites in Solomon Islands.

SITE	*S. longirostris* groups/100km			
	2009	2010	2011	**all**
North-east Guadalcanal	2.3	1.9	2.5	**2.2**
Florida Islands	1.9	1.4	1.1	**1.3**
South Santa Isabel	0.5	0.0	0.0	**0.2**
West Malaita	0.6	0.5	0.7	**0.6**
Total	**1.2**	**1.0**	**1.0**	**1.1**

Captive-dolphin holding facilities

In November 2009, 19 *T. aduncus* were held in captivity at the Honiara facility, Guadalcanal, while 27 were in the pens of the Gavutu Island facility, in Florida Islands. We were told that all of these dolphins were captured along the north-west coast of Guadalcanal, close to Honiara. In November 2010, a second visit to the Honiara facility showed that only eight dolphins were left, including six males and two females, according to the trainer. Three dolphins were exported in December 2009, while eight individuals were apparently released in front of the facility around July 2010. Also in November 2010, we found out that the Gavutu Island facility was closed with no dolphins left in the pens. Seven of the dolphins seen a year earlier were exported in December 2009. The fate of the remaining 20 dolphins is unknown. According to the former owner's blog (www.freethepod.com), six dolphins were released around June-July 2010, while the remaining 14 individuals died in captivity.

During November 2010 and July 2011, we also tried to visit a new facility belonging to a third entrepreneur and located at Mbungana, Florida Islands. Unfortunately, we were not granted access. Apparently, in November 2010, no dolphins were held in this facility yet. However, in July 2010, the entrepreneur confirmed that some dolphins were captured along the west coast of Malaita after our last visit and that they were currently held in pens at Mbungana. This was also directly confirmed to us by the fishing community at Taeloa, Malaita, which was in charge of capturing the dolphins. Although we had no clear evidence of how many dolphins were captured, or from which species, it turned out that 25 *T. aduncus* were exported overseas from the facility to later in 2011 (UNEP-WCMC 2012). An unknown number of dolphins are still held in this facility, as directly confirmed by the entrepreneur during the meeting held in June 2012 at Honiara.

Samples of sloughed skin were collected from captive dolphins held in the facilities at Honiara (n = 16) and Gavutu Island (n = 17). Unfortunately, no samples could be obtained from a third facility at Mbungana Island, despite multiple requests to the owner. Note that many of the skin-swabbing samples made available were of poor quality resulting in low concentration of DNA and making genetic analyses difficult.

Teeth collection from markets and drive-hunting communities

In total we collected 285 teeth. These were purchased from different sources, primarily in Honiara where some were for sale at the public market as well as in various handcraft shops (Appendix 4). The rest of the teeth were obtained in Malaita where they were directly bought from drive-hunting communities (either Fanalei or Bita'ama). The teeth were either integrated in pieces of jewelry (earrings, necklaces, and headband) or sold loose (Figure 7). The shapes and sizes of the teeth suggested that most of them were collected on pantropical spotted dolphins ("unubulu") or spinner dolphins ("raa"). However, some teeth were substantially larger and thus coming from different, bigger species ("robo").

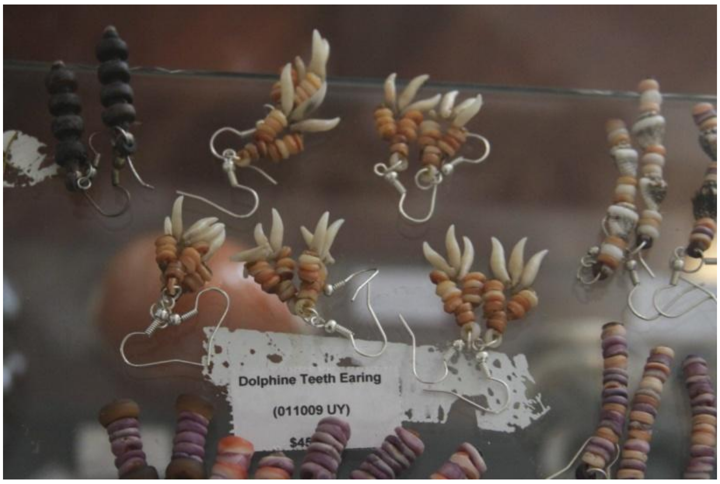

Figure 7: Earrings made of dolphin teeth for sale in a hotel of Honiara, Solomon Islands.

Visits to drive-hunting communities

Fanalei, November 2009 – During our first visit at the village of Fanalei, it was possible to briefly meet with some elders and hunters. They gave us a description of the hunt very similar to that reported by Takekawa (1996b, a). For the hunts, they use basic dugout canoes as well as stones that they clap under the surface to create to wall of noise (Figure 8). They also confirmed that Takekawa's account of the various species taken by hunters is accurate. Nonetheless, while trying to get further details on some particular species based on their traditional names, inconsistencies appeared among some of the community members regarding the morphological description and group behavior. That was particularly true for "robo" species which are less frequently caught that "unubulu" (*S. attenuata*) and "raa" (*S. longirostris*). However, they did confirmed that at least two forms of spinner dolphins occur around their island, "raa matakwa" and "subo raa", the later being a larger more pelagic form. At the time of this first visit to Fanalei, the community was not yet engaged in the MoU with Earth Island Institute.

Figure 8 : Dugout canoes and stones used for traditional drive-hunting of dolphins in Fanalei.

Bita'ama and Taeloa, July 2011 – Bita'ama used to be one of the primary hunting communities in the Solomon Islands and elders from the village insisted on the fact that they were the first to introduce this practice in the country a long time ago. We were not able to confirm this information or to get a date for the beginning of the hunt. However, by the time of our visit, the community has apparently not been involved in regular hunting in a long time, which had already been reported earlier by Kahn (2006). The last couple of catches that they made in recent years were of a group of spinner dolphins and a group of Risso's dolphins but they kept at least part of these groups alive for some time. It is thought that these catches were primarily motivated by the recent development of the live-capture and export trade and the hope to sell some of these dolphins to display facilities. It did not happen and all the animals eventually died in captivity or were killed. Not surprisingly, the Bita'ama representatives appeared to still be supportive of the EII MoU by the time of our visit. Indeed, EII offered financial support to the community in exchange for a stop to the traditional drive-hunting, which, in practice, they had already stopped years ago, with the exception of the couple of recent catches reported above.

Just south of Bita'ama, we also visited the community of Taeloa, which belong to the same family lineage as Bita'ama. To our knowledge, Taeloa has never been reported as a dolphin drive-hunting community in previous reports. We were made aware of the village because of its recent implication in the capture of *T. aduncus*. Elders and representatives did not deny this involvement but they also told us that Taeloa has a strong tradition of capturing dolphins as well. Contrary to Bita'ama, they have no agreement with EII. Apparently they refuse to sign the MoU but we actually have no evidence that EII approached this community to enter the agreement.

We were shown the traditional canoes that they use for drive-hunting the dolphins and which are different from the ones used in Fanalei (Figure 9). We were also shown numerous teeth presumably coming from drive-hunts conducted by the community. We believe that some of these teeth might have been of *T. aduncus* that were captured with speed boats and drift nets. Unfortunately, the representatives of the villages refused to sell us any teeth that could have help to address this hypothesis with genetic tools.

Figure 9 : traditional canoes used by hunters in Taeloa, Malaita and dolphin teeth from presumed drive-hunt.

Fanalei, March 2013 - From our interviews at Fanalei in March 2013, we were told that three species were hunted so far in the season: "unubulu", "raa" and "robo manole". The first two are clearly identified as the pantropical spotted dolphin and the spinner dolphin, respectively. According to Takekawa (1996b), “robo manole” is suggested to be the common dolphin (*Delphinus delphis*) although there was some uncertainty, as illustrated by Takekawa’s question mark following the Latin name for this species. After questioning the hunters on the group and morphological characteristics of the “robo manole”, it seems to us that the species is more likely to be the common bottlenose dolphin (*Tursiops truncatus*). We note that at the time of Takekawa’s work, the status of *Tursiops* in the Solomon Islands was still poorly known, which might have created some confusion. Indeed, recent molecular work based on biopsy samples collected at sea has confirmed the presence of two *Tursiops* species in the water the Solomon Islands: *Tursiops truncatus*, found in deep offshore waters, and *Tursiops aduncus*, found in shallow coastal waters (Oremus et al. 2013). Therefore, it is likely that Takekawa (1996b) misidentified the species locally called “Olo folosi walo” as being the *Tursiops truncatus,* when it was in fact *Tursiops aduncus*.

In addition to the teeth samples that were obtained from the communities, as mentioned above, we also collected pieces of meat from recently hunted dolphin, found in the village’s kitchens. These were used to confirm species identity of the recent hunt but also to build on the data sets on the current genetic diversity within the targeted populations.

Catch records for the 2013 hunting season were provided to us by one of the dolphin hunters from Fanalei who kept clear notes of the dates, species and number of dolphins caught for each hunt. These catches (n = 11 hunting events) are summarized in Table 5. It shows that the largest catch was the “unubulu”, or pantropical spotted dolphin, with over 1,500 individuals taken. The second largest catch was the “raa”, or spinner dolphin, but in much smaller numbers with a total of 159 dolphins killed. Finally, a group of 15 “robo manole”, or presumed common bottlenose dolphins were caught. Average number of dolphins taken per event was 154+. It appears that there is a substantial difference between catches of pantropical spotted dolphins (mean of 218+ individuals per event) and spinner dolphins (53 individuals per event).

Table 5: Summary of dolphin catches by the Fanalei community from the beginning to the 2013 season until the 23rd March 2013, as reported by one of the dolphin hunters from Fanalei (Pers. comm. Albert Balei).

	Date	Latin name	Traditional name	Number caught
1	21/01/2013	*Stenella attenuata*	Unubulu	700+
2	24/01/2013	*Stenella attenuata*	Unubulu	60+
3	05/02/2013	*Stenella attenuata*	Unubulu	126+
4	06/02/2013	*Stenella attenuata*	Unubulu	300
5	09/02/2013	*Tursiops truncatus*?	Robo manole	15
6	11/11/2013	*Stenella longirostris*	Raa	56
7	20/02/2013	*Stenella longirostris* *Stenella attenuata*	Raa Unubulu	33 70
9	06/03/2013	*Stenella longirostris*	Raa	70
10	20/03/2013	*Stenella attenuata*	Unubulu	54
11	23/02/2013	*Stenella attenuata*	Unubulu	214
			Total Unubulu	1,524+
			Total Raa	159
			TOTAL	1698+

The last hunt reported here happened the day after our visit. Since the typical hunting season could last for another month beyond the date of our visit, there could have been additional hunts that we are not aware off.

In addition to the 2013 records, we were also provided with accurate records of catches for the years 2000 to early 2003 season in Fanalei (Figure 10, Table 6). Only pantropical spotted dolphins and spinner dolphins were caught during this period, confirming the predominance of these species in traditional drive-hunt. The number of successful hunts per year was: 10 in 2000, 5 in 2001 and 11 and 2002 (data were incomplete for 2003). The difference between the number of pantropical spotted dolphins and spinner dolphins caught was not as marked as in 2013 (728 vs. 628, respectively, between 2000 and early 2003). On the other hand, the tendency for larger groups of pantropical spotted dolphins being caught was confirmed: mean of 94 individuals for pantropical spotted dolphin against 42 individuals for spinner dolphin.

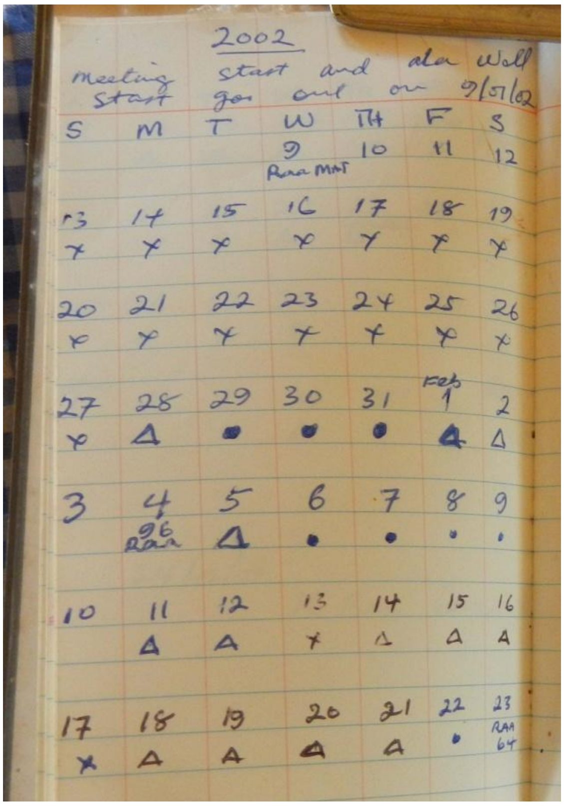

Figure 10: Example of catch records from Albert Balei notebook for the period 2000 to early 2003. (x) indicates that no boat went out; (•) indicates that boat went at sea but found no dolphins; (Δ) indicates that dolphins were sighted but there was no catch; local species name and total number of dolphins are indicated when caught.

Unfortunately, nobody was able to give us records for the 2003 to 2009 period, i.e. before the hunt temporally stopped in 2010. Kahn (2006) reported some overall annual catches for Fanalei for the period 1999-2004 (not 2001), which he collected after a visit to the community. For the year 2000, Kahn reported a larger catch that the data given to us (800 vs. 577) while for 2002, we got fairly similar numbers (700 vs. 648). The reason for the discrepancy for the 2000 numbers is unknown. While our total catch could be an underestimate for that year, the records provided to us seem to be very accurate, including days not going at sea and days going out with no catch (Figure 10). Therefore, we believe that the new total catches presented here are likely to be more accurate.

Table 6: Catch records by the Fanalei community between 2000 and early 2003 (Pers. comm. Albert Balei).

Year		Date	Species	Numbers caught
Year 2000	1	23/01/2000	*S. longirostris*	42
	2	15/02/2000	*S. longirostris*	15
	3	25/02/2000	*S. attenuata*	40
	4	02/03/2000	*S. longirostris*	55
	5	08/03/2000	*S. attenuata*	45
	6	27/03/2000	*S. longirostris*	44
	7	05/04/2000	*S. attenuata*	36
	8	06/04/2000	*S. attenuata*	274
	9	Sept 2000	*S. longirostris**	15
	10	02/12/2000	*S. longirostris*	11
Year 2001	1	31/01/2001	*S. longirostris*	19
	2	20/02/2001	*S. longirostris*	27
	3	17/03/2001	*S. longirostris*	54
	4	22/03/2001	*S. attenuata*	15
	5	24/03/2001	*S. longirostris*	16
Year 2002	1	09/01/2002	*S. longirostris*	9
	2	04/02/2002	*S. longirostris*	96
	3	23/02/2002	*S. longirostris*	64
	4	06/03/2002	*S. attenuata*	18
	5	08/03/2002	*S. longirostris*	128
	6	18/03/2002	*S. attenuata*	50
	7	25/03/2002	*S. longirostris*	13
	8	30/03/2002	*S. longirostris*	33
	9	08/04/2002	*S. attenuata*	72
	10	09/04/2002	*S. attenuata*	40
	11	17/04/2002	*S. attenuata*	125
Year 2003	1	14/04/2003	*S. attenuata*	400

*voluntarily entered in the lagoon.

Takekawa (1996b) gave some information on annual total catch at Fanalei for the period 1976 -1994 (based on his own observations as well as on Meltzoff (1983) and personal notes from community member J. Filei). He reported an average of 840 dolphins taken per year during this period (max close to 2000 in 1986; min less than 50 in 1979). The average number of individual caught per hunt was 115.5 (no details on the species) and the average number of successful hunts per year was 7.3. These numbers are roughly consistent with the new figures provided here. For instance, during the period 1999 to 2013, the mean annual catch was 793 dolphins, all species included. We summarized all available records or reports for total annual catches for Fanalei in Figure 11.

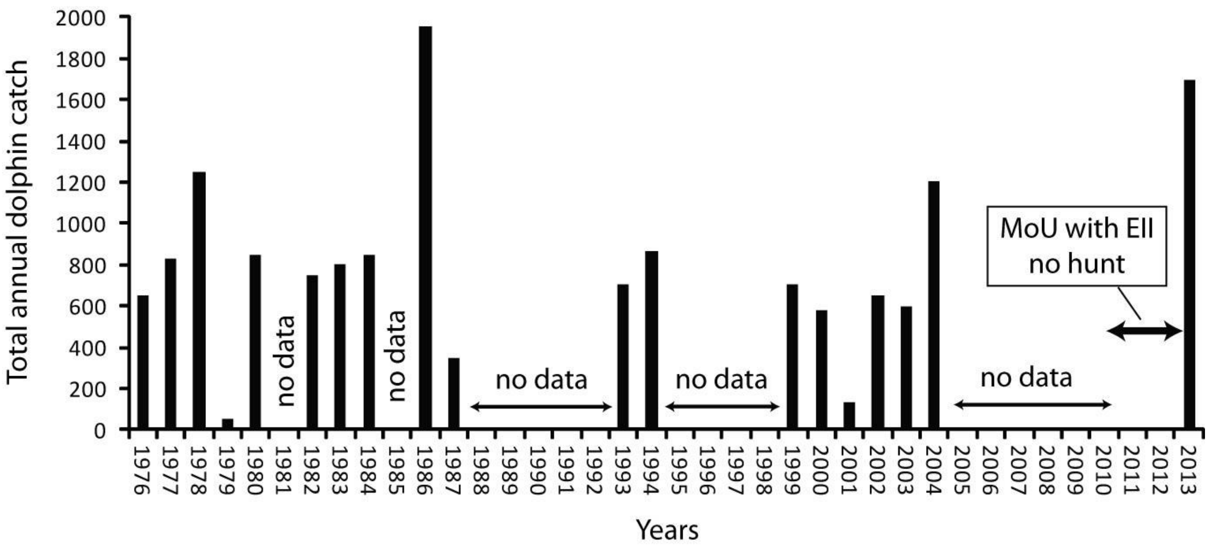

Figure 11: Summary of the total annual dolphin catch available for the Fanalei community between 1976 and 2013. Years 1976 to 1994 from Takekawa (1996b) and reference therein; years 1999, 2003 and 2004 from Kahn (2006); years 2000, 2001, 2002 and 2013 from present study.

Species identity of captive dolphins

DNA was extracted from all skin samples collected from captive *T. aduncus* during this study. Molecular sexing on captive dolphins was successful for 14 samples, indicating a biased sex ratio of 12 males and 2 females (exact binomial test of goodness of fit, $p < 0.05$). A total of 16 sequences of the mtDNA control region were obtained from presumed Solomon Islands *T. aduncus* in captivity. These sequences were aligned with haplotypes of *Tursiops* sp. from other regions of the Indo-Pacific (n = 145) after being truncated to a fragment of 290 base pairs available for most sequences. Doing so, all sequences were compared for the exact same portion of the mtDNA control region gene. All phylogenetic reconstructions based on the consensus fragment show that sequences from captive dolphins in Solomon Islands cluster with haplotypes of *T. aduncus* from the Indo-Pacific region, with > 0.95 posterior probability support values (Figure 8). *T. aduncus* from South Africa and *T. australis* form separate monophyletic clades while *T. truncatus* were paraphyletic.

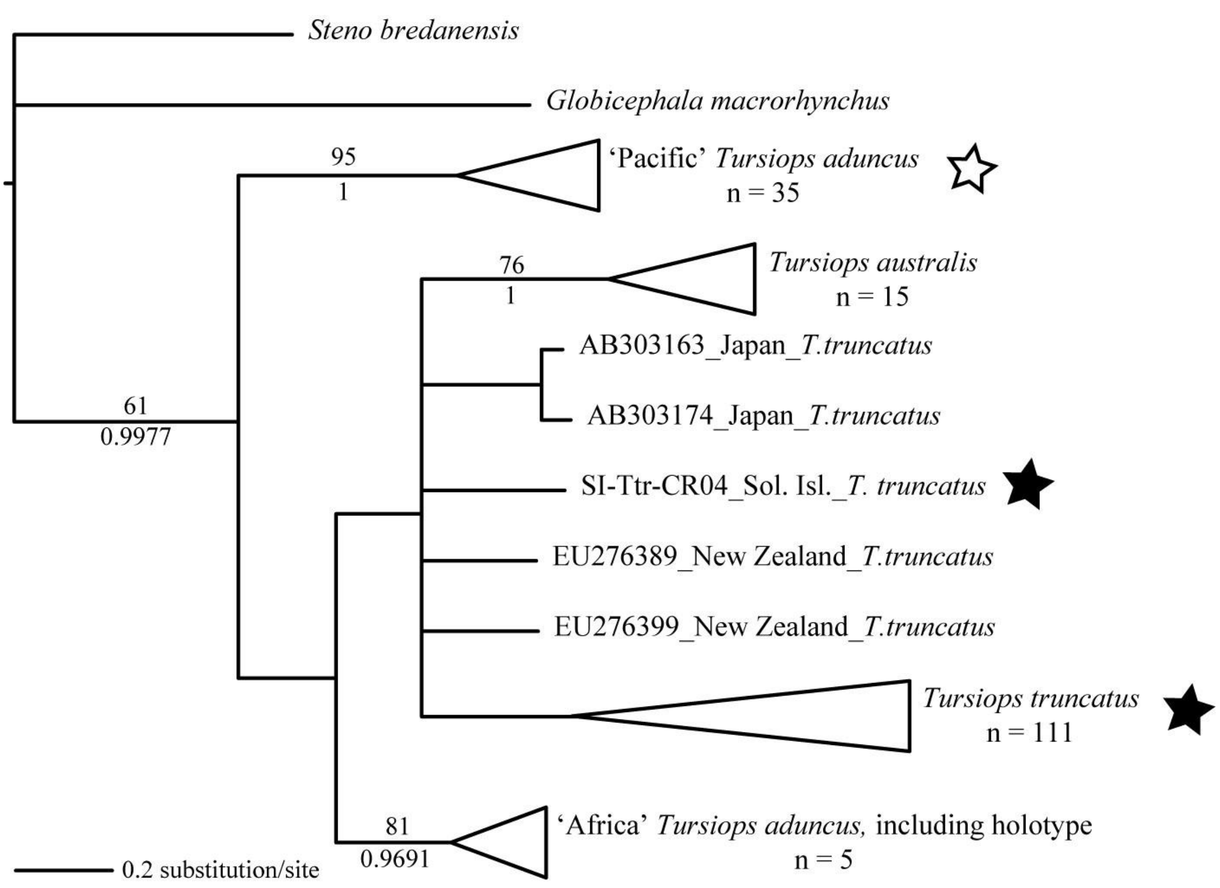

Figure 12: Phylogenetic relationship among mtDNA control region haplotypes of *Tursiops* sp., using Bayesian analyses. High posterior probability support values (> 0.95) are shown below branches. Numbers above branches indicate bootstrap values (of 5,000 simulations) obtained from Neighbour-Joining analyses. Placements of the Melanesian *T. aduncus*-like form and *T. truncatus*-like form haplotypes are indicated by a white or a black star, respectively.

Species identity of drive-hunted dolphins

DNA was extracted from a total of 37 teeth and 18 meat samples collected from drive hunted dolphins. MtDNA sequences were obtained from only nine teeth. By comparison, we got sequences from most of the meat samples (n = 16). Overall, results confirm that drive-hunted dolphins are primarily *S. attenuata* and *S. longirostris*. Of the nine teeth sample sequences, five were of *S. longirostris* and three were of *S. attenuata*. The last tooth sample sequence has been identified as coming from a pygmy killer whale (*Feresa attenuata*).

Unfortunately, no sequence could be obtained from the larger teeth. All of the sequences from meat samples indicate that they were collected from *S. attenuata*.

Genetic diversity and regional population structure

Tursiops aduncus

Despite representing the smallest sample sizes, the Solomon Islands and China/Taiwan *T. aduncus* showed a large number of haplotypes in comparison to East-Australia and New Caledonia (Table 7). This is further illustrated by higher haplotype diversity at the former two sites. The level of nucleotide diversity is particularly high for China/Taiwan but is also high in Solomon Islands, at least in comparison to East Australia and New Caledonia (Table 7).

Table 7: Summary of mtDNA genetic diversity for *T. aduncus* in Solomon Islands and neighbouring populations.

	N	# haplotypes	Haplotype diversity	Nucleotide diversity (%)
Solomon Islands	**16**	**7**	**0.8667 +/- 0.0567**	**0.9023 +/- 0.5744**
New Caledonia	79	2	0.5024 +/- 0.0134	0.3526 +/- 0.2658
East Australia	17	4	0.4950 +/- 0.0603	0.3855 +/- 0.2861
China/Taiwan	43	9	0.9118 +/- 0.0424	1.7492 +/- 1.0013

We only found one shared haplotype between any of the four regions, which was haplotype 1 shared between East Australia and New Caledonia. Overall level of differentiation between the four regions was highly significant (F_{ST} = 0.5489, $p < 0.0001$; Φ_{ST} = 0.5491, $p < 0.0001$; Table 8). Exact tests of population differentiation show highly significant degree of population genetic structure between each region represented ($p < 0.0001$ for each comparison).

Table 8: Genetic differentiation in *Tursiops aduncus* from different regions of the Pacific, based on mitochondrial DNA control region sequence data and pairwise F-statistics. F_{ST} values are below the diagonal; Φ_{ST} values are above the diagonal. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; ns: $p > 0.05$.

	China	New Caledonia	Solomon Islands	Australia
China	-	0.451***	0.220**	0.369***
New Caledonia	0.317***	-	0.702***	0.267***
Solomon Islands	0.101***	0.372***	-	0.579***
Australia	0.288***	0.252***	0.325***	-

Stenella longirostris

Levels of mtDNA diversity in *S. longirostris* were found to be fairly similar in the Solomon Islands, the Society Islands and Samoa. However, diversity was substantially lower in New Caledonia in terms of haplotype and nucleotide diversity (Table 9).

Table 9: Summary of mtDNA control region diversity for *S. longirostris* in Solomon Islands and neighbour populations.

	N	# haplotypes	Haplotype diversity	Nucleotide diversity (%)
Solomon Islands	**40**	**18**	**0.868 +/- 0.047**	**1.740 +/- 0.929**
New Caledonia	23	4	0.383 +/- 0.120	0.323 +/- 0.236
Society Islands	128	26	0.907 +/- 0.016	1.734 +/- 0.910
Samoa	30	21	0.975 +/- 0.014	1.908 +/- 1.020

Contrary to *T. aduncus*, many shared haplotypes were found in *S. longirostris* from different regions (Table 10). The proportion of haplotype shared with other regions was fairly similar for the Solomon Islands (61%), New Caledonia (50%), the Society Islands (54%) and Hawaii (55%). Interestingly, for Samoa, 86% of the unique haplotypes were found in other regions.

Table 10: Number of shared mtDNA haplotypes between *S. longirostris* from different regions in the Pacific. The number of haplotypes unique to each region is shown in the diagonal. h indicates the total number of haplotype for each region.

	SI	NC	Society	Samoa	Hawaii
Solomon Islands, h = 18	**7**				
New Caledonia, h = 4	1	**2**			
Society Islands, h = 26	8	1	**12**		
Samoa, h = 21	6	2	10	**3**	
Hawaii, h = 19	7	1	10	14	**13**

Overall level of differentiation between the Solomon Islands, New Caledonia, the Society Islands and Samoa was highly significant (F_{ST} = 0.153, p < 0.0001; Φ_{ST} = 0.109, p < 0.0001). Exact tests of population differentiation show highly significant degree of population genetic structure between each region represented (p < 0.0001 for each comparison). However, pairwise comparisons show no significant differentiation between Samoa and the Society Islands when using Φ_{ST}.

Stenella attenuata

Stenella attenuata mtDNA diversity was found to be higher in coastal ETP and offshore ETP than in Hawaii and China/Taiwan (Table 11). In comparison to these regions, the nucleotide diversity in the Solomon Islands appears to be intermediate although closer to the higher values of the ETP. Haplotype diversity in the Solomon Islands was the highest of this dataset.

Table 11: Summary of mtDNA genetic diversity for *S. attenuata* in Solomon Islands and neighbour populations.

	N	# haplotypes	Haplotype diversity	Nucleotide diversity (%)
Solomon Islands	**31**	**21**	**0.968 +/- 0.017**	**1.12 +/- 0.09**
Hawaii	113	10	0.450 +/- 0.255*	0.50 +/- 0.30*
Coastal ETP	135	66	-	1.35 +/- 0.30*
Offshore ETP	90	60	0.754 +/- 0.139*	1.39 +/- 0.30*
China/Taiwan	30	10	0.793 +/- 0.067*	0.80 +/- 0.50*

*value taken from Courbis (2011) and Escorza-Trevino et al. (2005).

As for *S. longirostris*, many shared haplotypes were found between regions (Table 12). Hawaii has the largest proportion of haplotypes shared with other regions (50%) while the smallest proportions were in coastal (27%) and offshore ETP (30%). The Solomon Islands *S. attenuata* was found to have an intermediate proportion of unique haplotypes (43%).

Table 12: Number of shared mtDNA haplotypes between *S. attenuata* from different regions in the Pacific. The number of haplotypes unique to each region is shown in the diagonal.

	SI	Hawaii	Coastal ETP	Offshore ETP
Solomon Islands, h = 21	**12**			
Hawaii, h = 10	2	**5**		
Coastal ETP, h = 66	6	2	**48**	
Offshore ETP, h = 60	5	2	14	**42**

T. aduncus *individual movements and site fidelity*

Over 13,000 photographs were collected for the purpose of photo-identification. Among these, 7,000 photographs were of *T. aduncus* and only this species is considered for the analyses below. *T. aduncus* photographs were obtained from 13 groups in 2009, 15 groups in 2010 and 16 groups in 2011. A total of 467 individuals were identified but 34 were excluded from subsequent analyses because the photographs available for these dolphins were not of sufficient quality to be confidently matched with others. Of the remaining 433 identifications, we found that 293 had a distinctiveness rate of (2) to (3) and therefore, they present dorsal fin marks distinctive enough to be useable for photographic matching and capture-recapture analyses.

Table 13: Number of unique individuals identified per study site and per year, using photo-identification.

SITE	2009	2010	2011	**All**
Guadalcanal	5	15	29	**36**
Florida Islands	16	35	14	**49**
Santa Isabel	46	32	39	**91**
Malaita	16	3	43	**50**
Total	**83**	**85**	**125**	**225**

The matching of the 293 distinctive dorsal fins revealed that 225 unique individuals are represented in the dataset, and therefore, we had 68 re-sighting events. The number of unique individuals identified at each of the four study sites range from 36 at Guadalcanal to 91 at Santa Isabel (Table 13). Twenty-two re-sightings were found within years (Table 14); seven at Guadalcanal, two at Florida Islands, four at Santa Isabel and nine at Malaita. Two of the Guadalcanal re-sightings are in fact between the North Coast of Guadalcanal and the Island of Savo, just 7nm to the north. There were no within-year resightings between any of the different study sites. Similarly, a total of 46 resighting events were found between years (Table 14). All of them are within the same study sites except one individual that was first observed in November 2009 around Florida Islands and was re-sighted in July 2011 on the North Coast of Guadalcanal.

Table 14: Summary of overall re-sighting history between November 2009, November 2010 and July 2011 (within year/between years).

	Guadalcanal	Florida Islands	Santa Isabel	Malaita	All
Guadalcanal	**7/6**	-	-	-	-
Florida Islands	0/1	**3/15**	-	-	-
Santa Isabel	0/0	0/0	**3/22**	-	-
Malaita	0/0	0/0	0/0	**8/3**	**-**
All	-	-	-	-	**22/46**

Likelihood analysis using SOCPROG shows that estimates of movement rates between study sites are all small (*pt* < 0.05) and, consequently, that probabilities for individuals to be re-sighted at the same site each year are high for all our study locations (*pt* > 0.7; Table 15). This is with the exception of a movement rate estimated at 0.14 from Guadalcanal to Florida Islands, a value that remains low in comparison to the probabilities of being re-sighted at the same site.

Table 15: Probability of resighting at the same study site (diagonal) and probability of movement from one area to another, as estimated using likelihood method in program SOCPROG. Standard errors are shown in brackets.

		To Area:				
		Florida	Guadalcanal	Isabel	Malaita	*External area*
From Area:	Florida	**0.7598**	0.0226 (0.03552)	0.0427 (0.02600)	0.0544 (0.03240)	0.1205 (0.03132)
	Guadalcanal	0.1410 (0.02750)	**0.7071**	0.0139 (0.02860)	0.0408 (0.03229)	0.0971 (0.03568)
	Isabel	0.0001 (0.00844)	0.0255 (0.01683)	**0.9070**	0.0378 (0.03338)	0.0295 (0.03424)
	Malaita	0.0001 (0.01480)	0.0315 (0.02349)	0.0040 (0.02335)	**0.9297**	0.0348 (0.02987)
	External area	0.0937 (0.03671)	0.0273 (0.02965)	0.0866 (0.03683)	0.1020 (0.03278)	0.6904

Photo-identification of captured and released T. aduncus

Visits to dolphin holding facilities allowed identification of 14 distinctive dolphins at Honiara in November 2009 and 14 distinctive dolphins at Gavutu in November 2009. In November 2010, we want back to the Honiara facility and identified four distinctive dolphins, including two individuals that were already identified in the same facility in 2009. Overall, 30 unique dolphins with distinctive marks on their dorsal fin were identified in holding facilities. Comparison of the captive dolphins' catalogue to the catalogue of dolphins from the wild has revealed only one match of a dolphin initially photographed in the Honiara facility in November 2009 and re-sighted on the North Coast of Guadalcanal in July 2011. None from Gavutu were resighted.

T. aduncus *population abundance estimates*

Given the evidence of high site fidelity at the four study sites, population abundance of *T. aduncus* was estimated separately for each site. As expected, abundance estimates were slightly different depending on the model used (Table 16a). Mh consistently provided the higher estimates of all models, while Mt resulted on the lowest estimates. Despite these small differences, the estimates were largely consistent across the models for each study site, with the exception of Malaita. Indeed, estimates for Malaita were less consistent, showing substantial differences between models, and less precise, as reflected in the lager CVs and wider CIs.

To assess total population sizes, we adjusted all estimates for the portion of the populations not distinctive enough to be used for photo-identification. These represent 32% of individuals overall based on good quality photographs. Slight differences in this proportion were observed between each of the four study sites with the percentage of unmarked individuals ranging from 29% at Santa Isabel to 35% at Florida Islands and Malaita. At Guadalcanal, the proportion of unmarked individuals was assessed at 32% of all dolphins.

After adjustment, we found that for Guadalcanal, Florida Islands and Santa Isabel, the total population sizes were in the low hundreds whatever the model used (Table 16b). Note, however, that Santa Isabel appears to shelter a larger population than Guadalcanal and Florida Islands. In regards to Malaita, the Mt model shows the smallest, but still large, CV and suggests a population of similar size than in Santa Isabel while the models Mo, Mh and Mth suggest that the population could be larger. However, as stated above, large CV and wide CI, indicate that best estimates for that island should be interpreted cautiously.

Finally, we calculated global abundance over the study area by summing the best estimates for each of the four study sites. We found that the total population of *T. aduncus* in the study area probably numbers 700-1300 individuals.

Table 16: Summary of abundance estimates at the different study sites using four closed-population models, including coefficient of variation (CV) and confidence interval (CI). Estimates are shown before (a) and after (b) adjustments for the proportion of un-marked individuals.

(a)

	Mo				Mt (Chao)				Mh (Chao)				Mth (Chao)			
	N	CV	95% CI low	95% CI high	**N**	CV	95% CI low	95% CI high	**N**	CV	95% CI low	95% CI high	**N**	CV	95% CI low	95% CI high
Guadalcanal	90	0.32	57	180	67	0.27	47	124	111	0.38	63	244	86	0.42	51	119
Florida Islands	85	0.18	66	129	78	0.17	62	115	103	0.24	72	176	89	0.35	60	201
Santa Isabel	178	0.15	139	249	176	0.17	135	255	231	0.21	164	361	203	0.31	132	401
Malaita	298	0.52	130	820	184	0.43	96	445	418	0.57	166	1226	370	0.60	145	1137

(b)

	Mo				Mt (Chao)				Mh (Chao)				Mth (Chao)			
	N	CV	95% CI low	95% CI high	**N**	CV	95% CI low	95% CI high	**N**	CV	95% CI low	95% CI high	**N**	CV	95% CI low	95% CI high
Guadalcanal	**132**	0.33	84	264	**98**	0.28	69	182	**162**	0.39	93	359	**126**	0.43	75	175
Florida Islands	**131**	0.20	102	198	**120**	0.18	95	177	**158**	0.25	111	271	**137**	0.35	92	309
Santa Isabel	**252**	0.16	197	352	**249**	0.18	191	361	**327**	0.22	232	510	**287**	0.31	187	567
Malaita	**459**	0.53	200	1263	**283**	0.44	148	685	**644**	0.58	256	1888	**570**	0.60	223	1751
Global estimate	973		582	2078	750	-	503	1405	1291	-	691	3027	1120	-	577	2802

***Assessment of Potential Biological Removals for* T. aduncus**

Values of PBR were calculated for each of the four study sites using the abundance estimates and CVs obtained through the various models (Table 17). PBR values are very consistent for each of the study sites regardless of the model used to estimate population abundance. Only PBR values for Malaita were substantially larger when using the most optimistic abundance estimates. Using the conservative recovery value recommended for populations subjected to past exploitation or very small populations (Fr = 0.1), all levels of sustainable removals are less than 1 individual captured per year, and as low as 1 individual removed every five years for Guadalcanal and Florida Islands. The PBR value was less than one dolphin removed every two years for Santa Isabel. Finally, the total population size for the area under investigation resulted in PBR values of less than 2 individuals per year.

Table 17: Summary of PBR values obtained for *T. aduncus* at the different study sites and overall, depending on the model of population abundance and on two values of recovery factor (Fr= 0.1 or 0.5).

	Mo		Mt		Mh		Mth	
	PBR (Fr=0.1)	PBR (Fr=0.5)	**PBR (Fr=0.1)**	PBR (Fr=0.5)	**PBR (Fr=0.1)**	PBR (Fr=0.5)	**PBR (Fr=0.1)**	PBR (Fr=0.5)
Guadalcanal	**0.2**	1.0	**0.2**	0.8	**0.2**	1.2	**0.2**	0.9
Florida Islands	**0.2**	1.1	**0.2**	1.0	**0.3**	1.3	**0.2**	1.0
Santa Isabel	**0.4**	2.2	**0.4**	2.1	**0.5**	2.7	**0.4**	2.2
Malaita	**0.6**	3.0	**0.4**	2.0	**0.8**	4.1	**0.7**	3.6
SUM of ALL	**1.5**	7.3	**1.2**	5.9	**1.9**	9.3	**1.5**	7.7

DISCUSSION

Cetacean diversity in the Solomon Islands

Information on the status of cetacean populations in Solomon Islands remains relatively scarce, other than previous reports by Shimada and Pastene (1995) and Kahn (2006), which provided the first information on cetacean diversity, distribution and density. The results we report here represents the most intensive research effort to date dedicated to gaining information on the marine mammals of this country. All of the nine marine mammal species encountered during our surveys were previously identified in Solomon Islands. Therefore, these are probably common species of this area. It is likely, however, that the description of cetacean diversity in Solomon Islands remains incomplete. Further research effort would be needed to identify additional species, in particular in offshore habitats. The primary focus of this work was to clarify the status of Indo-Pacific bottlenose dolphin population(s) and therefore, the largest part of our effort (73% of distance covered) was made in coastal area where this species is generally distributed. This explains in part why the number of species observed during our study remains limited.

Distribution and habitat use of **T. aduncus** *and* **S. longirostris**

As expected, our results confirmed that in Solomon Islands, *T. aduncus* are preferentially distributed near coast (< 1nm) and in shallow areas, as usually described in populations elsewhere (Wang & Yang 2009). Therefore, this species is particularly vulnerable to anthropogenic impacts such as habitat degradation, depletion of food resources, interactions with fisheries, pollutions and, obviously, live-capture.

In places where the species has been studied extensively, the Indo-Pacific bottlenose dolphins appear to exhibit strong year-round residency (e.g., around Mikura Island, Kogi et al. 2004). However, some seasonal movements may occur in some places, as suggested on the east coast of South Africa (Peddemors 1999). Here, comparison of November surveys to the survey in July does not suggest a seasonal variation in the occurrence of *T. aduncus* in the Solomon Islands. On the other hand, the rates of encounters (groups and individuals) suggest some differences of density between study sites with higher levels of encounter at Santa Isabel. The reasons for this pattern are unclear but they could be due to variation in the amount of suitable habitat between the study sites as well as to the recent impact of live-capture on the populations of Guadalcanal and Malaita, which show the lowest levels of individual and group encounter rates.

Similarly to the Indo-Pacific bottlenose dolphins, the spinner dolphin was commonly encountered in coastal waters. However, the rate of encounter with this species at the different study sites was very different to that of *T. aduncus*. The lower rate was found in Santa Isabel but this result is not entirely surprising. Indeed, a large plateau of shallow waters is found in front of the stretch coast surveyed at this island which might represents an unsuitable habitat for spinner dolphins. Spinner dolphins are frequent users of coastal habitats in tropical and sub-tropical areas around the world. However, unlike *T. aduncus*, they usually do not feed on coastal species since they travel offshore at night in deeper waters to chase mesopelagic fishes (Benoit-Bird & Au 2003). Such feeding habitat is probably too far from potential resting places on the coast of south Santa Isabel. The rate of encounter was also relatively low at Malaita although this island seems to offer suitable resting places for spinner dolphins with easy access to deeper waters for feeding at night. It is too early to draw any conclusions but it is possible that decade of traditional drive-hunts in Malaita as impacted the local populations of spinner dolphins.

Further work is clearly needed to clarify the status of spinner dolphins in Solomon Islands since separate populations and potentially sub-species could occur in the area, as suggested by the distinction made by traditional drive-hunt communities in Malaita. No clear evidence of these different forms was found during our surveys but ongoing work is looking into this question with the use of molecular tools.

Identification of captured and hunted species

Molecular identification conducted on skin samples from captive dolphins confirmed that the species targeted for live-capture is *T. aduncus*. This result does not come as a surprise since it has always been assumed that it was the species of choice for export traders in Solomon Islands. However, several studies have highlighted the complexity of *Tursiops* taxonomic status in regions surrounding Solomon Islands, including the recent description of a previously unrecognized species in South-East Australia (Charlton-Robb et al. 2011). It was therefore necessary to conduct further genetic analyses bringing new lines of evidence to confirm this identification. This work will benefit future investigation on the phylogenetic placement and taxonomic status within the genus *Tursiops* worldwide.

Molecular identification was also conducted on samples collected from drive-hunted dolphins. These analyses confirmed that the primary species targeted for these hunts are the pantropical spotted dolphin and the spinner dolphin, as shown by DNA identification from teeth and meat samples. The sequence obtained from the teeth of "Robo Manole" collected at Fanalei in March 2013 came out as a pygmy killer whale, not a common bottlenose dolphin as suggested to us by the hunters. This is surprising, as the pygmy killer whale has not been reported to be caught in previous reports on traditional drive-hunts. In fact, this is the first report of pygmy killer whale in the Solomon Islands. Unfortunately, we managed to amplify DNA from only a small number of teeth. Failure to obtain more sequences for species identification might be the result from a combination of factors: (1) To dislodge and clean the teeth from the jaws of freshly killed dolphins, the jaws are boiled for long periods of time which is likely to deteriorate the DNA contained in the teeth; (2) before being collected by us and stored in good conditions, the teeth were kept with no particular care for periods of months to years in the very hot and humid climate of the Solomon Islands, which has resulted in further deterioration of the DNA; (3) despite following protocols to extract and amplify ancient DNA, it was not possible to conduct the analyses in a fully equiped ancient DNA lab *per se*, and therefore, perhaps resulting in lower laboratory success. In the future, we will attempt to re-run at least some of the teeth samples in an ancient DNA lab to assess the potential to obtain more results from these data.

History and recent account on traditional drive-hunts

Across the total period for which records are available (1976 to 2013), a minimum of 15,444 dolphins were killed by the villagers (mean annual catch was 813 dolphins, SD = 464). This is clearly an underestimate of the number of dolphins hunted in the Solomon Islands, as we lack data for 16 hunting years across this period (excluding the 3 years of EII MoU) and only consider the community of Fanalei. If one considers that a usual annual catch would be between 600 and 1,000 dolphins (i.e. +/- 200 around the average catch), it appears that success rate is fairly stable across years. The community got lower success rate (< 600 dolphins) for three years (1979, 1987 and 2001) while they got high success rate (> 1000 dolphins) for four years (1978, 1986, 2004 and 2013). There is no clear tendency in success rate across years, which could indicate a minimal impact of the hunt on dolphin populations. However, such conclusion would be premature as data are lacking for numerous years. Furthermore the absence of information on the proportion of species caught for most years could obscure tendencies at the species levels. We note that the two successful years for which data were available during the next season (i.e. 1978 and 1986) were followed by a low catch rate the following year (1979 and 1987, respectively). However, this tendency could be explained by a lesser need for dolphin teeth in the community following a successful year, rather than local depletion of the dolphin populations.

Although the financial dispute over the MoU with EII has probably played an important role in the Fanalei community decision to resume hunting, the village representative told us that they did so simply because the MoU came to an end and there was no further agreement to maintain the ban. He also explained that stopping hunting had brought much tension in the village and that resuming it brought back peace among community members. Therefore, they intend to continue the hunt from now on.

It is important to note that dolphin teeth are used by many villages in Malaita and not only by the hunting communities. Teeth are also sent to other islands such as Guadalcanal and Florida Islands. Therefore, there is a high demand for them and stopping the hunt had consequences that went over the village of Fanalei. Since dolphin tooth prices are apparently set at Fanalei (as the main drive-hunting community), it is likely that the economical value of hunting has played an important role in the decision not to pursue the collaboration with EII.

From our discussions with villagers and previous reports, it appears that the price for dolphin tooth has increased greatly in recent decades. In 1964, a tooth valued at 5 Australian cents (Dawbin 1966), which is about 0.3 Solomon Islands Dollars or SBD with current exchange rate. In 1994, it was valued at 0.5 SBD (Takekawa 1996b). By 2004, Kahn (2006) reported that the price had increased to 1SBD. It was still the same price for “unubulu” and “raa” teeth during our first visit to Fanalei in 2009. However, as for our second visit in 2013, the price for “unubulu” or “raa” teeth has increased to 5SBD each (about US$0.7 or €0.55 or 0.4£). Price for teeth from any “robo” species (larger teeth) would be higher.

From discussion about the hunt of 134 dolphins by Ata’a villagers in December 2012, we were told that the species caught was the pantropical spotted dolphin and not bottlenose dolphins, as reported in the local newspaper. It was apparently the only hunt from this community this season. It was also the first hunt there in a very long time and therefore, it is unclear why they resumed the practice. According to the Fanalei community members, there were two possible explanations: 1) the demand for dolphin teeth has increased since the hunting was halted providing a good financial opportunity for any new catch; or, 2) Ata’a was not included in the EII agreement and resuming hunting was a way to attract attention for future consideration.

The people of Fanalei do not understand why they attract so much attention regarding the recent dolphin hunts, which they have been practicing for a long time. However, they are aware of conservation issues and were willing to discuss that. They first expressed concerned about dolphin by-catch by purse seiners in the Solomon Islands that they see as a threat for their resource. It would therefore be useful to inform them more precisely on this issue, which we were not able to do. Elders and hunters were not very receptive to the idea of using a quota as they are concerned that they would be too restrictive. On the other hand, they see the value of collecting scientific data that would help in gaining better knowledge on the status of local dolphin populations. The hunters understand that this is a necessary step for a good management of the populations in order to insure that they can continue the tradition of dolphin drive-hunting over the next generations. As such, they are willing to collaborate with any future scientific program that would work to this goal. In the future, the representative will try to improve communication with the Government of Solomon Islands Ministry of Fisheries and Minitry of Environment in order to provide records of catches through a monitoring program. They would also consider having observers in the village during the hunting season to could collect further data from the hunts.

Regional population structure

T. aduncus - Analyses of regional population structure revealed that for mtDNA, Solomon Islands *T. aduncus* populations are highly differentiated from neighbouring populations of New Caledonia, China/Taiwan and East Australia. None of the haplotypes described in Solomon Islands were found elsewhere, suggesting no or very low level of female-mediated gene flow between these regions. The limited connectivity suggested by mtDNA at a regional level highlights the risk of impacting local populations, which might have a low resilience due to absence of re-colonisation through neighbour areas. However, additional analyses would be needed, including nuclear markers (to examine male-mediated gene flow) and samples from Papua New Guinea. The relatively high level of mtDNA diversity of Solomon Islands *T. aduncus* in comparison to New Caledonia and East Australia is positive indicator given the problems associated with low genetic diversity (Frankham et al. 2002). However, this high diversity should not be interpreted as a function of population abundance. From an evolutionary history point of view, lower levels of diversity in New Caledonia and East Australia than in Solomon Islands are not unexpected since the former two are located at the distribution limits of the species.

S. longirostris – The pattern of genetic diversity of *S. longirostris* in the Solomon Islands was fairly similar to that of *T. aduncus*. First, the level of mtDNA diversity was found to be high and similar the level of diversity in *S. longirostris* in the Society Islands of French Polynesia.

Such level of diversity does not necessarily imply that the Solomon Islands shelter a very large population of spinner dolphins. In the Society Islands, it was shown that despite a high level of mtDNA diversity, the species tend to form small and resident populations that are genetically distinct from one island to another (Oremus et al. 2007).

Second, a comparison with populations from surrounding regions showed a clear pattern of genetic differentiation indicating low levels of gene flow, or reproductive exchanges, between these regions. Spinner dolphins might thus form one or several populations specific to the Solomon Islands. While this result suggests that the impact of traditional drive-hunt on this particular species might be restricted to the Solomon Islands (and maybe to Malaita), it raises further concerns in terms of conservation. Indeed, if spinner dolphins in the Solomon Islands form small resident populations as observed in the Society Islands of French Polynesia (Oremus et al. 2007) and in Hawaii (Andrews et al. 2010), there is a higher risk of population depletion from anthropogenic pressure than on a large panmictic populations. However, further studies are needed to clarify the status of spinner dolphins in the Solomon Islands. In particular, it would be interesting to test the hypothesis of small-scale population structure within the archipelago. Also, the question of the presence of multiple forms of spinner dolphins, as suggested by traditional drive-hunters, remains open. Based on discussions with members of the Fanalei community, it seems that hunters typically look for groups of dolphins in the open ocean, relatively far from shore in deep waters. Our surveys failed to identify an offshore population of spinner dolphins although a few groups (n = 4) were observed a few kilometres offshore Honiara in water about 500 m deep. All other groups (n = 51) were observed with less than 100 m of water. Surprisingly these four groups were all observed within just a few kilometres from each other (< 4 km) and in different years (1 in 2009, 2 in 2010 and 1 in 2011), suggesting that this area is a hot spot for non-coastal observation of spinner dolphins. Unfortunately too few sequences from spinner dolphin teeth samples were obtained to look at differentiation between hunted dolphins and the living dolphins that were biopsied close to shore during our surveys.

S. attenuata – Finally, high mtDNA diversity was found in pantropical spotted dolphins from the Solomon Islands, despite decades of removal pressure from the Solomon Islands drive-hunting which could have resulted on a depleted genetic diversity. The level of genetic diversity was substantially higher than that observed in the Hawaiian Archipelago. However, several independent studies have shown that many odontocetes populations of the Hawaiian Archipelago are genetically distinct and showing comparatively low level of genetic diversity probably as a result of an extreme geographic isolation (Andrews et al. 2010, Martien et al. 2011). Here, our preliminary analyses of genetic diversity in three species in the Solomon Islands suggest that populations from the Solomon Islands archipelago have experienced more gene flow over recent evolutionary history, which could explain relatively higher levels of diversity. However, it is still possible that contemporary populations of *S. attenuata* in the Solomon Islands are genetically distinct from populations in neighbouring regions. It was not possible to conduct regional population structure analyses with this species since we lack reference data sets with haplotype frequencies to compare it with the Solomon Islands. However, many shared haplotypes were found between different regions and in particular between the Solomon Islands and populations of the ETP. Future studies should look at investigating the boundaries of the Solomon Islands *S. attenuata* population(s) so that its conservation status can be established. At this stage, there is no information on such limit or on the population abundance. It is therefore not possible to assess the impact of traditional drive-hunts on *S. attenuata* populations occurring in Solomon Islands and beyond.

***Site fidelity of* T. aduncus**

Analyses based on photographic recapture over the whole studied area show that Indo-Pacific bottlenose dolphins in Solomon Islands have high level of site fidelity in comparison to interchange between study sites. Indeed, 98% of the recapture between years were made within one of the four study sites, suggesting the each of them shelter a distinct population or community of *T. aduncus*. The occurrence of one movement detected from Florida Islands to Guadalcanal indicates that low levels of exchange are possible between the study sites. However, it is likely that the populations around each of these islands are demographically independent from one another and that they should be considered as such when management and conservation decisions are to be taken. Indeed, if human-caused mortality occurs in only one area while the quota was based on total abundance over several populations, there is a risk of depletion and potentially extirpation within the area being impacted (Barlow et al. 1995).

Population abundance of **T. aduncus**

All population abundance estimates suggest that the four study sites currently support populations in the low hundreds at most (about 100 to 300 individuals). The only exception was Malaita, for which some of the best estimates were above 500 individuals (Table 8b). However, abundance estimates for Malaita should be interpreted cautiously since they show large CV and wide CI (in particular with Mh and Mth), indicating low confidence in the results. The best estimate for Malaita using Mt is less than half the estimate using Mh, suggesting a population size of less than 300. It is therefore difficult to decide on a reliable estimate for that island. The lack of precision for population estimates at Malaita is in part explained by a very limited number of identifications in November 2010, and thus a low recapture rate. It is also possible that our estimates are biased by the live capture of more than 25 dolphins between surveys 2 and 3, in July 2011. Considering that this number is relatively large in comparison to the assumed population size (in the low hundreds), such removal is likely to have biased upwards our estimates since they are based on closed population models where mortality is supposed to be negligible.

For Guadalcanal, Florida Islands and Santa Isabel, all four models provide consistent estimates with reasonably small CV, suggesting that these are relatively precise. When looking at the overall studied area, total population size using best estimates is between 700 and 1,300 individuals. A similar pattern of small resident populations was described for *T. aduncus* in other areas such as Amakusa-Shimoshima and Mikura Islands in Japan (Shirakihara et al. 2002, Kogi et al. 2004), Moreton Bay in Australia (Chilvers & Corkeron 2003) or New Caledonia (Oremus et al. 2009). Therefore, our results are consistent with previous knowledge on this species.

Sustainability of live-capture

One of the primary goals of this project was to assess the sustainability of the currently authorized quota of export, which was set at 50 dolphins per year. Although this quota does not specify the species, it was shown that only *T. aduncus* are effectively targeted for captures and captivity. Therefore, even though the assessment made here only concerns one species it can be compared to the official quota. The quota applies for all of Solomon Islands but in this study, we were only able to investigate part of the country. Covering the entire territory would require a huge survey effort that very few, if any, countries has been able to undertake so far to assess their marine mammal populations. Nonetheless, the effort here was substantial and the entire area where captures occurred to date (north coast of Guadalcanal and west coast of Malaita) was covered with the addition of two other sites not directly impacted by this practice (Florida Islands and south of Santa Isabel).

The PBR method was chosen to assess the sustainability of *T. aduncus* removals from wild populations in Solomon Islands because we consider it the most robust management procedure, given the available data. The PBR was developed to account for the uncertainty inevitably associated with estimates of abundance over a limited time frame (Wade 1998). Indeed, management methods relying on detection of population trends have proven inadequate for marine mammals. The variance typically associated with population estimates of dolphins means that the statistical power to detect declines is low, and in many cases even a decline of 50% would not be detectable statistically (Taylor et al. 2006). Therefore, the time required to detect population declines (e.g. by aerial or boat surveys) is so long that management actions based on such detection would not be initiated until populations have been seriously depleted.

A first rough assessment of sustainability can be made by comparing the export quota of 50 dolphins per year to PBR values obtained for the whole studied area. It shows that even the most optimistic estimate of sustainable removal based on high recovery factor (Fr = 0.5) and the largest abundance estimate (i.e. maximum of 9.3 dolphins removed per year) is still far below the current authorized level of removal. Therefore, it is likely that maintaining the current export quota, which does not include individuals that die in captivity before export, could lead to a decline and possible extirpation of the local populations of *T. aduncus* in the Solomon Islands. It is known, however, that the total number of dolphins exported (N = 108) since the beginning of the trade in 2003 is well below the authorized annual quota when considering the period of nine years over which these exports occurred. Over this period, an average of 12 dolphins per year was exported, but this is still above the most optimistic PBR for the whole area. More importantly, most exported dolphins came from Guadalcanal North Coast (n = 83), where the most optimistic PBR is 1.2 dolphins per year.

When putting past removals into perspective with the current abundance estimates for that area (Table 8b), it seems likely that a large portion of the resident population was removed because of live-captures. It is also important to note that 83 exported dolphins represent only a minimum estimate of the dolphins removed from that population. Four dolphins remain in captivity in Honiara, while there is little doubt that multiple deaths (> 20) occurred in the process of capturing the animals as well as during captivity. Furthermore, some of the captured dolphins were subsequently released back into the wild after an unknown period of time. The fate of these individuals is unknown, with the exception of one dolphin that was resighted in the wild after being initially photo-identified at the Honiara dolphin facility. Six dolphins captured in Guadalcanal were reportedly released in the waters of Florida Islands (i.e. outside their original habitat) after they were held in captivity at the Gavutu facility. None of the ones that were photographically identified at Gavutu were resighted in the wild. All in all, the real impact on the population might be much greater than we can assess. Assessment of capture impact in Malaita is more difficult because of uncertainties regarding the abundance estimate and thus, sustainable level of removal. However, we know that more than 25 dolphins were captured so far. Such a number suggests that this population has declined as a result.

Future management of live-capture

Our study indicates that several populations, or stocks, of *T. aduncus* should be considered for management purpose in the studied area. Therefore, it is inappropriate to apply an overall quota that could lead to the depletion of one conservation unit where most of the capture would be concentrated. For this reason we estimated PBR for each of the four sites where we identified distinct communities of dolphins. Based on photographic evidence suggesting demographic segregation between study sites, we chose to use four closed population models to estimate abundance. Slight differences were observed between models, but when applied to PBR estimates, we could see that recommended levels of removals were consistent across the models used. The only noticeable difference that we found was for Malaita for which our abundance estimates were not precise and highly variable depending on the model applied. However, because this population has already been impacted and because the larger abundance estimates are characterised by the largest CV, it is recommended that the most conservative abundance estimates are retained for management measures (i.e. Mt model).

The parameters chosen to calculate PBR can vary accordingly with the studied species and characteristics of the population. Here, we used a conventional Rmax = 0.04 as typically reported for cetacean species, but it should be noted that slower maximum growth rates (< 0.02) were estimated for dolphin populations elsewhere, based on specific assessment for these populations (Slooten & Dawson 2008). Therefore, a maximum growth rate of 4% is potentially optimistic and could inflate PBR estimates. We choose to report PBR estimates calculated using both high and low recovery factors (Fr = 0.5 and 0.1. respectively) to provide a clear assessment of the sustainability of the current authorized quota and effective number of *T. aduncus* removals under a broad range of assumption. However, it has been recognized that PBR is not sufficiently precautionary for small populations that are subject to demographic and environment stochastisity. For this reason, a recovery factor of 0.1 is recommended for management decisions regarding endangered species and populations (Wade 1998). Here, we can see that the three populations with reliable abundance estimates (Guadalcanal, Florida Islands and Santa Isabel) fulfill the IUCN Red List criteria D for endangered population due very small number of mature individuals (less than 250). A recovery factor Fr = 0.1 should therefore be considered for management decisions on the live-capture of *T. aduncus* in Solomon Islands.

Overall, the assessment of *T. aduncus* population status and sustainability of removals indicate that, to prevent decline and ensure the persistence of local dolphin populations in the future, no more than one dolphin every five years should be captured from the areas of Guadalcanal and Florida Islands, while no more than one dolphin every two and half years should be captured from the areas of Santa Isabel and Malaita.

Future research effort on the live-capture issue

As explained above, it was not possible during this study to cover the entire coastline of Guadalcanal, Malaita and Santa Isabel. Therefore, our description of *T. aduncus* populations around these islands is still incomplete in this respect. We provide population abundance estimates and sustainable levels of removal within the areas where past captures have occurred (north-west of Guadalcanal and west of Malaita) but we cannot discount the possible existence of other local populations of *T. aduncus* outside these ranges. In regards to Guadalcanal, we note that R.H. Defran reported the movements of a substantial number of dolphins between Marau (eastern point of Guadalcanal) and Honiara, suggesting a home range extending across most of the North Coast of Guadalcanal (Reeves & Brownell Jr. 2009). In the future, it would be important to extend the range of our surveys in order to cover the entire coastline of these islands. This could provide management information at an island scale. Such surveys should be conducted in priority around Guadalcanal and Malaita were live-capture has been taking place.

We note that a substantial number of *T. aduncus* photo-identification data were collected between 2005 and 2009, primarily around Guadalcanal but also in the Florida Islands and Malaita, during a research project conducted by R.H. Defran. Considering that our study area largely overlaps with this of Defran's project, it would be particularly interesting to compare catalogues between the two studies. A large number of dolphins were captured around Guadalcanal during the 2005-2009 period and, therefore, a comparison could help assess with more accuracy the impact of live-capture on the local population.

Finally, the difficulty in collecting biopsy samples of wild ranging *T. aduncus* (only two samples collected over the whole study) prevented us from conducting an analysis of population genetic structure at a local scale. A number of samples could be obtained from captive dolphins but they all originated from Guadalcanal and, therefore, we could not assess population differentiation between islands. To overcome this problem, we attempted to collect samples of the dolphins recently captured around Malaita. These which would have provided an opportunity to compare *T. aduncus* populations from Guadalcanal and Malaita. Unfortunately, this was not possible and the dolphins were since exported overseas. However, it remains possible to conduct this important research, assuming that the new owners of the dolphins agree to provide tissue samples.

RECOMMENDATIONS ON LIVE CAPTURE OF *T. ADUNCUS*

- Any quota to be set should be specific to the unit to conserve, i.e., the species and the population. Because the results of the study show that there are distinct populations of *T. aduncus* on the study site and because live-capture trade only targets *T. aduncus*, the quota should not be applied for the whole of Solomon Islands but for each of the distinct populations as identified by scientific studies.
- Given evidence of a likely past impact on the local populations of *T. aduncus* targeted for live-capture (namely Guadalcanal and Malaita), no future capture should be allowed in areas where data are unavailable on population status.
- Any future quotas should not exceed the PBR. Given past exploitation, we recommend use of the conservative recovery factor (Fr = 0.1).
- *T. aduncus* should not be taken during traditional drive-hunt, since it was shown that this species typically forms small coastal populations that could not sustain the large number of catches usually taken by drive-hunters.
- Any quota for live capture should refer to “capture” event and not “export”, as is currently the case. By referring to “export”, the quota ignore mortality events that are potentially numerous during capture and captivity.
- Any capture should be attended and supervised by local authorities (MFMR and/or MECDM) and precisely documented (e.g. timing, location, species, status, sex, measurements, DNA samples, dorsal fin photographs).
- Considering the likely impact on the Guadalcanal population (potentially as much as half of the population was removed), a capture ban is recommended for this population to allow recovery.
- A monitoring program should be developed to document the recovery (or not) of the populations in impacted zones. Furthermore, future research effort should extend the study area to cover the entire coastline of Guadalcanal and Malaita.
- A ‘DNA register’ should be developed, i.e. genetic samples of all dolphins captured should be collected systematically and archived to allow verification of its origin and legitimacy. Furthermore, the Government should request samples of Solomon Islands dolphins currently held overseas for genetic analyses.

RECOMMENDATIONS REGARDING TRADITIONAL DRIVE-HUNT AND POTENTIAL FOR DOLPHIN-WATCHING TOURISM

The cultural significance of the dolphin drive-hunt in Solomon Islands is widely recognized and the traditional methods changed little over time. However, there are various reasons to be concerned for the conservation status of dolphin populations in the area. Indeed, the species and numbers taken have been poorly documented but involve sometimes several hundred individuals a year (Takekawa 1996b, Kahn 2006). Furthermore, the dynamics of the hunt seem to have varied dramatically through time for unknown reasons (potentially because of temporary dolphin population decline), and key targetted species with the most highly-prized teeth (probably the melon-headed whale) may have disappeared from the region (Dawbin 1966, Takekawa 1996b). Therefore, a few initiatives are recommended to improve and facilitate the future management of this practise.

- A research project should be implemented to provide a population assessment of dolphins targeted by the traditional drive hunt. These are primarily spinner dolphins, *Stenella longirostris,* and pantropical spotted dolphins, *Stenella attenuata,* around the island of Malaita.
- Although local knowledge of spinner dolphin populations in Solomon Islands is still limited, it is recommended that this species should not be hunted unless groups were localized in offshore waters (several nautical miles off the coast). Indeed, coastal form of spinner dolphins tend to form small resident populations throughout the Pacific (Oremus et al. 2007, Andrews et al. 2010) and therefore, care should be taken not to hunt such vulnerable populations.
- Close collaboration should be initiated as soon as possible between the dolphin hunting communities, the local NGOs and the Government to help document drive-hunt events as accurately as possible. This could be implemented by having observers attending each of the hunting events. Observers would have the role of documenting the species caught, the number of dolphins, morphological measurements and biological sampling (e.g. skin samples for DNA analyses).

- The Solomon Islands Government should encourage and support the development of tourism around wild-dolphin watching as an alternative to live-capture of *Tursiops aduncus*. Although far from exhaustive, this current study clearly highlights the potential of such activity with numerous areas were the rate of encounters with dolphins is very high.

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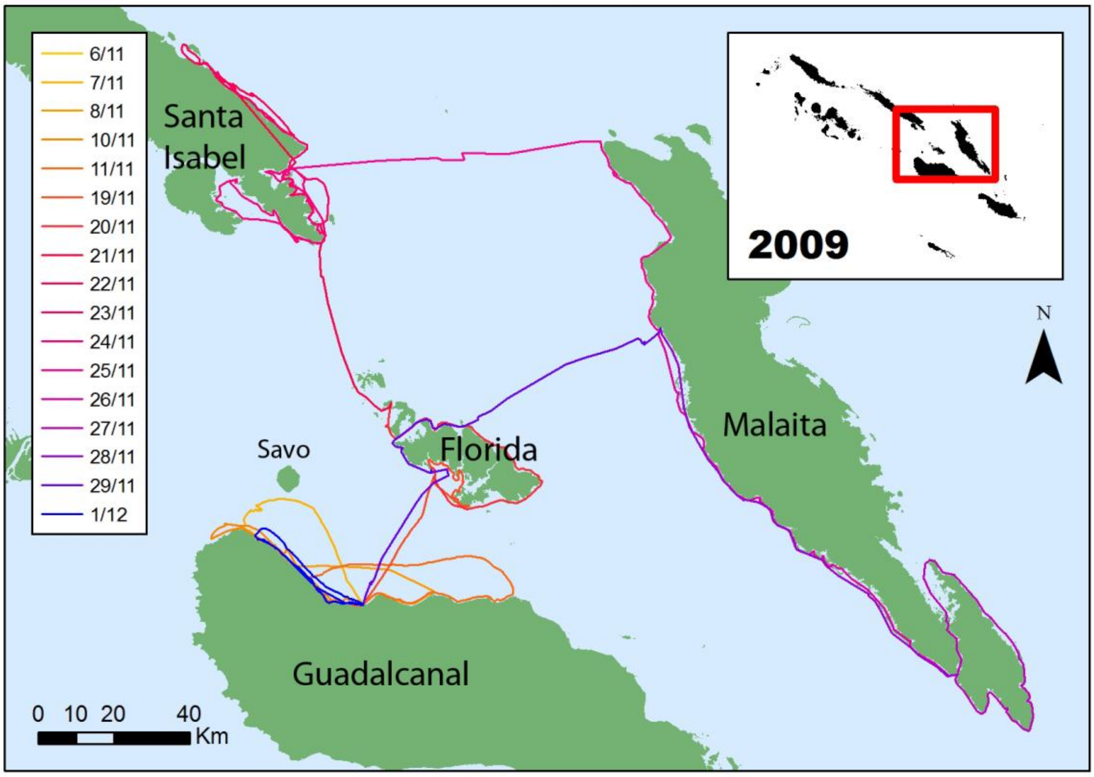
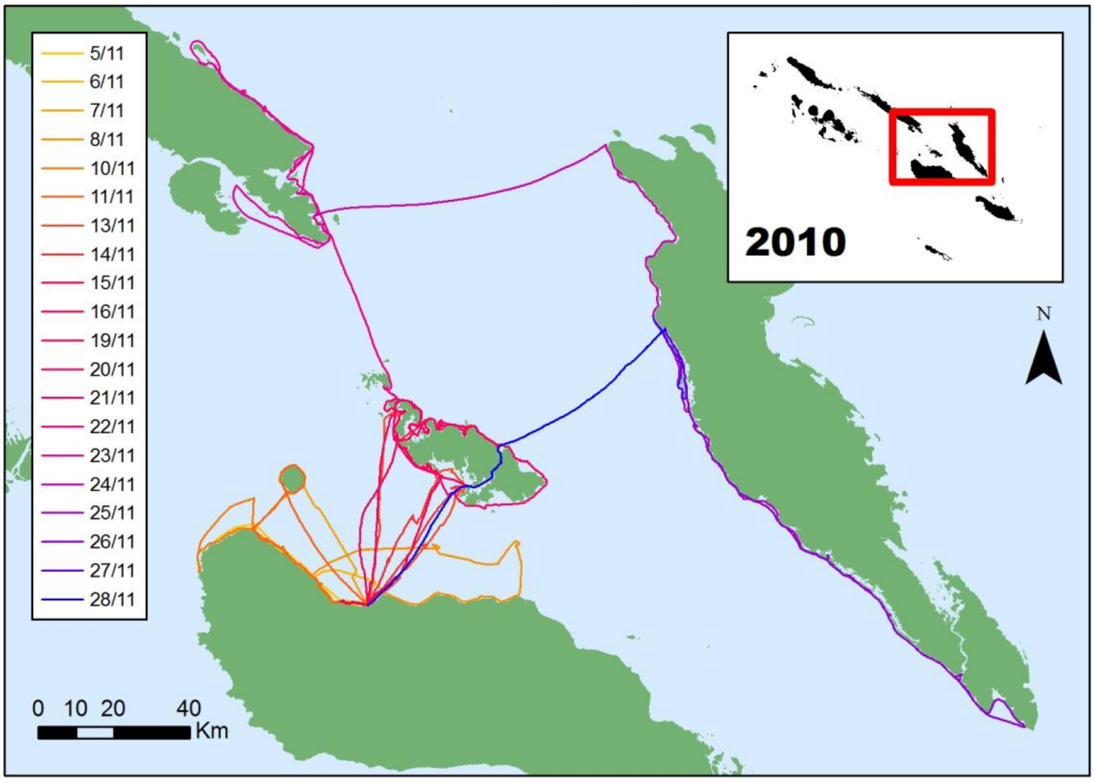
APPENDICES

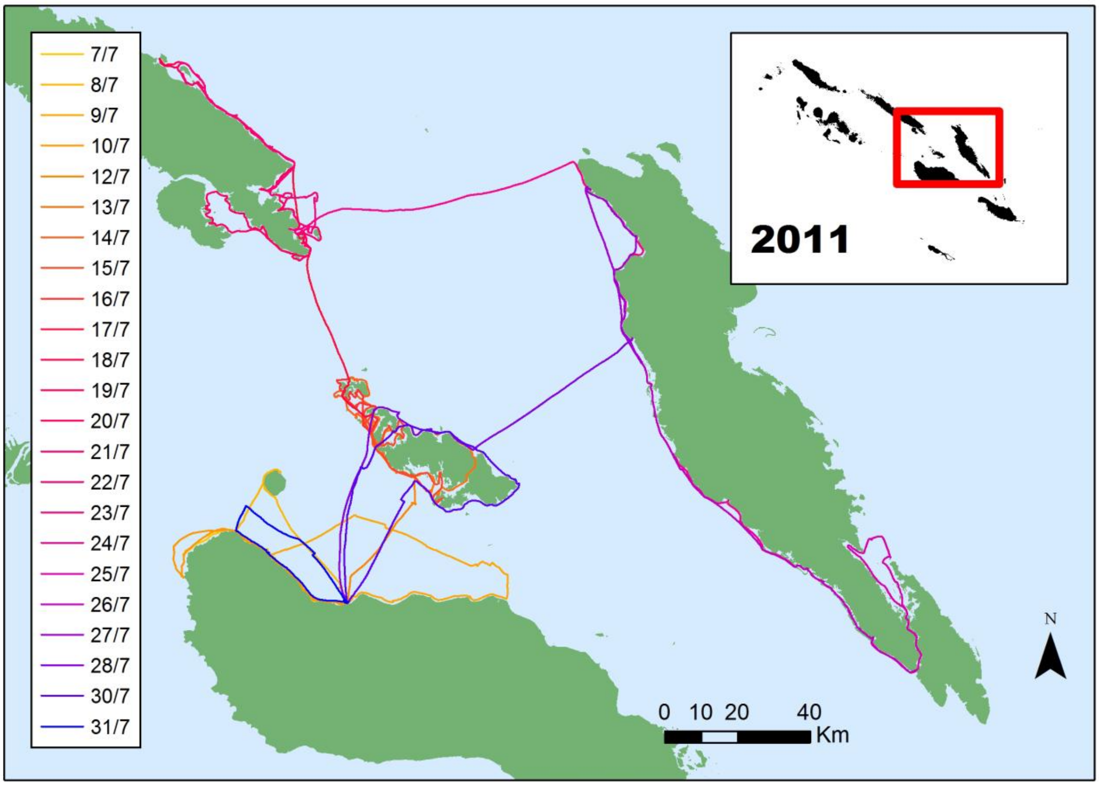
Appendix 1: List of mtDNA haplotypes used in the species identity analyses

Species	Location of origin	# haplotypes	Genbank #	References
Tursiops aduncus	**Solomon Islands**	**7**	**-**	**Present study**
	China/Hong-Kong/Taiwan	13	AF049100/AF056234-AF056243/AF355576-AF355581	Wang et al. (1999), Yang et al. (2005)
	East Australia	6	AF287951-AF287954/EF581128/GQ420670	Moller & Beheregaray (2001), Moller et al. (2007), Wiszniewski et al. (2010)
	Hawaii	1	EF672725	Martien et al. (2011)
	Indonesia	2	AF056237-AF056238	Wang et al. (1999)
	New Caledonia	2	-	Oremus et al. (2009)
	South Africa	4	EF636207-EF636212	Natoli et al. (2008)
Tursiops truncatus	China/Hong-Kong/Taiwan	14	AF056220-AF056232/AF355582-AF355586	Wang et al. (1999), Yang et al. (2005)
	East Australia	3	JN571470-JN571474	Charlton-Robb et al. (2011)
	French Polynesia	2	-	Tezannos-Pinto et al. (2008)
	Hawaii	19	EF672700-EF672718	Martien et al. (2011)
	Japan	21	AB303154-AB303174	Kita et al. (unpub)
	Kiribati	8	-	Tezannos-Pinto et al. (2008)
	New Caledonia	10	-	Oremus & Garrigue (unpub)
	New Zealand	19	EU276389-EU276412	Tezannos-Pinto et al. (2008)
	Palmyra Atoll	7	EF672708-EF672723	Martien et al. (2011)
Tursiops australis	South-East Australia	14	EF192140-EF192149/JN571464-JN571469	Bilgman et al. (2007), Charlton-Robb et al. (2011)

Appendix 2: Boat tracks per year



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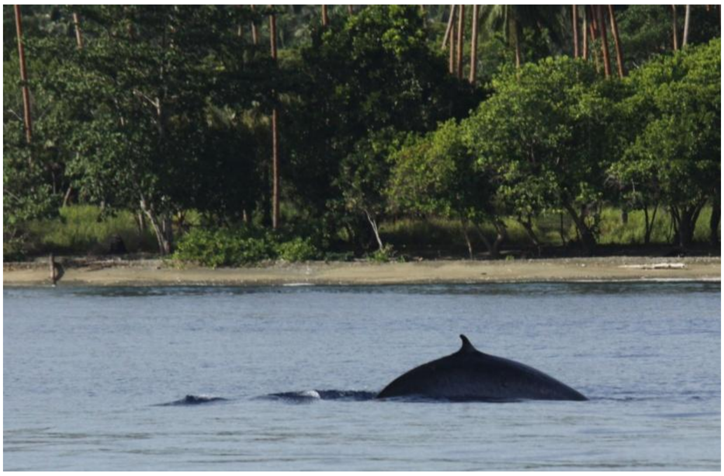
Appendix 3: Photographs of the baleen whales encountered during the Solomon Islands surveys



Balaenoptera sp. very close to shore in Guadalcanal (5 Nov 2010)

Balaenoptera sp. showing so white on the right side of the throat and lack of rostrum ridges.

Balaenoptera sp. Showing erect, falcate dorsal fin and mottling and circular scar on back.

Appendix 4: Summary of the dolphin teeth collected during the study

Item type	Traditional name	Date of purchased	Location	# teeth
Loose teeth	Unubulu	June 2009	Honiara market	12
Necklace	Robo	05/11/2009	Honiara market	21
Earrings	Unubulu	05/11/2009	Honiara, Mendana Hotel shop	4
Necklace	Robo	06/11/2009	Honiara market	1
Earrings	Raa	06/11/2009	Honiara market	16
Earrings	Unubulu	16/11/2009	Honiara, Mendana Hotel shop	6
Necklace	Unubulu	16/11/2009	Honiara, Mendana Hotel shop	6
Loose teeth	Raa	27/11/2009	Fanalei community	31
Loose teeth	Robo	27/11/2009	Fanalei community	2
Loose teeth	Robo	27/11/2009	Fanalei community	5
Loose teeth	Pseudorca	27/11/2009	Fanalei community	1
Loose teeth	Robo	02/12/2009	Honiara market	9
Necklace	Robo	02/12/2009	Honiara, handcraft shop	4
Necklace	Robo	02/12/2009	Honiara, handcraft shop	4
Necklace	Robo	02/12/2009	Honiara, handcraft shop	4
Earrings	Unubulu	02/12/2009	Honiara, handcraft shop	16
Earrings	Unubulu	03/11/2010	Honiara, Mendana Hotel shop	18
Earrings	Unubulu	03/11/2010	Honiara market	24
Headband	Raa	10/11/2010	Honiara, handcraft shop	24
Necklace	Unubulu	29/11/2010	Museum handcraft shop	28
Earrings	Unubulu	29/11/2010	Museum handcraft shop	6
Necklace	Robo	17/05/2012	Honiara, handcraft shop	10
Loose teeth	Unubulu	2011	Bita'ama community	10
Loose teeth	spinner	2011	Bita'ama community	10
Loose tooth	Risso	2011	Bita'ama community	1
Loose teeth	Unubulu	2013	Fanalei community	5
Loose teeth	raa	2013	Fanalei community	6
Loose teeth	Robo manole	2013	Fanalei community	1