THE REDMAP TASMANIA **REPORT CARD**: SUPPORTING INFORMATION

Redmap has developed a 'report card' to assess and report potential shifts in species ranges off the coast of Tasmania, using the observations collected by divers and fishers. The report card was funded by the Tasmania Climate Change Office, Climate Connect Grant, 2012. The purpose of this supporting information is to provide a detailed and transparent account of the methods used in the report card to inform and educate the wider public on the assessment process. The assessment framework developed for the report card will be reviewed by the international research community via peer review of a journal publication (Robinson *et al*. in prep). Improvements to the framework that are incorporated during the peer-review process can be incorporated in future assessments

BACKGROUND AND AIM

As the climate warms, numerous species living in the ocean have responded by shifting the geographic location of their ranges poleward (Parmesan 2006, Sorte *et al*. 2010, Burrows *et al*. 2011). A range shift can include an extension or a contraction in the boundary (or edge) of a species' range (see here for more info). In the oceans surrounding Tasmania, shifts in species ranges have been documented in several dozen marine species (Ling *et al*. 2009, Pitt *et al*. 2010, Johnson *et al*. 2011, Last *et al*. 2011) and these have consisted mostly of extensions at the southern edge of the range. The relatively large number of range shifting species in Tasmania has, in part, been attributed to the rapid rate of ocean warming off the south east coast of Australia (Johnson *et al*. 2011). This observation is consistent with the finding that there are a greater number of shifts in species distributions in regions with greater warming (Chen *et al*. 2011). However, not all marine species in Tasmanian waters are shifting their ranges (Stuart-Smith *et al*. 2010) and there is considerable variation in the rate and distance of range shifts among different species (Sorte *et al*. 2010, Angert *et al*. 2011, Burrows *et al*. 2011, Sunday *et al*. 2011).

Range shifts are generally detected using data collected over a period of ten years or more (Parmesan and Yohe 2003). However, an earlier indication of potential range shifting species may also be useful for managers and the general public to flag the arrival of some species that are more detrimental, or favourable, than others.

Redmap Tasmania has been monitoring range extensions in several species for approximately three years. Even though the program is well on its way to generating a long-term dataset, which is suitable for the detection and measurement of range shifts, it is not yet appropriate to apply existing quantitative methods. In the meantime, Redmap requires an assessment method that can be used on relatively short-term datasets (i.e. less than ten years old) that provides an early indication of which species are potentially shifting (or extending) their ranges.

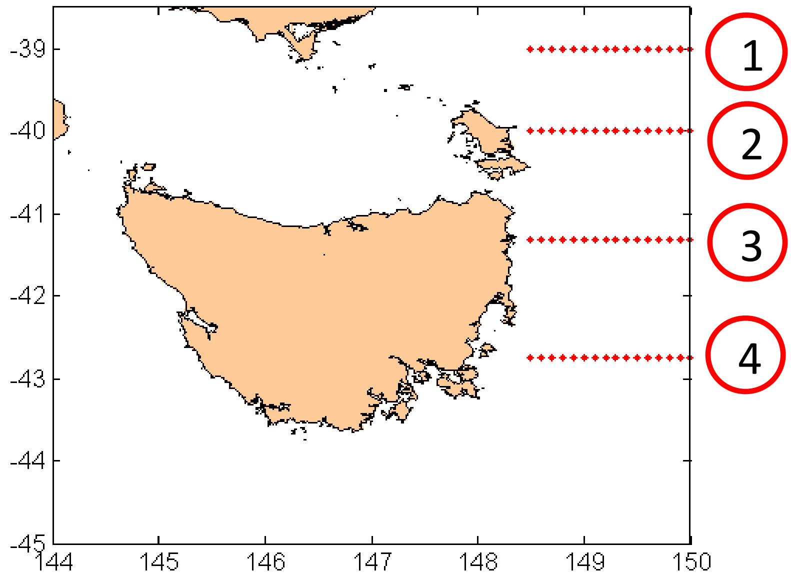
Due to an absence in existing assessment methods, a framework for assessing potential range shifts in Redmap species was developed by a working group that included 21 contributors with expertise in one or more of the following areas: biodiversity; marine ecology and assessment of species range shifts; data management; natural resource management; and/or science communication. The aim of the working group was to develop an assessment framework that was (1) rapid; (2) repeatable and transparent; (3) had few data requirements; (4) was relatively robust to sampling biases; (5) could cope with variable levels of information on both current data and knowledge of historical range boundaries; (6) considered imperfect detection; (7) incorporated diverse data sources and; (8) could include species that have natural variability in their range boundary (i.e. due to migratory behaviour).

THE ASSESSMENT PROCESS

Study area and data

Redmap started monitoring potential range-shifting species in waters around Tasmania in December 2009 (Figure 1) and additional species were added to the list in 2012. The list of potential range-shifting species was formulated through extensive discussions with fishers, divers, managers and scientists on species they had observed in novel locations in recent years. Several of these species have been assessed and classified as range shifting in recent and relatively independent evaluations (see Last *et al*, 2011; Ling *et al*, 2009).

Figure 1. The study area off the east coast of Tasmania with four frequently used southern reference points for reporting sightings of species: (1) In Bass Strait, (2) South of Flinders Island, (3) South of St Helens, (4) South of Maria Island. Note some species were included in southern reference point locations for presentation purposes. For a full list of reference points see Robinson *et al* (in prep).



In November 2012 Redmap commenced its report card project and at the same time expanded its monitoring to include all states in Australia. We confined our analysis to data collected on the east coast of Tasmania between December 2009 and October 2012 where approximately three years of data had been collected. The assessment was limited to the east coast of Tasmania (Figure 1) because there were a very small number of Redmap sightings on the west coast due to fewer people living on that side of the state. There was also less information on species historical ranges (i.e. the southern reference point) on the west relative to the east coast.

Southern reference points (also referred to as a "log it" points on the Redmap species- see redmap.org.au/species) are used by Redmap to represent the southern edge of a species range as known in December 2009 and defined which data were out of range after this time period (Figure 1). A southern reference point was established for each species using information from scientific sources (i.e. journals, books and websites) on the species historical ranges, in conjunction with geographical landmarks that were easy for fishers and divers to recognise in the field without a GPS (e.g. towns such as St. Helens).

Only sightings that were 'out of range' (i.e. south of the southern reference point) and verified with a photo by an expert scientist (i.e. 'photo verified') were included in the assessment. Additionally, to minimise potential biases in sampling, towards a particular species, time and/or location, we removed duplicate records from the same observer, day and location.

To increase the number of observations and rigour of our assessment, a number of different data sources were included in conjunction with the Redmap dataset, e.g. fisheries data (both catch and independent) and scientific survey data.

Two sources of catch data were included. The primary source was from the Tasmanian octopus fishery that included 24 sightings of *Octopus tetricus* from a single fisher's records. The second data source was a single presence sighting from a scientific survey that reported the puerulus (i.e. a very early life stage) of eastern rock lobster (*Sagmariasus verreauxi*). This is not technically fisheries catch data, but has been grouped with the catch data as there was only one sighting (Table 1).

Table 1. Number of sightings from each data source used in the potential range shift assessment

DATA SOURCE	TOTAL NO. OUT OF RANGE SIGHTINGS 2009-2012
Fisheries catch data	25
IMAS scientific survey data	55
Redmap citizen science data	55
RLS survey data using trained divers	5
Total	140

Scientific survey data collected in Tasmania by the Institute for Marine and Antarctic Studies (IMAS) and the Reef Life Survey (RLS) program were also included (for further details on data collection methods see Edgar and Barrett 1999, Edgar and Stuart-Smith 2009).

Theses scientific surveys (i.e. IMAS and RLS) collect abundance data on species (i.e. the total number of individuals sighted is counted in each sample). This differs from Redmap data where the presence of a species is noted (i.e. a sighting could represent one or a number of individuals), but generally the number of individuals is not counted. Therefore all scientific survey and catch data were reduced to presence only sightings.

Developing and applying a framework for assessing overall confidence in potential range shifts

The framework used a decision tree assessment approach similar to that used in classifying and detecting invasive species (Maguire 2004, Westbrooks 2004) to:

1. Classify evidence of potential range shift (i.e. extensions of southern range edges); and

2. Establish our confidence in southern reference points for each species (i.e. the locations that Redmap used to represent the southern edge of a species range) (Figure 2).

These two classifications were then combined to form an overall confidence in a potential range shift as a qualitative 'early indication' of species shifts (Figure 2).

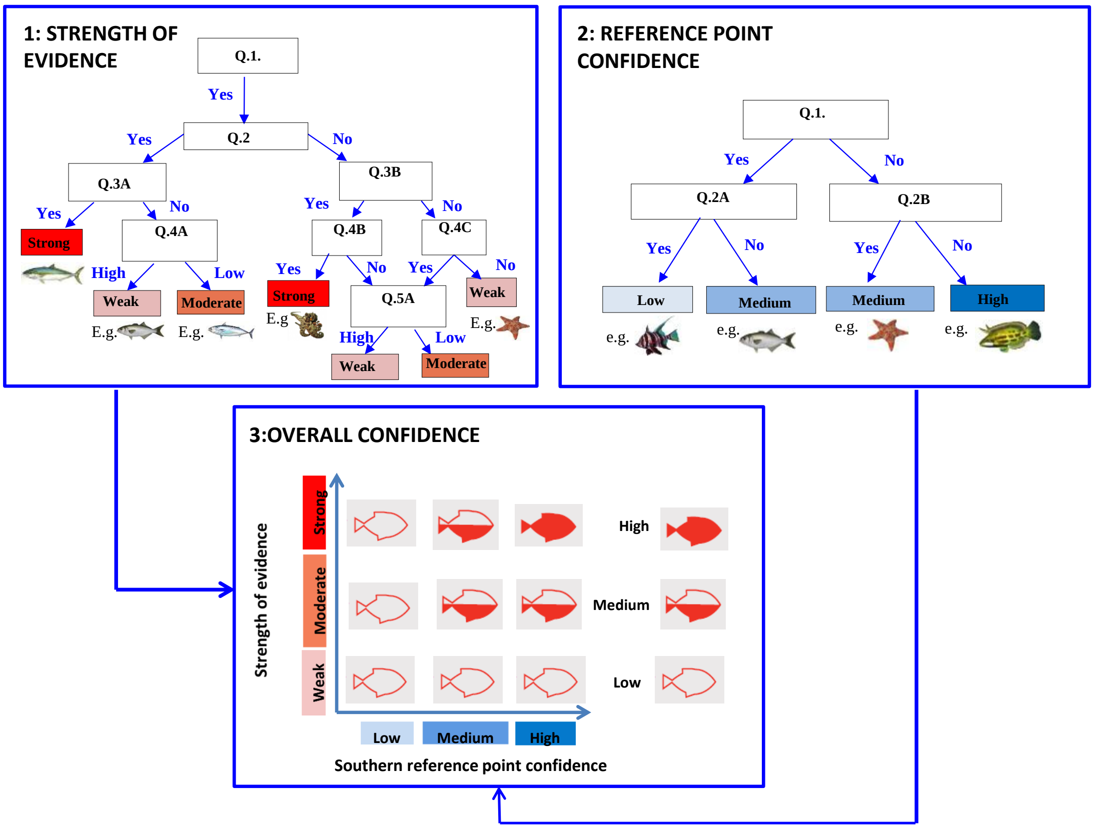


Figure 2. Framework for assessing overall confidence in potential range shifts

Strength of evidence

The first strength of evidence decision tree was based on five questions devised by expert contributors to develop our ecological understanding, while maximising the application of the data (Figure 3).

In those questions that focused on consistency through time (i.e. whether the species was spotted out of range in multiple years and/or in winter), we were trying to establish if a species was just visiting over the three year assessment period (i.e. a 'vagrant' species) or had become a likely resident (outside of their historical range). It is normal for species to be observed occasionally outside their expected distribution, so occasional sightings can indicate that the species was just 'visiting', which provides weaker support for a range shift. Contrary to this, consistent sightings through time can indicate the species may have become a resident outside of where it was previously located and provides stronger evidence of a potential shift.

Consistent sightings of a species through time also depends on whether a species generally remains present in an area all year round (i.e. is not migratory) or if it moves to different areas during different seasons (i.e. is migratory). For species that maintain the same distribution throughout the year, sightings over the cooler winter months provide stronger evidence of a range shift. On the other hand, if the distribution of a species generally moves on a seasonal basis we would not expect it to be present during winter, so for these species we only asked whether it was sighted over multiple years (Figure 3).

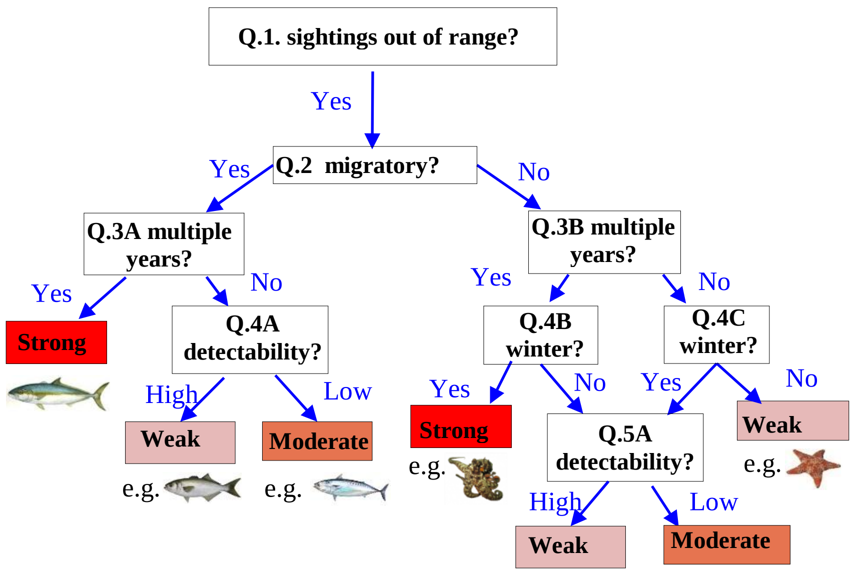


Figure 3. The decision tree used to classify strength of evidence of a potential range shift for species with more than one sighting. Example species that were assigned to different classifications in the tree are noted (L-R: Yellowtail kingfish-*Seriola lalandi*, Tailor- *Pomatomus saltatrix*, Frigate mackerel- *Auxis thazard*, Gloomy octopus- *Octopus tetricus* and Firebrick seastar- *Asterodiscides truncatus*) that separated into the different classification categories are noted.

We also incorporated detectability into the assessment because species that are harder to observe by divers or catch by fishers (i.e. had 'low' detectability) were more likely to have fewer sightings and consequently be classified in the 'weak' evidence category– irrespective of whether they were actually present or not. To compensate for this we established how easy or hard species were to spot/detect. If they were easy to spot, but not consistently observed they were classified as 'weak' evidence, but if they were hard to spot and not consistently observed they were classed as 'moderate' (Figure 3).

Confidence in the southern reference point

The second decision tree classified confidence in the southern reference point (Figure 4). This decision tree included questions that evaluated whether there was disagreement between references that described species historical ranges and whether there was disagreement between the southern reference point used by Redmap and the maximum southern range edge as described in the literature (Figure 4).

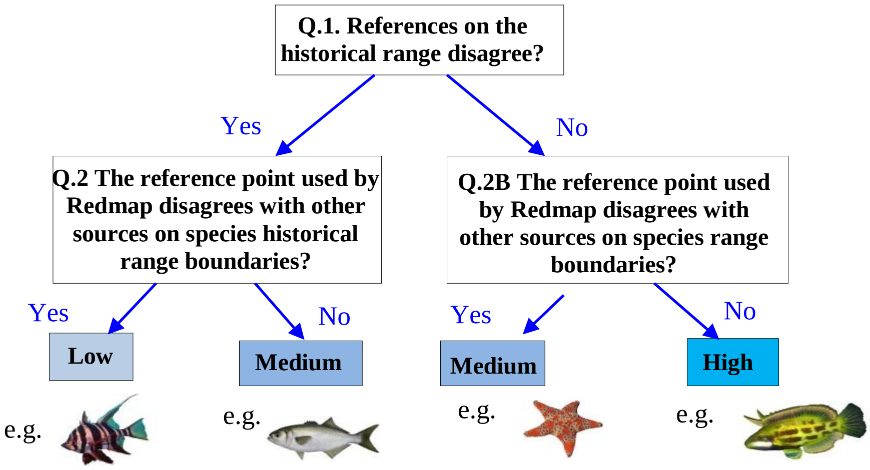


Figure 4. The decision tree used to classify confidence in a species southern reference point. Example species assigned to different confidence level classifications (L-R: Old wife- *Enoplosus armatus*,Tailor- *Pomatomus saltatrix*, Firebrick seastar- *Asterodiscides truncatus*, Rainbow cale- *Heteroscarus acroptilus*)

Overall confidence

The approach used to combine the classifications from the strength of evidence and the southern reference point confidence to generate the overall confidence is simple, conservative and has been used in other prominent report cards (e.g. MCCIP 2010). The approach is conservative because the overall confidence is defined by the minimum strength of evidence or the minimum southern reference point confidence. Therefore, overall confidence in a potential range shift can only be 'high' when both strength of evidence for a range shift is 'strong' and confidence in the southern reference point is 'high' (Figure 5).

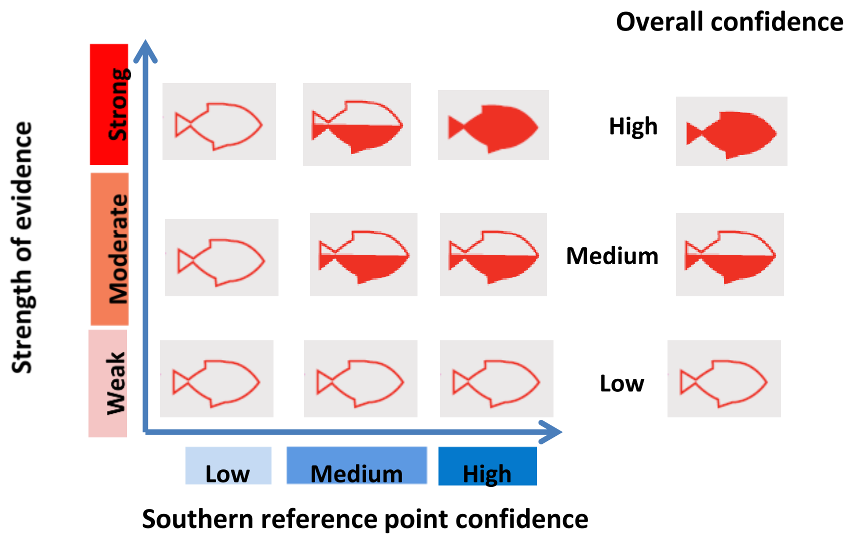


Figure 5. Diagrammatic representation of how overall confidence is formulated from strength of evidence and the southern reference point

Incorporating feedback from the community

Upon completion of the report card six divers and six fishers volunteered to give feedback on draft versions of the report card. Fishers and divers were specifically asked if there was any part of the results that they did not understand and what could be improved as far as clarity and appearance on all pages. This feedback improved the communication of the results to maximise the impact and uptake of the report card by the wider community.

IMPLICATIONS FOR THE PUBLIC, MANAGERS AND SCIENTISTS

The report card highlights to the public, natural resource managers and scientists the species off the coat of Tasmania that have likely shifted their ranges in the past three years. Additionally, the confidence in southern reference points reveals knowledge gaps and discrepancies that can be improved upon with further research and data collection.

The flow-on effects of this assessment include: better informed management and direction of research efforts to priority species, greater public awareness about potential changes in their local marine system and increased preparedness in dealing with future changes.

In terms of how the report card influences the general public, we anticipate a two-fold impact. The first is to inform the public on how their data are used and what it is telling us about potential range shifts (i.e. the overall confidence in a potential range shift). The second is to acknowledge the importance of volunteer contributions to the scientific community through this high quality research output.

RESULTS AND FURTHER INFORMATION

For the results from this assessment please see the Redmap Tasmania Report card (http://www.redmap.org.au/article/the-redmap-tasmania-report-card/) and for further details on methods and results please contact Dr. Lucy Robinson at lucy.robinson@utas.edu.au.

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