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RESEARCH PAPER

# An unlikely partnership: fishers' participation in a small-scale fishery data collection program in the Timor Sea

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**Abstract** Traditional fisheries stock assessment methods and fishery independent surveys are costly and time consuming exercises. However fishers trained in data collection and utilising other skills can reduce costs and improve fishery assessments and management. A data collection program was conducted by Australian and Indonesian scientists with small-scale Indonesian sea cucumber fishers to evaluate the approach and then capture its benefits. The data fishers recorded allowed for the first stock assessment of this trans-boundary fishery during its centuries-long existence at Scott Reef in north-western Australia. The program also included interviews with fishers capturing the social, economic, and demographic aspects of the fishery. Economic inputs to fishing were complemented by fishery revenue data voluntarily submitted when fishers returned to port and sold their catch. Catch data recorded by fishers demonstrated much higher abundances than estimates obtained using standard visual transect methods and accurately reflected the true catch composition. However, they also showed extreme rates of exploitation. Interviews revealed social and economic factors that would be important considerations if management interventions were made. The program's approach and the time scientists spent on the fishers' vessels were key ingredients to fishers' participation and the utility of the results. Despite the program's achievements the information generated has not led to improved management or had any direct benefits for the participants. Sustaining the program in the longer term requires that its value is better captured.

**Keywords** Indonesia · Australia · Monitoring · Sea-cucumber · Stock assessment · Fishery dependent

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## Introduction: the role of fishers in data collection and fisheries co-management

Small-scale fisheries are important to humanity, contributing as much as half the global capture fisheries production and employing as many as 90 % of all fishers (FAO 2015). Despite their clear economic, nutritional and social importance many small-scale fisheries are poorly researched and weakly managed. Though there are many and complex reasons for this, the high cost of research is certainly part of the problem despite potentially high cost-benefit ratios (Andrews et al. 2007; Agnew et al. 2013). However, the benefits of involving fishers in data collection and recognition of the role of fisher local knowledge has been gaining momentum globally (Almany et al. 2010; Danielsen et al. 2009; Ernst et al. 2010; Haggan et al. 2007; Hind 2014; Moller et al. 2004; Obura et al. 2002; Schroeter et al. 2009; Stanley and Rice 2007; Wiber et al. 2004) and is one way of reducing cost barriers.

Participation by fishers in data collection can be a first step towards them having greater involvement in fishery management decisions and thereby making them more likely to comply and ultimately leading to more sustainable livelihood practices (Almany et al. 2010; Ticheler et al. 1998). However, fishers in many fisheries are concerned that data they provide may cast their fishery in a negative way and lead to management decisions that are not in their short term interests or will literally be "used against them" (Wilson 2003). Generally, successful fisheries management occurs when fishers and managers work together to achieve a common goal (Gutiérrez et al. 2011).

Collaborative fishery data collection and monitoring between scientists, fishers and managers can vary in terms of the level of participation of fishers (Danielsen et al. 2009), the fishery, and type of research or management partnerships. Successful collaborative programs are thought to be attributed to a number of different factors relating to fishers' literacy (May 2005; Obura et al. 2002), personal relationships, good communication and trustful behaviours between research scientists and fishers (Almany et al. 2010; Wiber et al. 2004), community cohesion and leadership (Gutiérrez et al. 2011; Schroeter et al. 2009), addressing questions or topics that are important to fishers (Wiber et al. 2004); and fishers' awareness of the impact of exploitation and potential consequence on sustainability of the species and fishery (Ticheler et al. 1998).

The accuracy and adequacy of fisheries data needed for robust assessments of fisheries is frequently debated. But, coming out of these debates in recent times is a push for more "fishery independent" data to overcome such issues such as hyper-stable catch-per-unit-effort due to the behaviour of the target species or technological changes in the fishery (Erisman et al. 2011; Harley et al. 2001; Hilborn and Walters 1992). However, fishery independent surveys, such as visual transect surveys, are expensive and may in some circumstances lack spatial or temporal representativeness that are important in a particular fisheries context. Fisheries dependent surveys have the advantage of capitalising on the skills fishers bring to the surveys such as excellent powers of observation or the amount of survey effort (many fishers/much effort versus few researchers) which may be of greater importance when densities of animals are very low because of overfishing. From a technical perspective collecting data throughout the fishing season as opposed to one off costly surveys can be advantageous (Schroeter et al. 2009). For example, changes in catchability caused by tidal and lunar effects may be important aspects of the fishery which are only revealed when data collection spans one or more of these cycles and may be similarly important for a host of other variables. Data generated from a large proportion of fishers in a fishery can also prevent biases that may be present when a small number of fishers are "observed", another common approach to data collection.

In this paper we report on a fishery catch data collection program conducted by Australian and Indonesian scientists with Indonesian sea cucumber fishers at Scott Reef inside the Australian Exclusive Economic Zone (AEEZ) in the Timor Sea. The trans-boundary fishery operates under a Memorandum of Understanding (MOU) signed by Australia and Indonesia in 1974 and supplemented by "Practical Guidelines" for implementing the MOU in 1989. Under agreed arrangements traditional Indonesian fishers are permitted to fish in an area known as the "MOU Box" (Fig. 1). Our objective is to demonstrate the value and opportunities of a partnership approach to data collection which was possible despite the remoteness of the fishery and an international border.

The aim of the program was initially to evaluate the feasibility of involving fishers in fishery data

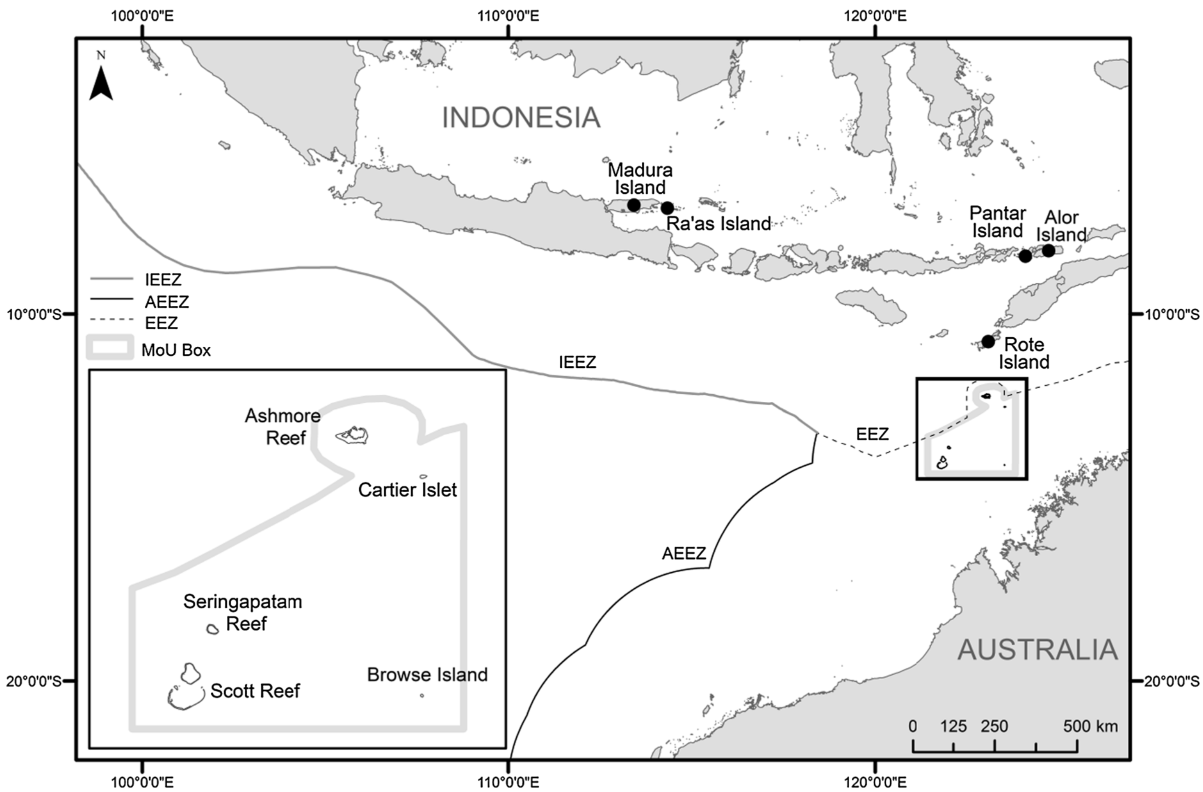


**Fig. 1** The MOU Box is shown where traditional Indonesian fishers are permitted to fish. The location of the current sea cucumber fishery at Scott Reef, and islands in Indonesia where the majority of vessels and fishers come from are indicated. The island of Tonduk is near Ra'as

collection in a remote area where the cost of research is very high. When this proved feasible the program was expanded to collect data to be used to assess the stocks of sea cucumbers which could provide an informed basis for management. An observation made very early in our field work was the extremely intense fishing pressure exerted over a short "season" when, at some times, more than 400 fishers were actively fishing on the reef day and night. Under these conditions it was likely that stocks would be depleted rapidly and "depletion methods" pioneered in fisheries applications by DeLury (1947) and later by Ricker (1975) seemed to offer promise. Hence the program focused on producing catch and effort data from the fishery that could be used for such a purpose.

Understanding the human dimension of fisheries is crucial for improved management and compliance (Kaplan and McKay 2004) and in this fishery to support discussions between two countries about the fishery in terms this dimension. We therefore complimented the collection of fisheries catch and effort data with socio-economic data collected through interviews and collected by other voluntarily completed catch sales log sheets at point sale in Indonesia.

## The trans-boundary sea cucumber fishery and research context

### Fishers and the fishery

Indonesian fishermen have harvested sea cucumbers in a wide expanse of northern Australian waters for centuries (MacKnight 1976) but contemporary traditional fishers are confined to the MOU Box and predominantly fish at just one reef complex, Scott Reef (Fig. 1). There are two important conditions Indonesian fishers must observe in the MOU Box: (1) using only sail powered fishing vessels to reach their fishing grounds; and (2) using non-motorised fishing equipment such as hand collection and free diving (Stacey 2007). In recent years the use of global position system receivers (GPS) to navigate has become common and kerosene pressure lamps are used for night fishing which is now the most productive fishing period. But despite adopting some more advanced fishing technology such as GPS, the fishery remains small-scale, and is undertaken by fishers from some of the least developed and less prosperous parts of Indonesia (Prescott et al. 2015). Sea cucumbers are targeted in this fishery due to their comparatively high value (Purcell et al. 2013) and the simple preservation methods (Eriksson et al. 2015).

The contemporary traditional fishery at Scott Reef is pursued by all male crews of three ethnic groups. Ethnic Rotinese fishers originate from the nearest Indonesian island of Rote Ndao (Rote) located approximately 200 nautical miles to the north. Alorese fishers come from the Lesser Sunda Islands via Rote where they arrange Rotinese owned vessels for the fishing voyage to Scott Reef. Madurese come from several communities on small islands at the eastern extremity of Java such as Ra'as and Tonduk, 800 nautical miles away. Madurese fishers on their way to Scott Reef transit through Rote where they remove engines from their vessels to comply with the Practical Guidelines.

Fishing at Scott Reef is seasonal owing to the dependency on the southeast trade winds to sail there and back to Indonesia and to avoid the dangerous storms and cyclones that are common in the area during the northwest monsoon. Consequently, most fishing trips to Scott Reef are undertaken between May and October. Some fishers have managed two trips to Scott Reef in one season however the usual pattern is a single trip of about 60 days duration. These lengthy voyages appear to be limited primarily by the drinking water and firewood the small vessels can carry, however during the voyages crews may also reach the limits of their endurance for the demanding physical work and diets entirely lacking fruit and vegetables.

Crews have characteristic styles of fishing and particular skills related to their ethnicity. Madurese harvest most sea cucumbers from the lagoons at depths ranging from several metres to more than 30 m. Alorese harvest from parts of the reef that overlap with both the Madurese and Rotinese who harvest almost exclusively from the reef-top at low tide and are therefore most tide dependent. In addition to these groups Bajo (or Bajau Laut) have occasionally harvested from the reef in recent years but were historically the major ethnic group undertaking the sea cucumber fishing (Fox 1977) but only a single vessel was observed in this program. Because of these different fishing behaviours the catch varies between groups in terms of catch-per-unit-effort (CPUE), species composition, and the size of harvested sea cucumbers. Given these differences it was important to ensure as far as possible that all ethnic groups were included in the data collection program to prevent bias in the catch data, although stock assessment has focused on the shallow reef-top harvests which were almost exclusively conducted by the Rotinese and Alorese crews (Prescott et al. 2013).

## Sea cucumber stocks and research

While the fishery is arguably the oldest extant commercial fishery in Australia, it has been little studied in a fisheries management context until recently. In 1998, the first quantitative study of the sea cucumber stocks in the MOU Box was undertaken using visual transect surveys (Skewes et al. 1999). At Scott Reef, 288 transects were randomly allocated within shallow reef habitat strata. In 2008 a team of scientists from the Australian Fisheries Management Authority (AFMA), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the Indonesian Ministry of Marine Affairs and Fisheries resurveyed 279 of the 1998 transect sites (Prescott 2008 unpublished report). Results of the 1998 and 2008 surveys were similar in terms of the species observed and their apparent density. Precision was very low because of the patchiness of the sea cucumber stocks and the generally low abundance leading to a high proportion of zero counts. Despite this surveys clearly indicated that many species (and all "high value species") were severely depleted based on, for example, comparisons between the densities observed at Scott Reef and the protected Ashmore Reef National Nature Reserve, located 120 nautical miles to the north (Fig. 1) and other less intensively fished reefs in Torres Strait (Skewes et al. 1999). From the Australian perspective, based on the survey results and many sea cucumber 'case studies' internationally such as reported in Toral-Granda et al. (2008), the fishery needed management intervention urgently. Indonesia on the other hand saw the situation at Scott Reef quite differently. Indonesian officials at a bilateral meeting in 2007 stated they were generally satisfied that its fishers continued to return home to their islands from the Scott Reef with valuable catches that were seen to partially provide the income needed to support the livelihoods for hundreds of fishers and their families (Prescott, Unpublished data).

During the 2008 research at Scott Reef, it was quickly observed that the catches taken by the fishers included substantial numbers of sea cucumbers including several species that dominated the catches but were entirely absent from both the visual surveys. The inconsistency between transect survey results and the fishers' catches posed an important challenge: how could the assessment of the fishery proceed such that it reflected the species being contemporarily exploited but were not being detected by the surveys? This led to the development of a fisher-based data collection program that began with the successful pilot data collection program in 2008 and continued with a data collection program in 2009, 2011 and 2012.

## Methods

### Fishery data collection

Subsequent to the pilot data collection program in 2008, during field work at Scott Reef in 2009, 2011 and 2012 (Table 1) every fishing vessel present at Scott Reef was visited by a research team comprised of Indonesian and Australian researchers (most often one from each country). Indonesian captains and crews universally consented to participate in semi-structured socio-economic interviews conducted aboard their vessels. This provided information on the crew's ethnicity, place of birth and residence, age and family relationships, education and vessel ownership among other social factors. We also tried to establish what other livelihood activities were important to the fishers and their families. Economic information on the inputs to the fishing operation was also collected for such inputs important in this fishery as food, kerosene, firewood, fresh water and fishing equipment. Finally, interviews sought to establish what fishery issues were important to the fishers and what solutions they would propose to resolve them ("what would you do if you were the boss"). Following each interview and, dependent on whether the crew would depart the reef soon or remain there and fish for a longer period of time, crews were 'enrolled' in a catch and effort data collection program (Table 1).

A simple pictorial catch and effort data sheet was developed that included the most common species of sea cucumber as well as some of the less common but important gastropods and several shark species that tended to be caught opportunistically but were still harvested for commercial purposes (See Online resource 1). The form included a photograph of the species and its Indonesian name, and adjacent columns to separately record the numbers of the respective species caught during day and night fishing episodes. There was also a place to record the time that fishers left the boat and returned from fishing, and the reef on which they fished, generally recorded as north or south Scott Reef but sometimes at a finer spatial level using the fishers' names for areas they distinguished.

To complete the catch and effort data sheets fishers needed only to be able to count and perform addition (to combine the catches of various crew members). These are skills that fishers, regardless of their social, cultural and educational circumstances had since their livelihoods depend on these skills. Recording the catch

**Table 1** Numbers of boat captains and crew interviewed at Scott Reef, crews participating in catch recording, catch and effort sheets completed, and catches recorded (catches recorded are the catches of each species by each fishing episode by each vessel)

| Season | Dates of data collection at Scott Reef | Crew interviews completed at sea | # Crews completing catch effort sheets | # Catch effort sheets completed | Catches recorded | Catch sales forms returned by crew |
|---|---|---|---|---|---|---|
| 2008 | 7–23 September (pilot survey) | 29 | 19 | 165 | 1315 | N/A |
| 2009 | 11 August to 13 September | 55 | 54 | 967 | 12,312 | 15 (28 %) |
| 2011 | 14–30 August & 5–16 September | 14 | 13 | 323 | 3049 | 8 (62 %) |
| 2012 | 29 July to 9 August | 22 | 21 | 577 | 5077 | 18 (86 %) |

Also shown are the numbers of correctly completed catch sales sheets submitted/received and percentage who completed forms on the data sheets required a little time and fortunately in this fishery there was sufficient time for crews to complete this task in between the twice daily low tide fishing episodes.

An example of a completed data sheet was provided as part of a kit that included, in most cases, enough data sheets for the crew's expected length of stay at the reef. Another data sheet with pictures corresponding to those on the catch data sheets and columns to record weight sold and price $kg^{-1}$ or total value on one side, and the distribution of revenue between the crew and vessel owner on the other side were provided (See online resource 2). The kit was completed with a clip board and pencils and a self-addressed and postage paid envelope for the fishers to send the data sheets to a local member of the research team in the Indonesian Ministry of Marine Affairs and Fisheries when they returned to port in Indonesia.

During the course of our research at Scott Reef we returned to vessels as frequently as possible (most vessels were revisited several times) to check on the crews' catch recording and identify and correct any errors that were detected by comparing their recorded catches against the sea cucumbers found drying on the vessels' decks. These short visits were also used to demonstrate our appreciation for the work done by the crews and to strengthen our relationships with them. On most visits we provided each crew member with a piece of fruit as a small token of our appreciation. However, once we left Scott Reef and when the fishers returned to port in Indonesia where many recorded additional data they received no further reward for their contribution to the voluntary research program.

From 2011 to the present, the research program established stronger links with the fishers in Indonesia with one of the authors (Riwu) living on Rote where most fishers begin and end their voyages. Activities on Rote included liaison with fishers when they returned and facilitating collection of their catch and catch sales data sheet(s). Catch data sheets were distributed to some vessel owners and crews prior to their departure for the MOU Box in 2012 and 2013 in an effort to give the program greater local ownership and be less dependent on our presence at the reef.

### Socio-economic data

Economic inputs (costs) were collected during interviews at Scott Reef were complemented by fishery revenue data voluntarily recorded when fishers returned to port and sold their catch (Prescott Unpublished data). Another data sheet patterned after the catch and effort data sheet was used for this purpose. Fishers were asked to record the weight of each species (or species groups like congeners in the genus *Bohadschia*) next to the photo of the species and also record the price received though in some instances the total value was recorded for each species. These were either posted to an Indonesian researcher on the project or collected in Rote usually with the catch and effort data sheets.

### Fishers' perceptions

Another part of the program was concerned with fishers' perspectives on the fishery data recording program conducted at Scott Reef described above. The aim of this was to collect information to provide a better understanding for the longer-term feasibility of the data collection program for the MOU Box and how it may be tailored to suit the participating fishers' interests better in the future.

A list of fishermen who had completed survey forms in previous years was prepared (Table 2) and from this, 12 men from two villages in Rote (Netenain and Oelua) were interviewed on the 8th August 2014. It was initially anticipated that we would interview approximately 30 fishers representing the different Rotinese, Alorese and Madurese fishers. However in 2014, much to our surprise very few boats and crews participated in the sea cucumber fishery (the reasons for which are still to be investigated) which meant only limited numbers of Rotinese crews and captains who resided more of less permanently in Rote could be interviewed.

A semi-structured interview questionnaire containing nine questions was prepared in the Indonesian language and Riwu asked fishers each question and recorded their answers. The interviews lasted about 5–15 min. Fishers were asked a series of questions about their participation in the program concerning the reasons for their agreement to participate; how they interpreted the activity; what they considered the data collected would be used for; whether they liked or disliked any aspect of the program; suggestions for improvement and finally researcher qualities they considered important. The questions were either yes/no; multiple choice or open-ended (Table 3). Fishers

**Table 2** Ethnicity of the captains and crews returning catch data and catch sale forms by year

| Ethnic group | Number of crews returning catch and sales data (catch, sales) | | |
|---|---|---|---|
| | 2009 | 2011 | 2012 |
| Alorese | 15, 3 | 6, 4 | 15, 13 |
| Madurese | 10, 2 | 1, 0 | 0, 0 |
| Rotinese | 29, 10 | 5, 4 | 6, 5 |

were provided with copies of data forms that they had completed during one year to help recollect their experiences.

## Results

### Verification of data recording

Each fishing season, the fishers we visited at sea universally consented to participate in the socio-economic interviews and voluntarily record their catches when asked if they would do so. However, data recorded by the crews varied in terms of how comprehensively they recorded their catch and in the accuracy of the records. How much of the seasons' catch taken by each crew that was accounted for by the catch data collection depended primarily on the point in time during their voyages that they were co-opted into the program since once they began recording they generally continued this activity until they returned to port. Most crews did not begin to record their catches until we visited them at the reef even if they were provided with materials prior to leaving Rote. The accuracy of the recorded catches was often difficult to quantify, however checks of the catch records against the catches observed on the vessels' decks (where they stay for a week or more after capture to dry) indicated some problems as well as some exceptionally accurate records. For example, the largest ever catch recorded was 1254 sea cucumbers taken during a single night. The fresh catch was photographed the following morning and carefully enumerated and it verified exact record keeping by that crew. Other catch records indicated that fishers were either rounding their catch numbers or may have estimated the numbers of some of the more abundant species in their catches, however these followed patterns expected because of the tide cycles and many fishers are able to estimate their catches well using, for example, volumetrics (all fishers used containers to carry their catch).

The catches recorded in 2009 were, with the exception of several low value species, much higher than abundance estimates obtained using visual transects in 1999 and 2008 (Prescott unpublished report; Prescott et al. 2013; Skewes et al. 1999) (Fig. 2). The differences between the catches reportedly taken during day and night fishing are consistent with a much lower detection probability during daylight hours for many species since effort expended during the day was similar to night fishing effort (Fig. 3).

Catch sales data sheets were returned by fewer than the number of fishers from whom we obtained catch and effort data sheets (Table 2). However the proportion of fishers who returned both types of data sheets to us improved substantially in 2011 and 2012 from the first trial of the catch sales recording in 2009.

### Fishers' perceptions

Although data from only 12 interviews on fisher perceptions were collected, surprisingly, the results showed that nine of the twelve fishers interviewed had previously participated in a program that they considered to be similar to ours (Table 3). However, some fishers may have interpreted this question as if they had been involved in our initial catch and effort data program. While our data collection program was potentially not the first participatory program that some fishers had involvement in, it is quite unlikely that they had ever produced data used to quantitatively assess a fishery before. All but one of the fishers responded that they had participated because they wanted to help the researchers and every one of the fishers said that they expected that the information they were collecting would be used for the benefit of the fishery.

As would be expected, how the program was interpreted and understood varied between captains. One thought he would get into trouble if he did not do as asked. A few felt that they would be seen as champions by participating and be seen favourably by

**Table 3** Responses to interview questions on fishers' perceptions about participation in the sea cucumber fishery data collection (August 2014)

| Question | Response | Number of responses |
|---|---|---|
| 1. Participating in the data collection was not compulsory—so you did it on a voluntary basis. Have you ever done anything like this before? | Yes | 9 |
| | No | 3 |
| 2. Can you tell us why you decided to agree to participate? | A. You thought that you must do this or you would get into trouble | 1 |
| | B. You recorded your catches because you wanted to help the researchers | 11 |
| | C. You expected some payment (either in money or some other form) in return | 0 |
| 3. How did you think that the numbers you recorded for each species would be used? And used by whom? (e.g. By government from Australia, Indonesia or by scientists from each of these countries) | A. For the researchers to find out how much of each species was being collected by fishermen and each perahu | 0 |
| | B. To help manage the fishery for the benefit of the fishermen | 12 |
| | C. To see if fishermen were doing anything illegal? | 0 |
| 4. Were there any problems or concerns you had in when recording your catches? | A. It was too much work | 0 |
| | B. Were you worried that you might make a mistake | 1 |
| | C. There were no bad points about data recording | 11 |
| | D. I didn't receive anything worthwhile for doing it for the government | 0 |
| 5. What was the part you enjoyed the most about recording your catches? | A. The researchers brought me a treat each time they visited. | 6 |
| | B. I just like having a job to do when I am not fishing—it helped pass the time | 1 |
| | C. The researchers made me feel like I was doing something important | 5 |
| 6. Some years (e.g. 2010, and 2013) the researchers didn't come to the reef. What did you think the reasons might be that they come some years but not others? | A. I wondered if it was important because sometimes we didn't do it | 3 |
| | B. I didn't really think about it | 0 |
| | C. I was ready and waiting to participate | 9 |
| 7. Usually it takes a long time to learn about what is happening to fisheries. So we want the data collection program to continue into the future. What do you think is the most important thing researchers can do to make sure of success in the future? | A. Show us that the information we collect is going to help us in the future | 9 |
| | B. Give us payment for our work | 0 |
| | C. Make sure that everyone in NTT and the rest of Indonesia understands that we are doing a good job—leading the way. | 3 |
| | D. Nothing will help—I don't want to do it anymore | 0 |
| 8. What qualities or behaviour are important for researchers when they interact with fishermen like yourself or conduct work such as this at the reef? | Ownership | 2 |
| | Kind/respectful/friendly | 8 |
| | good approach to engagement | 1 |
| | to be valued | 1 |
| 9. If you had one piece of advice for the Researchers for the future continuation of this data program what would it be? | Think about the future by making research effort to increase catches | 1 |
| | Must be implemented for all of fisherman not only the trepang fishery | 1 |
| | Making the information available so fishers can use it | 1 |
| | Overall well done; research to obtain a good price for the catch | 1 |

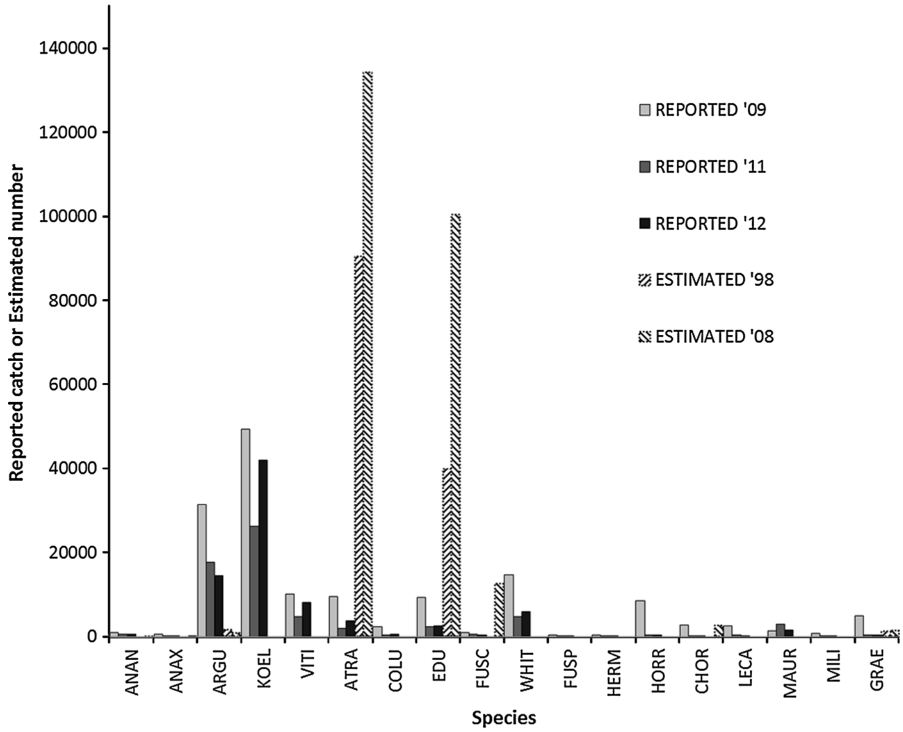


**Fig. 2** The estimated abundance of species from 1998 and 2008 visual transect surveys at Scott Reef (*dashed lines*) are plotted with the catches reported (estimated abundances were higher) by fishers in 2009, 2011 and 2012 (*solid lines*). Note that most of the catch was reported among species with a low or zero abundance estimate, i.e. none were observed on the transects. The species codes are: *Thelenota ananas* (ANAN); *T. anax* (ANAX); *Bohadschia argus* (ARGU); *B. koellikeri* (KOEL); *B. vitiensis* (VITI); *Holothuria atra* (ATRA); *H. coluber* (COLU); *H. edulis* (EDU); *H. fuscogilva* (FUSC); *H. whitmaei* (WHIT); *H. fuscopunctata* (FUSP); *Stichopus herrmanni* (HERM); *S. horrens* (HORR); *S. chloronotus* (CHOR); *Actinopyga lecanora* (LECA); *A. mauritiana* (MAUR); *A. miliaris* (MILI); and *Pearsonothuria graeffei* (GRAE)

others for participating and felt important. Some fishers reported they participated based on the incentive (fruit) provided but another fisher reported that one of the reasons he agreed to collect data was to pass the time while at the reef. Overwhelmingly, they reported that they participated because they wanted to (without incentive or threat of trouble for not participating) and that they considered the information would help the researchers and thus manage the fishery and by association help secure their livelihood. All of the respondents except one reported that they didn't have any negative experiences associated with the activity. The fishers who replied noted that the researchers needed to be friendly and respectful to fishers in undertaking this activity.

There was greater divergence in the responses in relation to what they enjoyed about participating, with fishers split almost equally between those that enjoyed it because researchers provided a treat on each visit and those that felt that the visits made them feel as though they were doing something important. Seventy-five percent of the interviewees stated that they were prepared to participate, when in 2010 and 2013, we did not have the means to conduct field work at the reef. Not surprisingly the same percentage of fishers said that the most important thing that researchers should do to keep interest up was to provide them with feedback on the data that they had collected so far. Fishers generally appreciated the researchers' friendly and respectful approach, which made them feel valued. However, one noted that the program should have been explained to them better.

## Discussion

Many countries around the world struggle to collect high quality catch and effort data from their small-

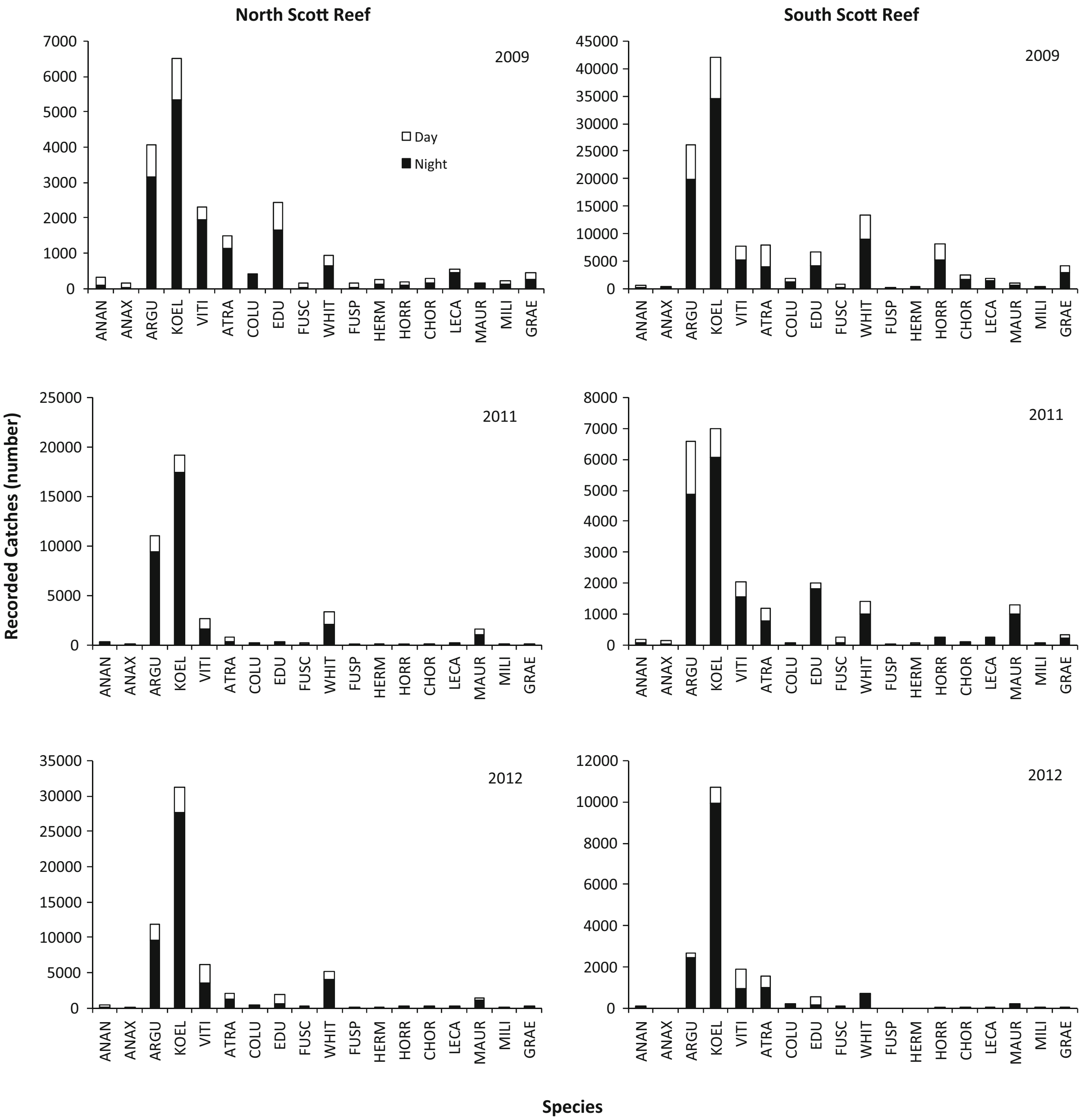


**Fig. 3** Catches recorded by fishers from day and night fishing episodes on north and south Scott Reef from fisher data collected in 2009, 2011 and 2012. Note the shift in catches recorded from South to North Scott Reef (*top right* to *below left*). Species codes are: *Thelenota ananas* (ANAN); *T. anax* (ANAX); *Bohadschia argus* (ARGU); *B. koellikeri* (KOEL); *B. vitiensis* (VITI); *Holothuria atra* (ATRA); *H. coluber* (COLU); *H. edulis* (EDU); *H. fuscogilva* (FUSC); *H. whitmaei* (WHIT); *H. fuscopunctata* (FUSP); *Stichopus herrmanni* (HERM); *S. horrens* (HORR); *S. chloronotus* (CHOR); *Actinopyga lecanora* (LECA); *A. mauritiana* (MAUR); *A. miliaris* (MILI); and *Pearsonothuria graeffei* (GRAE)

scale fisheries—data that routinely underpins fisheries assessments and management in most successfully managed fisheries. Socio-economic data have increasingly been given greater attention by jurisdictions moving towards more holistic approaches to their fisheries management, e.g. the ecosystem approach to fisheries management (EAFM) which should address broader societal objectives (FAO 2003). Despite resources and dedicated effort to expand catch and effort logbook programs many countries, for example in Indonesia where these fishers originate, many data are collected at the point of landing by dedicated "enumerators" or through the relevant fishery port authorities. However, by the time the catch is landed opportunities to collect relevant temporal and spatial data are usually lost. These are important data that often are needed to understand the dynamics of fisheries and to allow some assessment methods, for instance the removals method used to analyse the 2009 catch data in this fishery (Prescott et al. 2013) or methods applied to short-lived species (e.g. Zhou et al. 2009). The estimates of abundance and exploitation rates made using data recorded in 2009 are uncommon in sea cucumber fisheries but provide important information for management, such as acceptable levels of fishing effort, and were only possible because of the way the data were collected. Thus in this fishery and many other small-scale fisheries there can be enormous value in collecting data at the time and place that they are created and through an inclusive process with the fishers (Schroeter et al. 2009).

The 'quality' of the data recorded by fishers varied from perfectly accurate (validated by carefully enumerating the catch ourselves) to what were apparently estimates of the catch. While inferior to accurate counts of the catch, estimates by fishers are often accurate as it is in their interest to know their catches and in most fisheries reported catch data are generally estimated (FAO 1999) since most operations cannot weigh or accurately count catch at sea. However, how accurate (and unbiased) the estimates are is important. Given that the estimates from this fishery followed expected patterns influenced by the tidal cycles, the numbers recorded were consistent with our own observations of catch on board the vessels, and the estimates followed a common trend through the 3 years of data collection (Figs. 2, 3) we are confident that they accurately reflect the true catches. Finally, unlike in some fisheries where there may be perverse incentives for fishers misreport their catches, there were no such incentives in this fishery.

Recorded dates and times when fishers left and returned to their vessels was the one section of the data sheet in particular that was sometimes left blank or where reported times/dates became confused when fishing took place across the days, i.e. over midnight. However, even this confusing part of the form was completed remarkably well by some crews. Further, since the removals analysis (Prescott et al. 2013) binned the day and night catches and effort into seven day periods, these errors or omissions were unimportant in that analysis. And, since catches were recorded separately for day or night by design of the data sheet the issue of fishing times at the day scale were resolved. Collectively, the problems associated with the fishers recording their catches were not major and among the fishers some completed this task as well as fisher anywhere might be expected to do.

We experienced some of the common problems with fishery dependent data collection reported elsewhere, including difficulties around local and scientific names of some species (e.g. May 2005; Obura et al. 2002). With three ethnic groups involved in the fishery there were some differences in the local names, which required us to modify our data sheets in consultation with the fishermen. Taxonomy is also still problematic in sea cucumber fisheries and at Scott Reef the most numerous species in the catch was unknown to us when we started the program although it was readily distinguished by most of the fishers who knew it as "bintik loreng" or "polos loreng". It wasn't until 2013 that we finally identified it as *Bohadschia koellikeri* based on work by Kim et al. (2013).

The evaluation of fishers' perceptions of the data collection program showed that they felt trust and respectful behaviour was important to facilitate the benefits provided by their participation in the program and that the information collected could contribute positively to management of the fishery and ultimately improve their livelihood outcomes. Our program could have been improved with more frequent communication including about the program's objectives and its results. However, communicating with fishermen in remote communities in different parts of Indonesia was beyond our means. Disruptions in the continuity of the data collection program in 2010, 2013 and most recently in 2014 have caused some fishers at least to question the importance of the program which is unfortunate.

We believe the potential for collaborative fisheries monitoring programs like the one for this small-scale fishery and others similar to it should be pursued in the region but with added emphasis on fisher participation from the research design and interpretation stages (Stanley and Rice 2007) through to the management of the fishery alongside the researchers and managers. This approach is advocated for in the recently launched FAO Voluntary Guidelines for Securing

Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication, which are focussed on developing country contexts (FAO 2015).

While these approaches are very positive for the fishery at Scott Reef and many small-scale sea cucumber fisheries globally (e.g. see Eriksson et al. 2010; Purcell et al. 2013) serious challenges need to be met and overcome for the process to effect better sustainability outcomes. Data recorded by the fishers in our study were used to estimate the abundance of six important species of sea cucumbers in the harvest taken by fishers on South Scott Reef (Prescott et al. 2013). These estimates of abundance were, with the exception of several very low value species, much higher than estimates obtained using standard visual transect methods which in isolation could be seen as positive. However, the analyses also showed that the exploitation rates were extremely high leading to a situation where, in most managed fisheries a management intervention with serious short-term consequences for the fishery and its participants could have been triggered. Such situations are clearly problematic and fishers might have felt quite differently about ongoing participation if the data they collected were seen to harm them—emotions likely to be felt regardless of any perceptions fishers may have about the need for better management. On the other hand, if the fishery independent survey data which indicated extreme depletion but did not correspond well to the species and numbers they harvested had led to management intervention they may have found any intervention even more confronting.

Aside from the data produced, the participative data collection program provided many opportunities for the research team and the fishers to interact and discuss many issues of mutual interest and establish some durable personal relationships. We believe that this was also an opportunity to repeatedly test each other with regard to our true intentions and commitment to the program and build trust. Despite these 'quality' interactions we concede that our intentions and longer-term goals are still not well enough understood. Maintaining sustainable partnerships such as the one we have described will, over time, continue to present challenges as government priorities and funding opportunities wax and wane (Obura et al. 2002). In the fishery at Scott Reef there is the added element of negotiation and agreement between the Australian and Indonesian governments required to operationalise a longer term joint research program and manage the fishery (for background on these tensions see Fox 2009; Stacey 2007). While the research has produced positive outcomes it is left to management to utilise the information for it to have value by intervening to curtail overfishing, rebuild stocks while, hopefully, minimising effects on the livelihoods of the participants. The future of the fishery is also dependent on other issues such as global markets and commodity prices for luxury seafood products as well as a steady and secure collaborative bilateral relationship between the Australian and Indonesian governments to manage the offshore traditional fishery.

In the future, involving the fishers in fisheries or biodiversity monitoring in the MOU Box may not only be a cost-effective alternative and viable approach for informing management of this currently unmanaged fishery but could provide added benefits through economic incentives for fishers (Stacey et al. 2012). Numeracy and literacy capacity building could also be incorporated into the program (Ticheler et al. 1998; Wiber et al. 2004) and given greater support in fishing communities which could contribute to better fishery dependant livelihood outcomes overall (Agnew et al. 2013; Gutiérrez et al. 2011; Prince 2003).

Ultimately, the survival of the program will depend on committed effort by Australia and Indonesia to maintain it and a deeper understanding by fishers of the programs' objectives and potential to help them move towards more secure long-term livelihoods. This should include an informed agreement between researchers and fishers on how the results will be used and organic support by the fishers who understand that their data may not paint a 'pretty picture', and may lead to changes in access or other management intervention. This is another challenge but it is tractable and it should be pursued.

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## References

Agnew DJ, Gutiérrez NL, Butterworth DS (2013) Fish catch data: less than what meets the eye. Mar Policy 42:268–269

Almany GR, Hamilton RJ, Williamson DH, Evans R, Jones GP, Matawai M, Potuku T, Rhodes KL, Russ GR, Sawynok B (2010) Research partnerships with local communities: two case studies from Papua New Guinea and Australia. Coral Reefs 29:567–576. doi:10.1007/s00338-010-0624-3

Andrews N, Bene C, Hall SJ, Allison EH, Heck S, Ratner BD (2007) Diagnosis and management of small-scale fisheries in developing countries. Fish Fish 8(3):227–240

Danielsen F, Burgess ND, Balmford A, Donald PF, Funder M, Jones JPG, Alviola P, Balete DS, Blomley T, Brashares J, Child B, Enghoff M, Fjeldså J, Holt S, Hübertz H, Jensen AE, Jensen PM, Massao J, Mendoza MM, Ngaga Y, Poulsen MK, Rueda R, Sam M, Skielboe T, Stuart-Hill G, Topp-Jørgensen E, Yonten D (2009) Local participation in natural resource monitoring: a characterization of approaches. Conserv Biol 23:31–42. doi:10.1111/j.1523-1739.2008.01063.x

DeLury DB (1947) On the estimation of biological populations. Biometrics 3:145–167

Eriksson BH, Torre-Castro M, Eklöf J, Jiddawi N (2010) Aquat Living Resour 23:387–398

Eriksson H, Österblom H, Crona B, Troell M, Andrew N, Wilen J, Folke C (2015) Contagious exploitation of marine resources. Front Ecol Environ 13(8):435–440

Erisman BE, Allen LG, Claisse JT, Pondella DJ II, Miller EF, Murray JH (2011) The illusion of plenty: hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. Can J Fish Aquat Sci 68(10):1705–1716

Ernst B, Manríquez P, Orensanz JM, Roa R, Chamorro J, Parada C (2010) Strengthening of a traditional territorial tenure system through protagonism in monitoring activities by lobster fishermen from the Juan Fernández Islands, Chile. Bull Mar Sci 86(2):315–338

FAO (1999) Guidelines for the routine collection of capture fishery data. FAO Fisheries Technical Paper. No. 382. FAO, Rome

FAO (2003) The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. FAO, Rome

FAO (2015) Voluntary guidelines for securing sustainable small-scale fisheries in the context of food security and poverty eradication. FAO, Rome

Fox JJ (1977) Notes on the Southern Voyages and Settlements of the Sama-Bajau. Bijdragen Tot de Taal-, Land- en Volkenkunde 133(4): 459–465

Fox, JJ (2009) Legal and illegal Indonesian fishing in Australian waters. In: Cribb, R and M. Ford (eds) Indonesia beyond the waters' edge: managing an archipelagic state. Institute of Southeast Asian Studies, Singapore, pp 195–220

Gutiérrez NL, Hilborn R, Defeo O (2011) Leadership, social capital and incentives promote successful fisheries. Nature 470:386–389

Haggan N, Neis B, Baird IG (eds) (2007) Fishers knowledge in fisheries science and management. UNESCO, Paris

Harley SJ, Myers RA, Dunn A (2001) Is catch-per-unit-effort proportional to abundance? Can J Fish Aquat Sci 58:1760–1772

Hilborn R, Walters CJ (1992) Quantitative fisheries stock assessment. Chapman & Hall, New York

Hind EJ (2014) A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science. ICES J Mar Sci 72(2):341–358. doi:10.1093/icesjms/fsu169

Kaplan IM, McKay BJ (2004) Cooperative research, co-management and the social dimension of fisheries science and management. Mar Policy 28:257–258

Kim SW, Kerr AM, Paulay G (2013) Colour, confusion, and crossing: resolution of species problems in Bohadschia (Echinodermata: holothuroidea). Zool J Linnean Soc 168(1):81–97

MacKnight CC (1976) The voyage to Marege': Macassan Trepangers in Northern Australia. Melbourne University Press, Melbourne

May D (2005) Folk taxonomy of reef fish and the value of participatory monitoring in Wakatobi National Park, Southeast Sulawesi, Indonesia. SPC Traditional Mar Resource Manag Knowl Inf Bull 18:18–35

Moller H, Berkes F, Lyver POB, Kislalioglu M (2004) Combining science and ecological knowledge: monitoring populations for co-management. Ecol Sci 9(3):2

Obura DO, Wells S, Church J, Horrill C (2002) Monitoring of fish and fish catches by local fishermen in Kenya and Tanzania. Mar Freshw Res 53(2):215–222

Prescott J, Vogel C, Pollock K, Hyson S, Oktaviani D, Panggabean AS (2013) Estimating sea cucumber abundance and exploitation rates using removal methods. Mar Freshw Res. doi:10.1071/MF12081

Prescott J, Riwu J, Steenbergen DJ, Stacey N (2015) Governance and Governability: the small-scale purse seine fishery in Pulau Rote, eastern Indonesia. In: Jentoft S, Chuenpagdee R (eds) Interactive governance of small scale fisheries: global reflections. MARE Series 13. Springer. New York, pp 61–84

Prince JD (2003) The barefoot ecologist goes fishing. Fish Fish 4:359–371

Purcell SW, Mercier A, Chantal C, Hamel JF, Toral-Granda MV, Lovatelli A, Uthicke S (2013) Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. Fish Fish 14:1. doi:10.1111/j.1467-2979.2011.00443.x

Ricker WE (1975) Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada. Bulletin 191 Ottawa

Schroeter SC, Gutiérrez NL, Robinson M, Hilborn R, Halmay P (2009) Moving from data poor to data rich: a case study of community-based data collection for the San Diego red sea urchin (*Strongylocentrotus franciscanus*) fishery. Mar Coast Fish 1:230–243

Skewes T, Dennis D, Jacobs D, Gordon S, Taranto T, Haywood M, Pitcher C, Smith G, Milton D, Poiner I (1999) Survey and stock size estimates of the shallow reef (0–15 m deep) and shoal area (15–50 m deep) marine resources and habitat mapping within the Timor Sea MOU74 Box. Volume 1: Stock estimates and stock status. Technical report, CSIRO Marine Research

Stacey N (2007) Boats to Burn: Bajo fishing activity in the Australian Fishing Zone. Asia-Pacific Environment Monograph Series. ANU E Press, Canberra

Stacey N, Karam J, Meekan M, Pickering S, Ninef J (2012) Prospects for whale shark conservation in eastern Indonesia through Bajo traditional ecological knowledge and community-based monitoring. Conserv Soc 10(1):63–75

Stanley RD, Rice J (2007) Fishers' knowledge? Why not add their scientific skills while you're at it? In: Haggan N, Neis B, Baird IG (eds) Fishers' knowledge in fisheries science and management. UNESCO Publishing, Paris, pp 401–420

Ticheler HJ, Kolding J, Chanda B (1998) Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu Swamps, Zambia. Fish Manage Ecol 5:81–92

Toral-Granda V, Lovatelli A, Vasconcellos M (eds) (2008) Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. FAO, Rome

Wiber M, Berkes F, Charles A, Kearney A (2004) Participatory research supporting community-based fishery management. Mar Policy 28:459–468

Wilson DC (2003) The community development tradition and fisheries co-management. In: Clyde WD, Neilson JR, Degnbol P (eds) The fisheries co-management experience; accomplishments, challenges and prospects. Kluwer Academic Publishers, Fish and Fisheries Series 26. Dordrecht, pp 265–277

Zhou S, Punt AE, Deng R, Dichmont CM, Ye Y, Bishop J (2009) Modified hierarchical Bayesian biomass dynamics models for assessment of short-lived invertebrates: a comparison for tropical tiger prawns. Mar Freshw Res 60:1298–1308