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Elviro A. Cinco, Lydia C.L. Teh, Kyrstn Zylich
and Daniel Pauly

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Email: eacinco@gmail.com

RECONSTRUCTING THE MARINE AND ESTUARINE FISHERIES OF BRUNEI DARUSSALAM, 1950 TO 2010

Elviro A. Cinco[a], Lydia C.L. Teh[b], Kyrstn Zylich[b] and Daniel Pauly[b]

[a] Department of Fisheries, Ministry of Industry and Primary Resources,
Jalan Menteri Besar, Berakas BB3910, Brunei Darussalam
[b] *Sea Around Us*, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, Canada, V6T 1Z4

eacinco@gmail.com; Lydia.teh@fisheries.ubc.ca; k.zylich@fisheries.ubc.ca; d.pauly@fisheries.ubc.ca

ABSTRACT

Following a brief review of coastal resources development in Brunei Darussalam since the early 1950s, notably offshore oil, a short history of its fisheries resource exploitation is presented. The reconstructed total catch of the domestic fisheries is presented for 1950 to 2010, which exceeds by a factor of 4 times the figures reported to the Food and Agriculture Organization of the U.N. The mean annual catch taken from the waters later claimed as Exclusive Economic Zone (EEZ) were, in the 1950s, 2,900 t·year^{-1}, and were generated exclusively by small-scale fisheries (mainly artisanal, some subsistence, notably by the inhabitants of 'Kampong Ayer', the 'water village' at the heart of Brunei Bay). The fishery was industrialized starting in the early 1970s, and industrial catch doubled by 1984 when trawling began in earnest, with total catches reaching a first peak in 1991 at 10,100 t. Catches started to increase again in 1999 and have averaged 17,050 t·year^{-1} since 2000, with about a third consisting of purse seine and bottom trawl landings and their discards. Whereas landings reported to the FAO suggest a reduction of 53% in total catches in the 2000s compared to late 1990 levels, this reconstruction shows an increasing trend. Proportional declines in the industrial sector have been offset by increased contribution from the small-scale sector, which averaged 66% of total catch in the 2000s, and a small but growing recreational fishery which contributed about 1.3% of Brunei's total catch since 1970.

INTRODUCTION

Fisheries are a minor economic sector in Brunei Darussalam (hereafter referred to as 'Brunei'), contributing only 0.3% to national GDP in 2010 (JPKE 2011). The main source of income for Brunei is (offshore) oil and gas, upon which the country has been reliant since the late 1920s, and which accounts for over 90% of exports[1]. While marginal in terms of national income, Brunei's marine fisheries play an important role in obtaining seafood, of which the population annually consumes up to 47 kg·person^{-1} (Lo 2013), although about half is currently imported from neighbouring countries[2]. The majority of fishing in Brunei is undertaken by small-scale artisanal fishers using motorised boats and traditional gears. The industrial 'large-scale' sector entered its growth phase in the 1980s, and has been subject to close monitoring by the Department of Fisheries (DoF). Brunei's small-scale sector is less scrutinised; DoF started monitoring the catch of full-time fishers in 1982, but not the catch of part-time fishers (Chua *et al.* 1987), who are significantly more numerous than the former. Inconsistencies exist in data collection and reporting, where total fish landings are only partially reported to the FAO and do not correspond with total withdrawals from Brunei's waters. These shortcomings in Brunei's marine fisheries catch statistics will be addressed in this report, which assembles data from the primary literature, unpublished national records, and fisheries experts, as well as estimates unreported catches from fish discards, recreational fishing, and illegal fishing, to present a comprehensive picture of historical marine fish catches in Brunei from 1950-2010 as is possible with available information.

[1] The Brunei Economic Development Board. URL: www.bedb.com.bn /why_ecoverview.html. Accessed 18 March 2014.
[2] http://en.wikipedia.org/wiki/Fishing_industry_in_Brunei Accessed 18 March 2014; see also Subramaniam (1993).

Background

Brunei Darussalam, a small Islamic sultanate on the north coast of Borneo (or 'Kalimantan'; Figure 1), is surrounded by the Malaysian state of Sarawak and has a coastline that faces the South China Sea. The near-shore habitat is characterised by soft bottom substrate and minor patches of coral reefs. The Exclusive Economic Zone (EEZ) of Brunei is, with 38,600 km^2 (Silvestre *et al.* 1992) rather small and limits domestic catch levels. Brunei's population in 2010 was 393,000, with some 85% of the population living along the coastal zone (Silvestre *et al.* 1992).

Marine fisheries in Brunei can be split into 'small-scale' and 'large-scale' segments. Small-scale fishing in Brunei take places primarily around Brunei Bay and in near shore waters (within 3 nm) in the South China Sea, although fishers from some communities travel up to 40 km offshore daily (Lim 1986), using small boats with outboard engines ranging from 25 to 40 hp (Chua *et al.* 1987). About 60% of the fish caught in Brunei originates from small-scale fishers, who use traditional gears including trammel nets, hand lines, gill nets, small purse seines, traps, drift nets, and cast nets (Chua *et al.* 1987). Small-scale fisheries are multi-species in nature, with catches comprising a mix of small pelagics, demersals, and shrimps.

The large-scale commercial fishing fleet (here labelled as 'industrial) consists primarily of trawlers, followed by purse seiners and long liners. The offshore demersal trawl fisheries started operating in 1984, and in 1985 purse seiners were licensed for the offshore pelagic fishery. In general, the issuance of industrial licenses is tightly controlled by the DoF, and the current fleet is made up of 43 fishing vessels, almost half of them trawlers. Trawl catches are dominated by ponyfish (Family Leiognathidae), which make up one third to over half of total trawl catches (Chua *et al.* 1987; Silvestre *et al.* 1992), while purse seiners land mostly scads (*Selar* spp.), sardines (e.g., *Sardinella* spp.), and Indian mackerel (*Rastrelliger kanagurta*) (Silvestre *et al.* 1992). A substantial amount of trawled fish is discarded at sea, hence not reported as part of fish landings (Chua *et al.* 1987), due to the absence of a market for low value fish in Brunei. On the other hand, small pelagic fishes from purse seines are utilised for making fish crackers and other dried or salted food products[3].

Brunei has one of the highest *per capita* fish consumption rates in the region, reported to range between 40 to 47 $kg \cdot person^{-1} \cdot year^{-1}$ (Silvestre *et al.* 1992; Lo 2013). However, the local fisheries do not meet the country's seafood demand. Since the mid-1960s, the proportion of marketed fish that is locally caught decreased substantially from 80% to about 45% by 1990 (Silvestre *et al.* 1992), and Brunei relies on imports for about half of its fresh fish supply (Lo 2013). The bulk of fish imports arrive by air, land and sea from neighbouring Sarawak and Sabah (Mohd Ariff and Bakeri 1998).

Historical development

In the past, Brunei's culture and economy was strongly tied to the marine environment. The majority of the population lived in an area known as Kampong Ayer (Water Village), the historical hub of Brunei (Chua *et al.* 1987), and actively participated in maritime trade (Abdul Rahim 2007b). This marine orientation decreased when the then Sultan of Brunei accepted the British residency system (1906-1959), under which a land-based economy was sought and people were gradually shifted from fishing to agriculture and mining jobs. Fishing declined further during World War II, when residents of Kampong Ayer fled into the jungle to avoid the oppression of occupying Japanese troops. Steps to improve fisheries management were put in place after the war. In contrast to the previous decade, the 1950s saw plans for modernising Brunei, as set out in the first 'Rancangan Kemajuan Negara' (RKN, Country Development Plan) for 1953-1958. To realise the infrastructure and economic development goals set out in the RKN, migrant labourers from China, India and neighbouring countries were brought to Brunei. The arrival of these additional people necessitated additional food supply, and fish, being the cheapest source of protein, was the preferred source (Abdul Rahim 2007b). For this reason, in 1955 financial resources were directed towards improving traditional fishing methods with the goal of accelerating fisheries development in Brunei.

[3] Juna MH, Wahab RHA, Cinco EA. National Country Report for Brunei Darussalam. Department of Fisheries, Brunei Darussalam. URL: http://www.seafdec.org.my/tag/PDF/Brunei/htm.

Initial fisheries surveys carried out by the Brunei government in 1949 and 1950 were in shallow waters in Brunei Bay as well as the open sea, used a variety of gears including trawls, seine nets, and gill nets, and concluded that there was not adequate fish for commercial operations (Birkenmeier 1969). Offshore fisheries development was targeted to increase local fish production. To this extent, the trawl fishery - starting with one vessel in 1967 - concentrated its operations off the northwestern coast of Brunei, relatively close to its main markets in the capital city of Bandar Seri Begawan. This led rather rapidly to a local depletion of the trawlable biomass, detected due to regular research trawl surveys (see Pauly 1989), and the decision was taken to embed an evaluation of Brunei's marine fisheries in a comprehensive coastal zone management project[4], whose key results were presented in Chua *et al.* (1987) and Silvestre *et al.* (1992).

Fisheries management

Brunei's fisheries fall under the authority of the Department of Fisheries, Ministry of Industry and Primary Resources, which is responsible for overseeing all aspects of management, including fisheries research, enforcement, marketing, conservation and development (Silvestre *et al.* 1992). The DoF has generally been conservative in its approach to fisheries management, as seen in the cautious expansion of the country's industrial offshore fisheries. Overall, the government's objective for fisheries development is to improve food security, national self-sufficiency, and socio-economic status of fisheries sector workers (Chua *et al.* 1987).

A key fisheries management initiative is the use of fishing zones to ensure sustainable exploitation of marine resources and to minimise conflict between small- and large-scale fishers. The fishing grounds were split into 4 zones defined by distance from the coast, with regulations defining the type of gear, fishing method, and vessel type that are permissible in each zone. Fishing effort in the industrial sector is controlled by limiting the number of licenses that are issued to trawl, purse seine and long line fishing vessels, and catches are monitored through monthly catch logbooks that industrial fishing vessels are required to complete. In addition, a series of offshore fisheries resource surveys have been conducted to assess the status of demersal stocks, and from 2003 to 2005 biological data were collected on pelagic fishes[3]. Fishing effort in the small-scale sector is not controlled as tightly, as the number of fishers was allowed to double between 2000 and 2005. Monitoring of small-scale fish catches is limited to those from full-time fishers (Chua *et al.* 1987), despite the fact that there can be up to 3 times more part-time fishers.

Fisheries statistics have been published annually in the Brunei Darussalam Statistical Yearbook since 1987, and include marine production, participation level, gear usage, and the volume and price of fresh fish sold at licensed markets throughout Brunei. These statistics, however, do not include detailed species composition, nor are they broken down by fishing gear. Data for the industrial sector is fairly reliable due to existing controls, with fish discards from trawling being the main omission. Small-scale catches are estimated based on a sample of registered fishers by village or district, with each type of fishing gear being represented in the sample. Fishers provide daily records of their catch, including the gear used and species caught. Total daily catch data are then extrapolated to weekly, monthly and annual catch estimates. There is discrepancy between nationally reported fisheries statistics and those reported to the FAO, with national statistics being much higher.

Brunei's fisheries resources were relatively well documented during 1987-1991 as the result of a coastal zone management project (see Pauly *et al.* 1997; Silvestre and Garces 2004), as were the economics of their exploration (Cruz-Trinidad *et al.* 1997). Indeed, it is because this knowledge of marine resources had been generated that Brunei would become the first country to which Ecospace, a spatial ecosystem modelling software, was applied (Walters *et al.* 1998). A more up to date review of Brunei's fisheries resources is now needed.

In recent years, there is growing concern over the increasing numbers of fishers and the degradation of the marine ecosystem (Ebil *et al.* 2013). Illegal fishing by foreign fishing vessels in Brunei's EEZ is also a recurrent, unresolved problem that incurs a large environmental and economic cost to Brunei (Masli

[4] This project, which benefited from USAID funding, was executed by the Manila-based International Center for Living Marine Resources (ICLARM), now the WorldFish Center, based in Penang, Malaysia.

2011). Challenges for future sustainable fisheries management in Brunei include improving the fisheries data collection and reporting system, implementing an effective Monitoring, Control, and Surveillance MCS) system[5], and developing adequate technical expertise and scientific knowledge among fisheries officers.

METHODS

Reported landings

Annual reported marine fisheries landings from 1950-2010 were extracted from FAO FishStat (Garibaldi 2012), and represent the 'reported' data baseline used in this reconstruction. Brunei's marine landings were categorized into 8 taxonomic groups covering finfish and invertebrates. Landings were not further disaggregated by fishing gear or vessel type.

Unreported catch

Total marine fish landings in Brunei that are recorded in national fisheries statistics are only partially reported to the FAO; thus the unreported portion is treated as 'unreported catch' (with respect to FAO data) in this reconstruction. Unreported catches in Brunei originate from the following sources: i) unlicensed and part-time small-scale fishers; ii) the industrial sector; iii) discards; iv) illegal fishing; and v) recreational fishers.

National fisheries catch statistics

In the absence of dedicated fisheries statistics from 1950 to 1976, the bulk of information for this time period was extracted from successive *Annual Reports on the State of Brunei*, which was one of the few annually issued publications that included short descriptions of the fisheries of the country[6]. These reports, which contain general socio-economic and political statistics for each year, also include fisheries catches (in piculs and katis[7]), but without any detailed species composition. They also include the number of licensed fishing gears, but without catch breakdown by gear type. Limited fisheries catch statistics were also extracted, for 1974 to 1986 from the *Brunei Statistical Yearbook*, and from its successor, the *Brunei Darussalam Statistical Yearbook* (from 1987 onwards). These statistics however, also lack detailed breakdown of catch by species and gear type.

Issues of the *Fishery Statistical Bulletin for South China Sea Area*, and its successor, the *Fishery Statistical Bulletin of Southeast Asia* issued by the Southeast Asian Fisheries Development Center (SEAFDEC) for 1973 to 2009 were also used, although the data therein referred mainly to the industrial sector, i.e., the landings of bottom trawlers, as provided by the Brunei Department of Fisheries.

Small-scale catch

Small-scale sector catch statistics from 1950-2010 were provided by the DoF. These data account for unregistered fishers, whose numbers have been much reduced in recent years (E. Cinco, pers. obs.). For validation, a second, independent estimate of small-scale catches was conducted.

Total catch from the small-scale sector (C_{ss}) from 1950-2010 was also estimated on the basis of local fish consumption as:

$$C_{ss} = P * F * SS$$

where P is Brunei's total population, F is the *per capita* fish consumption, and SS is the percentage of fish that is caught by the small-scale sector

Fish consumption was 35 kg·person^{-1}·year^{-1} and 38 kg·person^{-1}·year^{-1} in 1985 and 1990 respectively (derived from Silvestre *et al.* 1992), continued to rise to 40 kg·person^{-1}·year^{-1} in 2002 (Mohd Ariff and

[5] Combating IUU Fishing in the Southeast Asian Region. URL: www.seafdec.or.th/iuu.
[6] State of Brunei Annual Report, 1950-1975. Printed by Simon Marinus Buse, Government Printer for the State of Brunei.
[7] One pikul = 100 katis; 1 pikul = 60.48 kg; 1 kati = 0.6048 kg.

Bakeri 1998) and was 47 kg·person^{-1}·year^{-1} in 2010 (Lo 2013). We applied the 1985 fish consumption rate to all years from 1950 to 1985, and linearly extrapolated values between these anchor points.

The catch estimated through *per capita* fish consumption rates was only used to validate the data and was not used in the final database. The proportion of fish caught by the small-scale sector (*SS*) was calculated from Brunei fish catch data provided by the DoF, where total catch was broken down by small-scale and industrial sectors.

Industrial catch
Industrial sector catch statistics from 1975-2010 were provided by the DoF. No further validation was conducted given the close monitoring of this sector by the DoF, hence reported industrial data were accepted as the most accurate data available.

Discards
Brunei's trawl fisheries have high discard rates due to the lack of markets for low value fish (Funge-Smith *et al.* 2005). Estimates of discard rates range from 30-40% of total trawl catches in 1984-1988 (Silvestre *et al.* 1992; Abdul Rahim 2007a) to almost 75% in 1998 (Kelleher 2005). We started to account for discards in 1975, applying the average discard rate of 35% for the 1984-1988 period and then linearly increased it to the second anchor point of 75% in 1998 and kept this value constant until 2010.

Foreign illegal catch
Illegal catch data were provided by the DoF for 2006-2010. During this period, illegal catch ranged between 8 to 38% of total annual industrial catch, and are considered a conservative estimate of the actual level of illegal fishing that takes place in Brunei's waters (Masli 2011). We started accounting for illegal fishing in 1970, around the time industrial trawlers were at their peak in Southeast Asia (Butcher 2004), and applied a very conservative average illegal catch rate of 23% to derive a minimal estimate of illegal catch in all years without DoF data. We assumed that illegal fishing was conducted primarily by vessels from Vietnam and Malaysia, as fishers of these nationalities have been detained and fined by Bruneian authorities in the past three years (Bandial 2011; Masli 2011).

Recreational fishery
We start accounting for recreational catches in 1970, assuming that the sector established its presence in the same year as that in neighboring Malaysia (Teh and Teh 2014). Interest in marine sport fishing in Brunei has grown considerably in the past 10 years and the sector is expanding (Airudin 2013). Recreational fishers are required to obtain a license that permits fishing for 3 days, but this requirement does not appear to be strictly enforced. Some recreational fishers may be registered among part-time fishers, who are given a one year fishing license. Data on the number of issued recreational licenses were not readily accessible and limited to 3 years - 2007, 2008 and 2010, in which there were 165, 177, and 165 registered recreational fishers, respectively. We found no strong evidence of catch and release fishing, although it is supported by some local sport fishing operators (Airudin 2013).

The only other indication of the number of recreational fishers we could find was a report of 240 participants in a sport fishing competition in 2009 (Anon. 2009). In the United States, the percentage of recreational fishers who participated in tournaments varied from 3% for catfish anglers in North Carolina in 2011 (Responsive Management 2012), to between 0% and 9% for freshwater fishers in Texas between1989-1997 (Hunt and Ditton 2002). As we were more interested in recreational fishers' tendency to participate in tournaments rather than the type of fishing that took place, and further due to lack of data on fishing tournament participation rates in Asia, we applied the United States rates to Brunei. We assumed that the number of participants in the 2009 fishing competition represented no more than 10% of recreational fishers in Brunei. This resulted in 2,400 recreational fishers in 2009, or 0.62% of the country's total population. To account for growth in the sport fishing sector in the past decade (Airudin 2013), we halved the proportion of recreational fishers (i.e., 0.3%) in 2000 and linearly increased forward to the anchor point in 2009, which was then kept constant to 2010. We assumed that from 1970 to 1999, the proportion of recreational fishers remained the same as that in 2000.

Recreational catch: We searched the internet for photo documentation of recreational fish catches in Brunei (e.g. Brunei Sport Fishing blog URL: http://bruneisportfishing.blogspot.ca/) and estimated the weight of fishes by approximating their length and applying the length-weight relationship (www.fishbase.org). Fishes caught included brackish water fish such as barramundi (Latidae), mangrove jack (Lutjanidae), grouper (Serranidae), grunts (Haemulidae), jacks (Carangidae), tuna (Thunnidae), mackerels (Scombridae), rays and at least one hammerhead shark. All assessed fishes were caught using fishing lines from shore-based locations along Brunei's coast or from boats in open water. Based on this qualitative assessment, we estimated an overall average catch of 6 $kg \cdot fisher^{-1} \cdot trip^{-1}$, and further assumed that recreational fishers fished 2 times per month, 10 months per year[8], to arrive at an annual recreational catch rate of 120 $kg \cdot fisher^{-1}$. Total annual catch from the marine recreational sector was then estimated by multiplying the number of recreational fishers by the annual catch rate.

Sectoral breakdown

According to the DoF, FAO reported landings from 1950-1963 can be attributed to the small-scale sector, and thereafter to the industrial sector. Small-scale sector catches were further categorised as either subsistence (i.e., non-commercial) or artisanal (i.e., commercial) catch. We define subsistence catch as that fished primarily to satisfy household consumption needs and artisanal catch as that fished primarily to bring to market. The following anchor points were used for splitting small-scale catches to their subsistence and artisanal components.

1950: In the early 1950s, Bruneian fishers began developing relationships with (ethnic) Chinese middlemen, whereby the latter acted as outlets for the sale of fresh fish and providers of capital (e.g., for outboard engines) (Lim 1986). This suggests that the majority of fishers were selling at least part of their catch in order to earn income to equip their boats with outboard engines, which were introduced in Brunei in 1952 (Lim 1986). Given the pervasiveness of the cash economy in Brunei at that time, we assume that at least 75% of fishers could be classified as 'artisanal'.

1980: In 1980, an anthropological study of a Brunei fishing village documented that about 7% of a fisher's total daily catch was kept for home consumption or given away to friends, while the remainder was sold (Lim 1986). We assumed that the proportion of consumed/marketed fish was representative of the subsistence/artisanal split among fishers, i.e., 93% of small-scale catches are allocated as artisanal and 7% as subsistence.

2010: We assume that almost all fishers sell at least some of their catch for income, and halve the proportion of subsistence catches to 3.5% of small-scale fishers' catch.

Catch composition

The composition of trawl catches from 1993-2010 was provided by the DoF, and those for 1970, 1980, and 1990 were based on trawl demersal surveys (Beales 1982; Silvestre *et al.* 1992). Linear interpolation was used to fill data gaps between anchor points. Purse seine catches in 1985 and the period 2003-2005 were broken down as shown in Table (2). We linearly interpolated between anchor points to fill in missing data, and kept the 2005 values constant to 2010. We applied the trawl catch composition to illegal foreign fish catches, given that illegal fishing vessels detected in Brunei are usually identified as being trawlers[9] (Chua *et al.* 1987). We assumed that the composition of fish discards from trawlers was similar to that in neighbouring Malaysia. We selected all species that made up >5% of Malaysian discards and then broke down Bruneian discards according to the relative abundance of selected Malaysian discard species (Table 3).

Temporal data on small-scale catch composition were available only for the period 1982-1991, and were provided by the DoF. In the absence of further data, we broke down catches in 1995 using the composition of fish landed and marketed in two towns located along Brunei Bay in neighbouring Sarawak (Mohd Ariff

[8] http://www.fredfishing.com/fishcomp/news2009/bb/bbfishcomp.html. Accessed 25 March 2014.
[9] The Brunei Times, 26 November 2008. *'Marine police bust illegal trawlers'* URL: http://www.bt.com.bn/home_news/2008/11/26/marine_police_bust_illegal_trawlers. Accessed April 2014;

and Bakeri 1998). The 1982 catch proportions were applied to all years prior, back to 1950, while the 1995 anchor point was kept constant to 2010.

Recreational catch composition was approximated on the basis of photos posted on a sport fishing website (www.bruneifishing.com), which suggested that most fishers fished from shore, with typical catches consisting of demersal fishes. Pelagic fishes such as marlins, tunas, jacks, and Spanish mackerels are reportedly abundant in offshore fishing grounds (Bahrum 2009). Given the absence of data, we assumed that a major proportion (i.e., 80%) of recreation catch consisted of demersals from shore-based fishing and the remainder (i.e., 20%) of pelagic fish. We then evenly weighted the major fish groups within the two categories, i.e., 16% to each of sea catfish (Family Ariidae), barramundi (Latidae), emperors (Lethrinidae), snappers (Lutjanidae), groupers (Serranidae); and 5% each to jacks (Carangidae), marlins (Istiophoridae), mackerels (Subfamily Scombrinae) and tunas (Thunninae).

RESULTS

Brunei's reconstructed domestic catch increased from an average of 2,900 t·year^{-1} in the 1950s to an average of 17,000 t·year^{-1} in the 2000s (Figure 2a). This estimate is 4 times the landings reported by the FAO on behalf of Brunei. A further 20,600 t was taken illegally from Brunei's waters since the early 1970s.

Unreported domestic catches totalled 369,000 t during the period of the reconstruction, with about 79% stemming from small-scale artisanal and subsistence fishing, followed by industrial fishing (6.5%), discards (14%), and recreational fishing (1.3%). Reconstructed industrial landings (discards not included) grew most between 1977 and 1987, when they comprised on average 41% of reconstructed total catch compared to 20% in the late 2000s. Catches from the 1950s to early 1960s were entirely small-scale in nature, but in the 2000s, this contribution averaged 64% of reconstructed total catch, primarily from artisanal (i.e., small-scale commercial) fishing (Figure 2a).

Pelagic fish were a major component of reconstructed catches, with sardines (Clupeidae) and small mackerels (Scombridae) accounting for one third of total catch. Penaeid shrimps were also abundant in the catch, making up 17% of total reconstructed catch from 1950-2010, but declining from 28% in the 1950s to 14% in the 2000s. In contrast, low value and/or 'miscellaneous fish', including *Apogon* spp., *Saurida* spp., *Stolephorus* spp., and inedible crabs, have increased in the catch (largely due to discards) from a low of about 2% in the early 1960s to an average of 14% in the 2000s (Figure 2b).

Total small-scale catch (1950-2010) calculated as part of the validation process amounted to 359,000 t, which was 20% higher than the estimated 300,000 t by the DoF. Differences varied across time, with the largest discrepancy occurring in the 1980s when DoF small-scale catch data averaged 3,600 t·year^{-1} compared to 6,000 t·year^{-1} from the fish consumption approach.

DISCUSSION

This reconstruction represents a first attempt at estimating total marine fish catches (i.e., extractions, thus including discarded catch) taken from Brunei's EEZ from 1950 to 2010. We found that reconstructed total catch was 4 times the data reported by FAO on behalf of Brunei. Incomplete statistical coverage of the small-scale sector and limited monitoring, control, and surveillance capacity[5] are issues that can impede future sustainable management of Brunei's fisheries.

Small-scale catch statistics provided by the DoF appear to adequately account for the small-scale sector in the 1950s and from 2002-2010, when they were on average 27% higher and within 1% of catch estimated from fish consumption data, respectively. From the late 1970s and reaching into the 1990s, DoF reported small-scale catches were lower than the amount required to meet domestic fish consumption needs (as calculated by the validation method), but the shortfall appeared to be accounted for by the addition of industrial catch and imports. For the period 1975-1992, *per capita* fish consumption derived from DoF reported small-scale catch with the inclusion of industrial catch and imports was 32 kg·person^{-1}·year^{-1} (versus 16 kg·person^{-1}·year^{-1} without industrial catch and imports), which was within the range of the applied consumption rate of 36 kg·person·year^{-1}. Assuming that 36 kg·person^{-1}·year^{-1} was not under-estimating actual fish consumption in the 1975-1992 period, then DoF small-scale catches appear to be

reasonable. A change in data enumeration method or statistical reporting seems to have occurred between 2001 and 2002, when nationally reported small-scale catch jumped from 6,800 t to 10,800 t.

Small-scale fishers have and continue to play an important role in supporting Brunei's local economies and national food security, but the incompleteness of basic fisheries statistics pertaining to this sector may hinder future sustainable management. Small-scale fishing is more crucial to national food security (through the direct provision of domestically sourced fish protein) than what the public may realize. It is generally reported that Brunei relies heavily on fish imports (Lo 2013) - imported fish made up on average 46% of total fish marketed in Brunei from 2007-2010 (JPKE 2011). This statistic does not refer to total catches, but only to that which is landed and sold at select (i.e., monitored) markets. Typically, small-scale catch is channeled through middlemen who may sell directly to customers, restaurants or informal markets; sold by the fishers themselves; or shared with neighbors and friends (Lim 1986). Thus, the proportion of imported fish to actual small-scale catch is likely lower, and reliance on local small-scale fishing is higher than commonly perceived. On the other hand, it is an accepted practice to land fish originating from outside Brunei, that arrive by sea, as Bruneian catch. These fish are then marketed as local fish rather than as imports (Mohd Ariff and Bakeri 1998). An unknown quantity of foreign fish is landed as Brunei fish through this manner, and this accounting discrepancy is an issue that requires further attention.

The industrial sector has historically been subject to close regulation, thus catches are less likely to be under-reported (Ebil 2013). However, discards from trawling are not reported and can add up to a significant amount of extracted catch (despite non-utilisation, this adds to fisheries related mortality). In this study, discards made up 11% of reconstructed total catch, about half the amount of that contributed by the entire industrial sector. The wasteful discarding of fish may be reduced in coming years as the Brunei government develops the seafood processing industry – the recent opening of a seafood processing factory turns once unmarketable low value fish into marketable products such as surimi (Lo 2013). Another source of under-reporting is illegal fishing by foreign vessels, an activity which has cost Brunei an estimated $13 million dollars in lost fish in the past decade (Masli 2011).

While coarse, this reconstruction provides a first attempt at quantifying the catch of marine recreational fishers in Brunei. The popularity of recreational (sport) fishing has increased in the past decade, but little is known about the impact of this sector on local stocks. Despite a licensing requirement, there are no reliable records of the number of recreational fishers in Brunei, nor their catch (Ebil 2013). We estimated that this sector caught around 4,800 t of fish in the period 1970 to 2010, representing about 1.3% of reconstructed total catch. Besides local recreational fishers, Brunei is moving towards becoming a regional fishing destination (Bahrum 2009). This as yet untapped 'tourism' market segment was not accounted for in this reconstruction, but is likely to become more prominent in the future (Bahrum 2009).

While Brunei's national fisheries statistics are more comprehensive than those provided to and by the FAO, they nonetheless can be improved. Inconsistent reporting leads to misinterpretation and at worst, wrong information. Different versions of catch statistics are reported by different institutions (e.g., DOF, FAO, SEAFDEC, JKE), which makes it confusing and difficult for users to clearly understand the state of Brunei's fisheries. For example, total landings reported by the FAO in 2010 were only 20% of small-scale catch recorded by the DOF, which leads one to different conclusions about Brunei's fisheries, depending on which set of catch statistics was used.

Brunei's fishing sector has historically been overshadowed by the dominant oil industry, yet societal well-being is highly dependent on local fisheries for food security. There is a general impression that Brunei's fisheries are still lightly exploited compared to neighboring countries (Chua *et al.* 1987; Silvestre *et al.* 1992), arising perhaps from the small number of fishers in the country (<1% of the population). Yet, fishing effort can grow rapidly without control. Thus, small-scale fishing gears, in Brunei, were apparently exceeding optimum levels of effort in the 2000s[10]. It is also unclear how the fishing effort of part-time fishers, who make up about two-thirds of the total number of fishers, is accounted for in DoF's small-scale

[10] SEAFDEC. Marine Fishing in Brunei Darussalam. URL: http://map.seafdec.org/Monograph/Monograph_brunei/marine.php.

catch estimates. Increasing industrial catches in the last decade have resulted in a shift in finfish community structure towards lower trophic pelagic fishes, a trend that suggests ecosystem-level impacts. Finally, illegal fishing by foreign vessels needs to be stopped, as unknown quantities of valuable fisheries resources have been lost to Brunei over the years.

The reliance on incomplete and likely under-reported national data may put authorities under serious risk of over-licensing fishing access and mismanaging marine ecosystems and consequently national food security. Overall, improvements in the marine fisheries statistical records over time were observed and it is hoped that further improvements can be achieved in the future, especially when all records are fully incorporated in a functional database.

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Table 1. Major composition of industrial trawl catches (% of total catch) in Brunei.

	1970[1]	1980[1]	1990[1]	2000[2]	2010[2]
Carangidae	3	5.5	4	3	5
Miscellaneous fish	67	80.0	70	56	53
Other demersals	10	10.0	18	-	3
Other invertebrates	1	-		3	9
Penaeid shrimps	-	-	-	10	5
Sharks and rays	19	3.0	8	7	5
Small mackerels	-	-	-	1	-
Snappers and groupers		1.0	-	1	2
Tunas	-	-	-	1	-

[1]Derived from Silvestre et al. (1992)
[2]Derived from data provided by the Department of Fisheries, Brunei Darussalam

Table 2. Major composition of industrial purse seine catches (% of total catch) in Brunei.

	1985[1]	2003[2]	2004[2]	2005[2]
Carangidae	7	-	-	-
Loligo spp.	-	5	-	-
Megalaspis cordyla	2	8	1	-
Rastrelliger kanagurta	9	18	7	11
Sardines	1	12	16	58
Sciaena spp.	-	-	5	-
Scomberomorus commerson	-	4	1	-
Small carangids	65	31	10	11
Sphyraena spp.	2	-	-	-
Tunas	-	8	58	9

[1] Derived from Silvestre et al. (1992)
[2] Derived from National Country Report for Brunei Darussalam, Department of Fisheries Brunei Darussalam. URL: www.seafdec.org.my/tag/PDF/Brunei.htm

Table 3. Major composition of small-scale catches (% of total catch).

	1995
Other demersals	3
Other invertebrates	6
Penaeid shrimps	20
Sardines	43
Sharks and rays	1
Small mackerels	21
Snappers and groupers	1
Miscellaneous fish	4

Source: Mohd Ariff and Bakeri (1998).

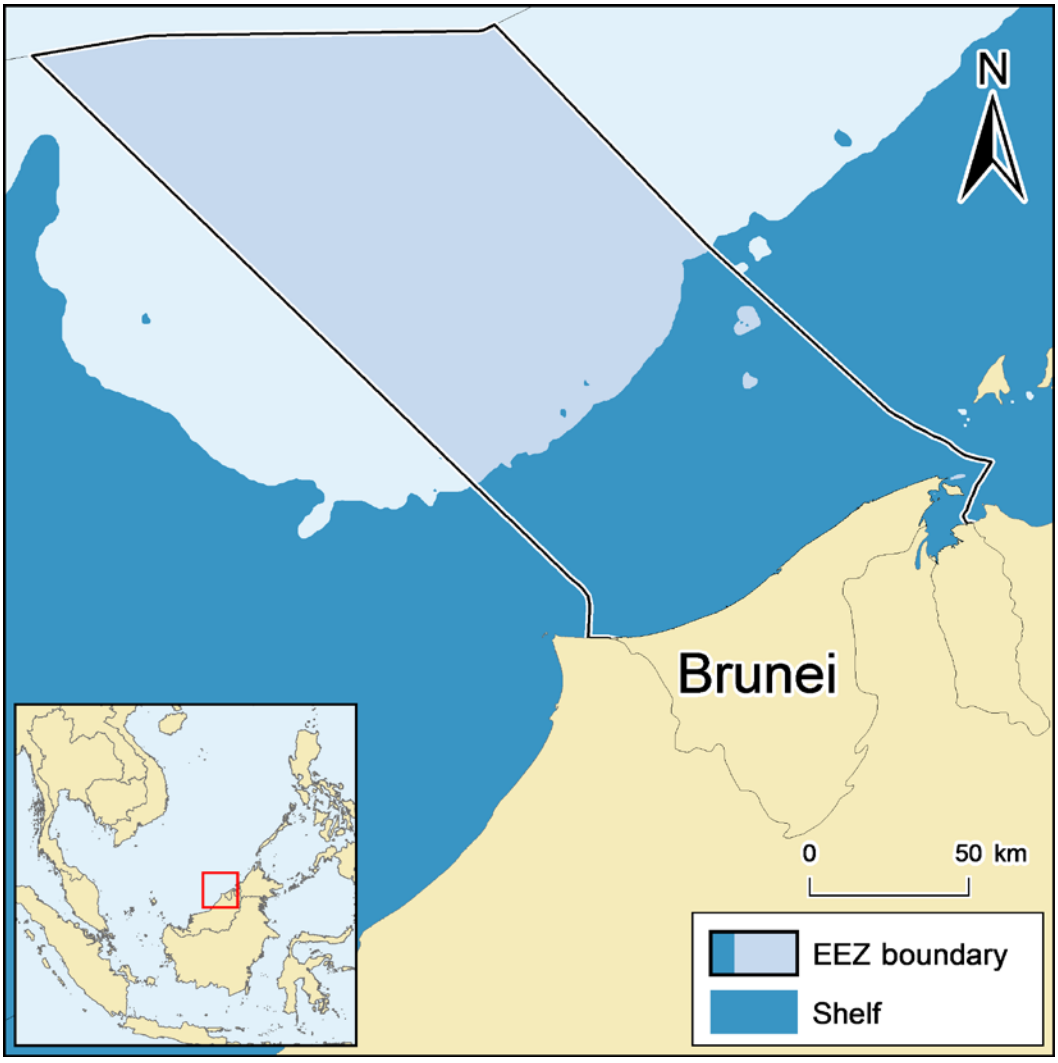

Figure 1: Map of Brunei with Exclusive Economic Zone (EEZ).

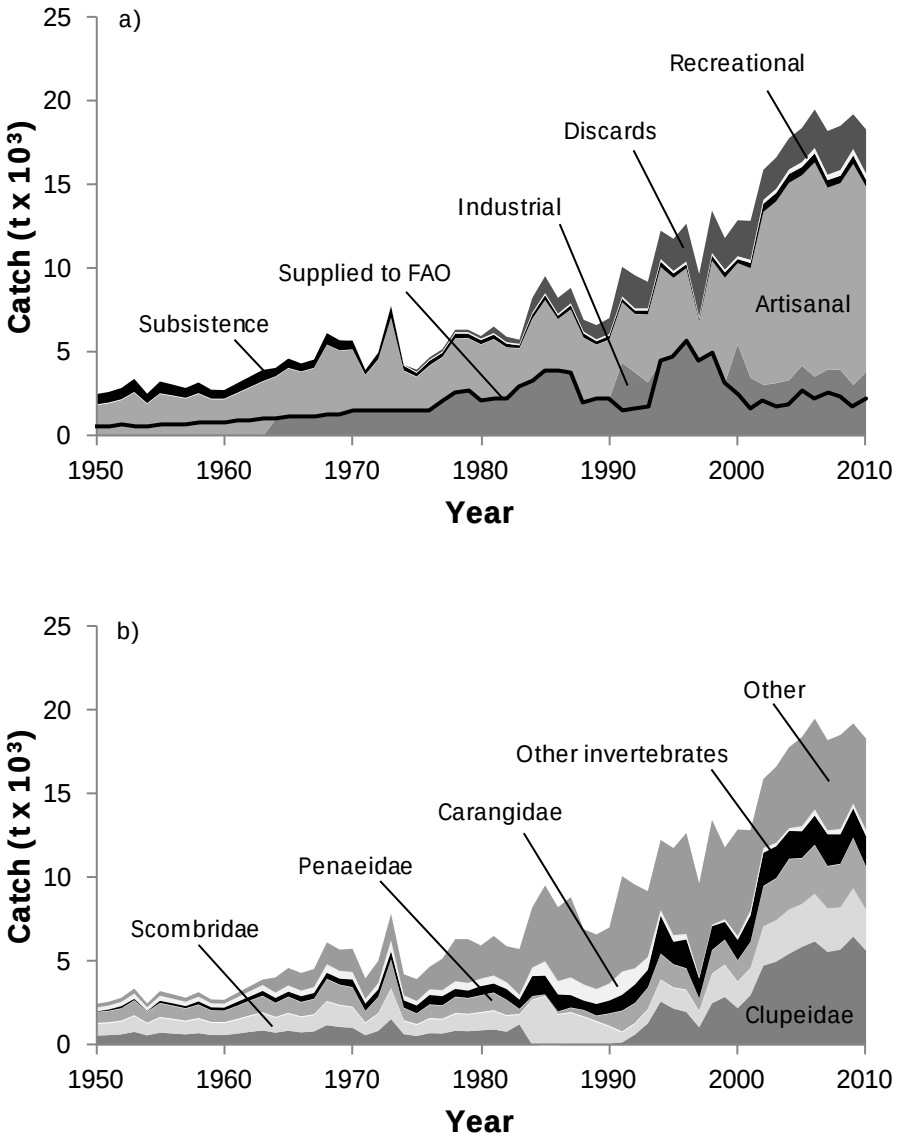

Figure 2. Total reconstructed domestic catches by Brunei, 1950-2010, a) by sector, with discards shown separately and data reported by FAO overlaid as a line graph; and b) by major taxa. 'Others' represents 23 additional taxonomic categories.

Appendix Table A1. Total reconstructed catch vs. FAO landings (in tonnes), and catch by sector with discards shown separately for Brunei, 1950-2010, by sector.

Year	FAO landings	Total reconstructed catch	Industrial	Artisanal	Subsistence	Recreational	Discards
1950	500	2,460	0	1,850	615	0	0
1951	500	2,600	0	1,960	633	0	0
1952	700	2,840	0	2,160	675	0	0
1953	600	3,380	0	2,600	785	0	0
1954	500	2,490	0	1,930	563	0	0
1955	700	3,230	0	2,520	710	0	0
1956	700	3,040	0	2,390	650	0	0
1957	700	2,840	0	2,250	590	0	0
1958	800	3,170	0	2,530	640	0	0
1959	800	2,730	0	2,200	535	0	0
1960	800	2,710	0	2,200	515	0	0
1961	900	3,110	0	2,540	573	0	0
1962	900	3,520	0	2,890	626	0	0
1963	1,000	3,920	0	3,250	674	0	0
1964	1,000	4,040	1,000	2,540	505	0	0
1965	1,100	4,600	1,100	2,940	561	0	0
1966	1,200	4,310	1,200	2,630	479	0	0
1967	1,200	4,540	1,200	2,850	495	0	0
1968	1,300	6,130	1,300	4,140	686	0	0
1969	1,300	5,700	1,300	3,800	598	0	0
1970	1,500	5,750	1,500	3,660	546	49	0
1971	1,500	3,980	1,500	2,130	302	51	0
1972	1,500	5,030	1,500	3,060	410	53	0
1973	1,500	7,830	1,500	5,570	702	56	0
1974	1,500	4,230	1,500	2,390	283	59	0
1975	1,500	3,940	1,500	2,020	225	61	130
1976	1,561	4,680	1,560	2,640	274	64	135
1977	2,110	5,160	2,110	2,590	250	67	139
1978	2,621	6,320	2,620	3,200	286	69	143
1979	2,709	6,320	2,710	3,130	258	72	147
1980	2,122	5,940	2,120	3,340	252	75	152
1981	2,245	6,510	2,250	3,540	261	77	390
1982	2,239	5,900	2,240	3,040	221	79	320
1983	2,949	5,730	2,950	2,290	163	82	247
1984	3,341	8,210	3,340	3,650	255	84	878
1985	3,872	9,510	3,870	4,250	291	86	1,017
1986	3,945	8,220	3,950	3,030	204	89	948
1987	3,796	8,820	3,800	3,760	248	91	919
1988	1,934	6,910	1,930	3,930	254	94	703
1989	2,188	6,590	2,190	3,260	206	96	848
1990	2,244	7,010	2,240	3,510	217	98	942
1991	1,546	10,060	4,390	3,590	218	101	1,762
1992	1,667	9,560	3,810	3,470	206	103	1,963
1993	1,703	9,170	3,230	4,030	234	106	1,580
1994	4,441	12,220	4,440	5,660	321	108	1,688
1995	4,712	11,730	4,710	4,740	263	110	1,908
1996	5,714	12,630	5,710	4,320	234	113	2,254
1997	4,504	9,640	4,500	2,350	124	115	2,544
1998	5,014	13,410	5,010	5,480	282	118	2,515
1999	3,160	11,770	3,160	6,300	317	120	1,877
2000	2,464	12,840	5,490	4,850	237	122	2,140
2001	1,578	12,800	3,500	6,530	311	139	2,322
2002	2,044	15,840	3,070	10,350	480	154	1,791
2003	1,784	16,580	3,180	10,870	491	170	1,868
2004	1,912	17,730	3,350	11,810	518	186	1,860
2005	2,709	18,330	4,210	11,400	485	203	2,032
2006	2,279	19,430	3,570	12,830	530	220	2,289
2007	2,550	18,150	4,000	10,880	436	238	2,606
2008	2,357	18,460	3,970	11,170	433	256	2,631
2009	1,766	19,150	3,070	13,230	496	288	2,065
2010	2,272	18,250	3,850	11,080	402	288	2,629

Appendix Table A2. Brunei Darussalam reconstructed catch (t) by major taxa, 1950-2010. 'Others' represents 23 additional taxon groups.

Year	Clupeidae	Penaeidae	Scombridae	Other invertebrates	Carangidae	Other
1950	589	683	636	106	236	212
1951	610	707	659	156	244	220
1952	657	762	710	206	263	237
1953	806	935	870	158	322	290
1954	596	692	644	106	239	215
1955	755	876	815	208	302	272
1956	708	821	764	207	283	255
1957	657	762	710	206	263	237
1958	728	844	786	257	291	262
1959	619	718	669	256	248	223
1960	614	712	663	256	246	221
1961	702	814	758	307	281	253
1962	802	931	866	308	321	289
1963	890	1,033	961	359	356	320
1964	758	879	819	366	323	897
1965	873	1,013	943	368	372	1,034
1966	775	899	837	417	334	1,047
1967	833	966	900	418	357	1,068
1968	1,203	1,396	1,300	423	508	1,297
1969	1,096	1,271	1,183	422	465	1,258
1970	1,048	1,215	1,136	523	451	1,379
1971	607	704	660	516	278	1,220
1972	866	1,004	940	518	384	1,314
1973	1,563	1,813	1,694	526	666	1,566
1974	665	772	724	514	309	1,243
1975	561	651	612	550	270	1,299
1976	727	843	792	639	338	1,338
1977	709	823	773	626	360	1,870
1978	869	1,008	946	539	458	2,500
1979	846	981	920	513	460	2,601
1980	896	1,039	975	617	448	1,968
1981	947	1,098	1,030	606	477	2,352
1982	813	943	886	711	414	2,134
1983	1,250	564	278	629	296	2,712
1984	39	2,656	165	1,267	508	3,577
1985	1	2,905	54	1,189	859	4,506
1986	15	1,802	118	1,093	804	4,386
1987	35	1,898	240	818	1,058	4,767
1988	49	1,631	347	641	965	3,280
1989	46	1,350	292	775	889	3,242
1990	109	1,004	707	847	1,022	3,322
1991	182	580	1,226	1,019	1,392	5,664
1992	647	632	1,172	1,174	963	4,969
1993	1,310	805	1,260	1,119	771	3,909
1994	2,606	1,295	1,518	2,310	330	4,161
1995	2,187	1,230	1,356	1,397	390	5,174
1996	1,988	1,294	1,251	1,775	318	6,007
1997	1,077	927	720	1,238	145	5,531
1998	2,507	1,744	1,379	1,470	72	6,238
1999	2,878	1,909	1,473	1,099	149	4,266
2000	2,211	1,555	1,249	1,262	237	6,324
2001	2,988	1,609	1,529	1,618	305	4,756
2002	4,745	2,346	2,396	1,997	253	4,107
2003	4,983	2,472	2,497	1,930	168	4,529
2004	5,451	2,646	3,022	1,671	127	4,812
2005	5,860	2,575	2,726	1,613	261	5,297
2006	6,185	2,871	2,905	1,758	326	5,389
2007	5,562	2,604	2,516	1,911	194	5,367
2008	5,699	2,534	2,581	1,779	278	5,593
2009	6,472	2,909	3,010	1,757	233	4,770
2010	5,636	2,454	2,557	1,834	328	5,438