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RECONSTRUCTING VIETNAM'S MARINE FISHERIES CATCH, 1950-2010

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ABSTRACT

We reconstruct marine fisheries catches for Vietnam from 1950-2010. Annual national landings statistics are considered to be incomplete and underreported. A disorganised small-scale sector and lax licensing policies give rise to illegal and unreported catches. This reconstruction provides a more comprehensive estimate of Vietnam's marine catches by accounting for these IUU catches. Total reconstructed catch in Vietnam was 79 million t from 1950-2010, suggesting that actual catches were around 75% higher than the 45 million t of catches reported by FAO on behalf of Vietnam. This reconstruction did not account for the catch of foreign fishing vessels in the waters of Vietnam, which represent another source of fishing pressure, and could be significant. Our results suggest that Vietnam's marine fisheries are in decline, and urgent action to improve fisheries monitoring and enforcement is needed.

INTRODUCTION

Marine fisheries play an important role in Vietnam, accounting for 87% of total fisheries yield from 1990-2010, on average (GSO 2010), with the remainder originating from freshwater fisheries and aquaculture. The fisheries sector is among the top three economic activities in Vietnam, and made up about 10% of the country's export revenues in 2006 (Pomeroy *et al.* 2009). Fishing has a long tradition in Vietnam, and small-scale fishing dominates in inshore areas. Over the past two decades, the fishing sector has experienced rapid and uncontrolled growth, leading to over-exploited inshore ecosystems (Son and Thuoc 2003; Pomeroy *et al.* 2009) and reduced socio-economic well-being for coastal communities (Pomeroy *et al.* 2009). Fisheries management institutions in Vietnam have been restructured several times since the mid-1950s, but the different regimes have been largely ineffective in controlling the race to fish. Weak monitoring and enforcement capacity has led to high non-compliance with existing fishing regulations (Boonstra and Dang 2010), user conflicts over fishing in coastal areas, and the intrusion of immigrant boats in an already overused marine environment (Boonstra and Dang 2010). The severity of the situation is compounded by inadequate fisheries statistics for planning sustainable fisheries yield, management, and resource conservation. It is believed that reported landings under-estimate the true level of fishing that takes place (van Zwieten *et al.* 2002; DERG and MoPI 2010)

Thus, this report aims to reconstruct the marine fish catches of Vietnam from 1950-2010 to produce a more comprehensive picture of past and present human reliance on marine capture fishing (i.e. excluding aquaculture), and investigate the impact of fishing on Vietnam's marine fisheries. The information can help facilitate actions towards sustainable and comprehensive fisheries management.

Background

Vietnam has an Exclusive Economic Zone (EEZ) of about 418,000 km² (Figure 1), and its long coastline is shared by 29 coastal provinces and around 1000 coastal communities. The country has four principal fishing grounds – The Gulf of Tonkin in the north, the South China Sea in the central and south-eastern part of the country, and the Gulf of Thailand to the southwest. The continental shelf of Vietnam is broad and shallow in the north and south while the central region is narrow and has a steep slope that drops to depths of up to 500 m within 30 to 50 km from the coast (Son and Thuoc 2003). In 2006, the coastal population numbered 18 million, i.e., over 20% of the country's total population (Pomeroy *et al.* 2009).

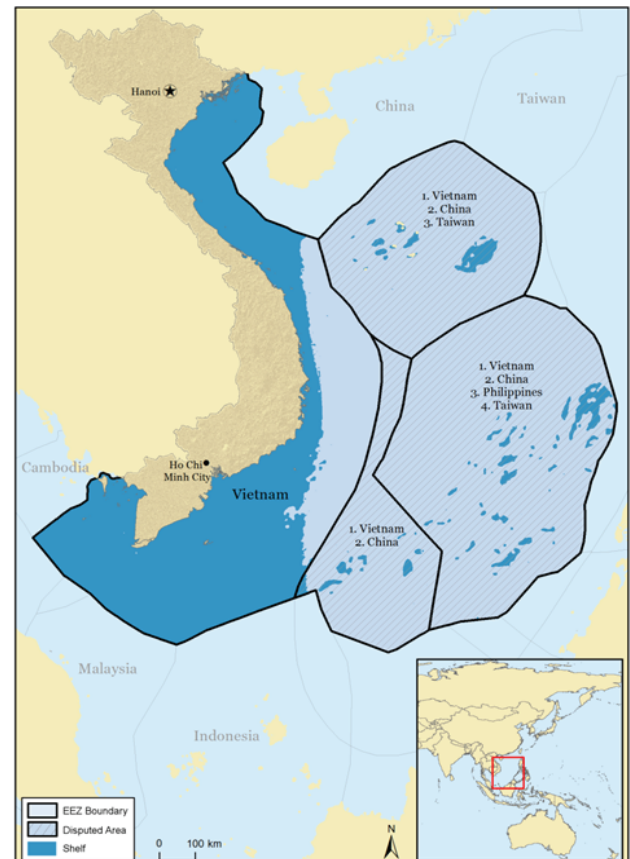


Figure 1. The Exclusive Economic Zone (EEZ) and shelf area (<200 m depth) of Vietnam. Shown also are Vietnam's EEZ area claims that are disputed.

Vietnam's marine fisheries are largely small-scale, multi-species and multi-gear. The majority of fishing takes place in coastal waters over habitats including seagrass and algal beds, coral reefs, mangroves and estuaries (Son and Thuoc 2003). Marine fisheries in Vietnam are commonly categorised as being either 'near-shore'¹ or 'offshore'. A number of factors are used to define the type of fishing, whereby distance from shore, depth of fishing grounds, and the size of the boats' engines are commonly used for this purpose. Near-shore fishing refers to that undertaken by fishing vessels with engines that are less than 90 horsepower (hp),² or which occurs in water within the 30 m isobath in the Gulf of Tonkin and southern regions, or within the 50 m isobath in the central region. In 2010, only 14% of fishing vessels were classified as offshore (DERG and MoPI 2010). Pomeroy *et al.* (2009) reported that approximately 72% of the country's motorised boats have engines 45 hp, and 84% have engines 90 hp. Most of these boats operate in water depths of less than 50 m between 4 to 5 nautical miles from shore, and fish caught within this inshore area account for approximately 82% of the country's total catch (Pomeroy *et al.* 2009). Although there is a licensing system in place, boats that are under 0.5 tonnes are not required to be licensed; however, many boats that are over 0.5 tonnes are also not licensed, and fishers that do apply for a license are generally granted one (DERG and MoPI 2010). Hence, Vietnam's marine fisheries can be characterized as being open access fisheries.

The major fishing gears used in Vietnam in terms of percentage of total catch are trawl nets (30%), purse seine (26%), gillnets (18%), lift nets (5%), and long lines (6%) (FAO 2005). Numerous other small-scale gears are also used near to shore but are rarely, if ever, reported in official statistics (van Zwieten *et al.* 2002). Commonly used small-scale gears include small gillnets, small shrimp trawls, handline and longline, push nets, small liftnets, and traps (Pomeroy *et al.* 2009). Small-scale fishers are typically poor and their catch is either used for household consumption or as 'trash fish', i.e. fish meal or other products (DERG and MoPI 2010), notably the famous fermented 'fish sauce' or *nuoc mam* (Pauly 1996; Ruddle 2005). In contrast, the catch of offshore fishing vessels is almost entirely sold commercially or exported (DERG and MoPI 2010). Intensification of fishing in inshore coastal areas and subsequent over-exploitation of near-shore resources has led to conflicts between both small-scale sectors (i.e., nearshore) with large-scale industrial (i.e., offshore) fleets (Pomeroy *et al.* 2009).

There are about 130 fish species that are of commercial importance to Vietnam's marine fisheries. Shrimp of the family Penaeidae comprise the most valuable commercial species (Son and Thuoc 2003), followed by various finfish (tuna, snappers, groupers, and small pelagics), squid, crab, and molluscs (Son and Thuoc 2003; FAO 2005). Marine catches feature high species diversity but low species abundance (Son and Thuoc 2003), and assemblages vary by gear. Pelagics such as yellowtail round scad (*Atule mate*), bigeye scad (*Selar crumenophthalmus*), jacks (Carangidae), Indian mackerel (*Rastrelliger kanagurta*), frigate mackerel (*Auxis thazard thazard*), and kawakawa (*Euthynnus affinis*) dominate purse seine catches, while Scombridae, Sphyraenidae, and Trichiuridae are the main families in gillnet catches. Trawl nets primarily catch demersal species such as bigeye (*Priacanthus* spp.), golden threadfin bream (*Nemipterus virgatus*), lizardfish (Synodontidae), groupers (Serranidae) and snappers (Lutjanidae), as well as squid (Loliginidae) and cuttlefish (Sepiidae). Low value species, small sized fish, or juveniles of commercially important species now dominate marine catches, making up as much as 60% of total catch (DERG and MoPI 2010).

Historical development

Traditional fishing in Vietnam involved the collection and/or capture of invertebrates and finfish directly from the beach, in mangroves, estuaries, lagoons and deltas (FAO 2005). During the French colonial period (1870-1954), Vietnam's marine fisheries were viewed as being under-developed (Robequain and Gourou 1936) with little potential as a revenue-generating activity, and hence were largely ignored by the colonial administration. Local institutions such as *van chai* (Ruddle 1998; Thong and Thieu 2009) and *ca lan* provided structure for regulating fisheries, which were mainly conducted at a subsistence level (Kleinen 2007). In 1954, following a war of liberation ('First Indochina War'), Vietnam gained independence and transitioned to a socialist regime in the North and the rule of U.S. supported generals in the South. This division lasted from 1955 to 1975, after the 'Second Indochina War' ('Vietnam War') ended with the country's reunification under the dominance of the North.

Technological advancement during the 1950s to 1970s in both North and South saw, among other things, the motorization of fishing fleets, and the introduction of nylon nets. Following national reunification in 1975, collectivisation, initiated earlier in the North, was extended to the South, with a focus on increasing marine fisheries catches. Fishing vessels were put under public ownership and state controlled fishery co-ops were developed, leading to the gradual decline of local self-management institutions such as *van chai* (Ruddle 2009; Boonstra and Dang 2010). However, this centralised approach was inadequate to manage local resource use and inefficiencies in the state run cooperatives resulted in only moderate catch increases (Boonstra and Dang 2010).

In the mid 1980s, Vietnam moved towards a market-oriented economy, signalling the end of the collectivisation period (Ruddle 2009). The transition was marked by a *doi moi* 'renewal' policy in 1986, which liberalised trade by allowing private enterprise and access to foreign markets. The focus was on economic development through increased catches and exports. Subsequently, fishing effort in both inshore and offshore operations grew rapidly from 1986 to the 2000s.

¹ In this paper, 'nearshore' refers to both 'small-scale' fisheries; artisanal and subsistence

² Note that it is unclear if the 'horsepower' used in Vietnam is the English measure, i.e., 1 hp = 0.7557 kW, or perhaps more likely, given the earlier French colonization of Vietnam, they are a translation of 'cheval-vapeur', i.e., 1 c.v. = 0.7355 kW.

Fisheries management

Vietnam's marine fisheries are administered by the Ministry of Fisheries and governed by the Fisheries Law of 2003. The objective of the Fisheries Law is to achieve sustainable and responsible fisheries by implementing ecosystem approaches and integrated management. To this extent, the Law prohibits the use of destructive fishing gear and the capture of certain species; declares closed seasons and areas; and makes provisions for fisheries co-management, among other regulations. Nevertheless, a long trend of financial constraints, weak enforcement, and limited technical capacity to implement actions has led to an overall ineffective fisheries management system (Pomeroy *et al.* 2009).

Fisheries statistics

In their comprehensive assessment of Vietnam's fisheries monitoring and data collection system, van Zwieten *et al.* (2002) stated that the usefulness of Vietnam's fisheries data was hindered by "1) low categorical resolution and 2) non-transparent aggregation of data into mere administrative spaces". Reported landings are broken down to seven major groups, and there is no further disaggregation by gear or boat type. Landings statistics are not linked to the number of reported fishing vessels or fishers, therefore catch per unit effort information cannot be examined spatially, and the final disposition of landings is not tracked. As such, the quality of Vietnam's fisheries statistics is insufficient to meet fisheries management needs.

Fisheries data collection falls under the responsibility of two separate agencies – the General Statistics Office of Vietnam and the Ministry of Fisheries. As of 2010, both agencies operated their own data collection system, but there are plans to unify and synchronise these parallel systems (DERG and MoPI 2010). Fisheries data (catch and effort) are collected by enumerators at the commune and district levels about once or twice a year, through interviews with fishers categorised by the horsepower of their vessels. These interviews are the basis for total catch estimates, which are then relayed to the appropriate provincial fisheries department.

The reliability of Vietnam's fisheries statistics is affected by several factors. Raw catch data rely on fishers' memory and honesty in reporting, and given that taxation is based on catch volumes, there is high incentive for fishers to under-report their catches. On the other hand, since fisheries statistics in Vietnam are geared towards meeting 'production' targets, there may be incentive to over-report catches at the enumerator or higher level of reporting authority to meet these targets, similar to that documented for China (Watson and Pauly 2001). Furthermore, enumerators do not have a systematic method of collecting data, and periodic changes in methodology or definitions lead to non-standardised data that have to be treated with caution. With the help of foreign development agencies, the fisheries statistics system in Vietnam is now slowly undergoing change that should result in a more organised, transparent and informative system in the future. In the meantime, we hope that the present reconstruction will at least highlight areas requiring attention and serve as a historic baseline of more accurate total catches.

METHODS AND MATERIALS

Reported landings

Annual reported marine fisheries landings from 1950 to 2010 were extracted from FishStat (FAO 2012). FishStat historical data merge marine landings from the formerly separate North and South Vietnam into one unified data series (Garibaldi 2012). Marine landings were categorised into 7 groups – 'cephalopods', 'lobsters', 'marine crabs', 'marine fishes nei', 'marine molluscs', 'natantian decapods', and 'tuna-like fishes'. As previously mentioned, no further disaggregation to species or at least family level (see footnote 4 for an exception), gear type, fishing vessel, or fishing ground is available.

Unreported catch

Unreported catches in Vietnam originate from unmonitored small-scale sectors, artisanal and subsistence fisheries (van Zwieten *et al.* 2002) and unregistered boats (Boonstra and Dang 2010), including immigrant fishers from nearby countries such as China and Hong Kong (Kleinen 2007; Boonstra and Dang 2010). We assumed that these sources of unreported catches were considered in the unreported catch ratio described below.

Unreported catch ratio

We raised reported landings by an *unreported catch ratio* (UR) to derive total estimated marine fisheries landings from 1950-2010. A marine capture yield of 4 million t was reported for Vietnam in 1999 (van Zwieten *et al.* 2002) based on estimates by the Assessment of Marine Living Resources programme (AMLRV) (Anon. 2001), a foreign funded enumerator programme implemented by the Research Institute of Marine Products (RIMP). Personal communication by the senior author with Mr. van Zwieten (Aquaculture and Fisheries Group, Wageningen University, The Netherlands) revealed that the published figure was in fact too high, and it had subsequently been revised to 2 million t with input from Vietnamese and FAO scientists. A range of 2.5 to 3 million t of marine catch had also been suggested by the AMLRV (van Zwieten, Aquaculture and Fisheries Group, Wageningen University, pers.

comm.). In the absence of other information, we decided to take the middle point of 2.5 million t as representative marine catch in 1999. The unreported catch ratio (UR) was then calculated by dividing total estimated marine catch (2.5 million t) by reported landings of 1.3 million t in 1999, which yielded an UR factor of 1.9. Reported landings in all years, with the exception of the time periods described below, were raised by this UR to arrive at total estimated marine catch.

1965-1973

The Second Indochina War (1959-1975) was a period during which fishing ceased (Boonstra and Dang 2010) or experienced a drastic decline, especially after 1964 (Kleinen 2007). In contrast, reported landings show an increasing trend in marine fisheries catches over this entire period, with reported landings growing by 84% from 345,000 t-year⁻¹ in 1961 to 634,650 t-year⁻¹ in 1973. Given the historical context, we were not confident that fisheries expanded so much during a time of war, although according to one source, fishery was the least affected economic activity of the war (Anon. 1969), likely due to the small-scale and subsistence nature of Vietnamese fisheries. There was a large drop in reported landing between 1973 and 1974, when catches fell almost 40% from 635,000 t-year⁻¹ to 395,000 t-year⁻¹. According to Kleinen (2007), this was “due to the closing war effort and the flight of the fishing fleet.”

We reconstructed marine fisheries statistics to reflect a decline rather than increase in catches starting in 1965 until 1973. We chose to start the decline in 1965 as it was the year the war escalated with the initiation of open warfare by the United States against North Vietnam over the Gulf of Tonkin incident. Two anchor points were set, with reported landings of 509,970 t-year⁻¹ for 1964 and 395,080 t-year⁻¹ in 1974. Data gaps between anchor points were filled by linear interpolation.

2000-2010

Despite an annual increase in reported landings during this period, analysis of catch per unit of effort suggests a less optimistic trend. Since 2000, catch per vessel has levelled off after a period of rapid growth in the 1990s (Figure 2). When viewed in terms of catch per unit horsepower (hp), catches per hp actually started to decline in the mid 1980s and have continued to do so from 2000 to 2008 (Figure 2). Thus, the cumulative horsepower of the fleet may be taken as a more accurate indication of effective effort, and hence catch per unit of horsepower as a more reliable CPUE. In 1990, catch in t-year⁻¹·hp⁻¹ was about 0.9 before dropping to around 0.47 in 1999 and to 0.34 by 2005.

The decline of CPUE in the past two decade suggests that fishing levels were already overstressing the resource base; therefore it is unlikely that catches could maintain a continuous growth as in the reported landings. Thus, we held reconstructed landings (i.e., ignoring discards) from 2000-2010 constant at the 1999 level of 2.5 million t-year⁻¹.

Sectoral breakdown

We treated all catches from 1950-1986 as coming from the small-scale sector, and assumed that the industrial (i.e., large-scale) sector developed after 1986 with the implementation of the *doi moi* policy, which encouraged economic growth and development. The industrial sector is defined as fishing that is done by vessels with engine power 90 hp. Prior to government investment in offshore fisheries, Vietnam's fisheries were dominated by small-scale fishers using unmotorised or motorised vessels with engines 90 hp. Starting from 0% in 1986, we linearly increased the proportion of the industrial sector to 37% of total catch in 1998 (Son and Thuoc 2003). In 2010, due to lack of data, we capped industrial sector catch at 60%, based on the statement that “the offshore fisheries supply [...] less than 60% of estimated marine capture landings.” (FAO 2005). Data gaps from 1998 to 2010 were filled using linear interpolation.

The small-scale sector consists of the subsistence and artisanal subsectors, where the distinguishing factor is the final disposition of the majority of the catch. Subsistence fishing is done primarily to meet household consumption and socio-cultural needs, while artisanal fishing is conducted with the primary intent of selling at least the majority of one's catch. During the early 1900s, foreign Chinese junks were given access to fish in Vietnam and established a marine trade network. In contrast, fishing by Vietnamese households, particularly in the north, was undertaken as a supplement to farming or other manual work (Kleinen 2007), implying fishing at a subsistence level. Fishing was more prevalent in the south, where there were villages known as *van chai*, a term that was applied when the majority of village inhabitants were professional fishers (Thong and Thieu 2009). Kleinen (2007) indicated that in the 1940s, less than 3% of fishers residing in northern Vietnam were professional fishers, while in the South there were 35,000 professional fishers (Vietnamese and Chinese combined). We assumed that the proportion of professional fishers represented the size of the artisanal sector. Anchor points for the artisanal sector from 1950-2010 were determined as below:

1950 – We used the proportion of professional fishers in the 1940s as the anchor point in 1950. Since we had no information on the total number of fishers in South Vietnam in the 1940s (then known as ‘Cochinchina’), we assumed the proportion of professional fishers was at least as large as that in North Vietnam (3%). This is a conservative estimate since it is likely that the South had more professional fishers than the North.

1967 – We based the artisanal sector proportion on the percentage of marine catch that was processed, using the rationale that processing added value to a product and made it more suitable for trade. In 1967, the percentage of processed marine production out of total marine production was 36%, and included fermented fish and dried

and cured products.³ Since processing in the 1960s was likely still primarily small-scale, we assumed that some processed catch was kept for household use and not traded. In the absence of other data, we assumed that 50% of processed marine catch was kept for subsistence purposes, i.e., 18% of marine catch was traded. This percentage was used as the artisanal sector anchor point in 1967, and then held constant until 1974.

1975-1988 – This was the period of collectivization following national reunification. During this time, fishers were allowed to retain their catches to sell on the open market (Ruddle 2009). Thus, we started to linearly increase the artisanal sector from 18% of total catch in 1974 to an anchor point of 32% at the end of the collectivization period in 1988. The anchor point in 1988 was derived by calculating the average proportion of processed marine catch out of total marine catch from 1967-1972.³

2010 – In neighbouring Cambodia, the artisanal sector made up 60% of small-scale fisheries in 2010 (Teh *et al.* in prep.). Due to lack of data for Vietnam in this period, and given that the small-scale fisheries of both countries share various socio-economic characteristics, we applied Cambodia's artisanal sector proportion (i.e., 60%) to Vietnam. Data gaps between 1988 and 2010 were filled using linear interpolation.

Discards

The practice of discarding fish is not widely practiced in Vietnam where there is a ready market for low value fish in the fish meal and fermented fish industries. Only large trawlers that operate offshore (90 hp) for several days discard low-value fish (Long 2003), which typically makes up around 50% to 60% of their total catch (Long 2003). Small trawlers that return to port daily do not discard low-value fish. We calculated discards as a percentage of the total catch taken by industrial trawlers (90 hp). Two anchor points were established:

1986 - 50% of industrial catch by trawlers

2010 - 60% of industrial catch by trawlers

In 1997, trawl gear (small- and large-scale) accounted for about 43% of total marine catches (Son and Thuoc 2003). We used this same proportion to calculate the amount of industrial catch that is caught by large trawlers (90 hp). We maintained the 43% value throughout the reconstruction due to lack of other data sources. Discards were thus calculated as:

$$Disc_t = 0.43(Ind_{total})_t * DR_t$$

Where $Disc_t$ is the total discards (t) in year t (1986-2010);

Ind_{total} is the total reconstructed industrial catch (t) in year t ;

and DR is the discard rate in year t .

Catch composition

We assumed that the species composition of reconstructed catches resembled that of reported landings, which are categorised into seven major taxonomic groups: 'cephalopods', 'lobsters', 'marine crabs', 'marine fishes nei', 'marine molluscs', 'natantian decapods', and 'tuna-like fishes'. From 2000 to 2010, 'tuna like fishes' were disaggregated to yellowfin tuna, bigeye tuna, skipjack tuna, albacore, swordfish, black marlin, and blue marlin⁴.

'Marine fishes nei' made up 84% of total reported catches on average. We broke down this category into low value fish and finfish, where finfish were allocated to pelagic or demersal groups.

Low value fish- We started to account for low value fish in 1958, the year in which 15 otter board trawlers were brought into operation in Vietnamese waters⁵. Starting from 0% in 1958, we linearly increased the proportion of low value fish in the total catch of 'marine fishes nei' to 60% in 2000 (DERG and MoPI 2010), then held this value constant to 2010. The species composition of low value fish is shown in Table 1.

Finfish- Non low value fish were broken down to demersal and pelagic groups. Anchor points in 1950, 1980, and 2010 were established (Table 2). Data gaps from 1950 to 2000 were filled by linearly interpolating between anchor points, and the 2000 anchor point was held constant to 2010. Due to lack of Vietnamese disaggregated catch data, we assumed that the species composition of demersal fishes in Vietnam mirrored that of reported demersal landings in neighbouring Thailand (FAO 2012). Dominant pelagic families caught by major gear types in Vietnam (including purse seine, trawl nets, lift nets, and gillnets) were: Carangidae (44%); Scombridae (35%); Engraulidae (10%); and Clupeidae (10%) (Son and Thuoc 2003).

Table 1. Composition (%) of low value fish catches. Source - Thuoc and Long (1997).

Low value fish	Proportion
Synodontidae	31
Acropomatidae	19
Leiognathidae	18
Sparidae	14
Priacanthidae	6
Sciaenidae	6
Ariidae	3
Mullidae	3

Table 2. Percentage (%) of finfish belonging to demersal and pelagic fish groups

Year	Demersal	Pelagic
1950 ^a	16	84
1980 ^b	67	33
2000 ^c	35	65

^a Unpublished data (Teh *et al.* in prep.)

^b Thuoc and Long (1997)

^c Lewis (2005)

³ "The RVN's Environment & People" by Dr. Phan Quang Dan, 1975. In: Pêche et poissons au Vietnam (unpublished report).

⁴ Prior to August 2013, data extracted from FishStat reported zero catches in 'tuna-like fishes' from 2000-2010. However, tuna catch data have now been updated in disaggregated form, reflecting an improvement in fisheries data reporting.

⁵ SEAFDEC: http://map.seafdec.org/Monograph/Monograph_vietnam/trawl.php

Recreational fishing

According to the FAO, recreational fisheries in Vietnam are not developed except for ornamental fish culture (FAO 2005). This is supported by anecdotal evidence from internet sport fishing forums, where a number of international sport fishers have expressed difficulty finding guides and charter boats to go sea fishing in Vietnam.⁶ On the other hand, stories of local fishing trip accidents⁷ indicate that some recreational fishing does occur, but that it is likely not well organised. We thus assume that marine recreational fishing is not well developed in Vietnam at present, and that catches from this sector are negligible. Thus, marine recreational fishing is not addressed in this reconstruction, but may need addressing in the future.

RESULTS

Vietnam's reconstructed catch totalled 79 million t from 1950-2010 (Figure 3a). This estimate was 75% higher than total marine landings of 45 million t that were reported by FAO on behalf of Vietnam for the same period. The small-scale sector made up the largest proportion with 70% of reconstructed total catches, followed by the industrial sector with 24% and discards at 6%. Unreported catches totalled 34 million t, of which the artisanal and subsistence sectors comprised 21% and 47%, respectively from 1950-2010 (Figure 3b). Discards totalled 4.7 million t from 1987-2010, and made up 14% of total unreported catches. The decade 1990-2000 saw the highest difference between reconstructed and reported catches, when reconstructed catches were on average 2 times higher than FAO reported catches.

Marine catches in the 1950s consisted mainly of finfish, but the proportion of demersal and pelagic fishes started to decline in the 1960s as the proportion of low value fish increased. Cephalopods, including Sepiidae, Loliginidae, and Octopodidae, increased as a proportion of total marine catches from 1950-2010. Low value fish such as lizardfishes (Synodontidae), ponyfishes (Leiognathidae), breams (*Nemipterus* spp.) and bigeyes (*Priacanthus* spp.) were among the top contributors to total catches from 1950-2010. Other top taxa were pelagics such as Carangidae and Scombridae, as well as shrimps (Figure 4).

DISCUSSION

This historical reconstruction is, as far as we know, the first attempt at presenting a more comprehensive estimate of Vietnam's total marine catches. We estimated that from 1950-2010 Vietnam caught approximately 79 million t of marine fishes and invertebrates, representing an increase of 75% over total reported landings for the same time period. Vietnam's marine fisheries statistics are considered to be under-reported and like many developing countries in Asia, large and unorganised small-scale sectors coupled with limited technical and financial capacity have hindered fisheries monitoring and management in the past.

Reported landings in the period 1959-1975 did not appear to align with socio-political events at the time, when most activities, including fishing, were disrupted by war (Kleinen 2007). To reflect this, the reconstruction shows that marine catches increased by only 18% during the peak war years compared to an 84% increase in reported marine landings in the same time period.

The 1999 marine capture anchor point of 2.5 million t underpinned the reconstruction. This figure was based on the expert opinion of a source who was involved in a joint Vietnamese-Danish marine resource assessment project that aimed to improve the fisheries data collection system in Vietnam (van Zwieten *et al.* 2002). We assumed that the estimated marine catch of 2.5 million t was proportionally representative of Vietnam's reported landings, i.e., it included catches taken from Vietnam's EEZ by Vietnamese fishers in the industrial and small-scale

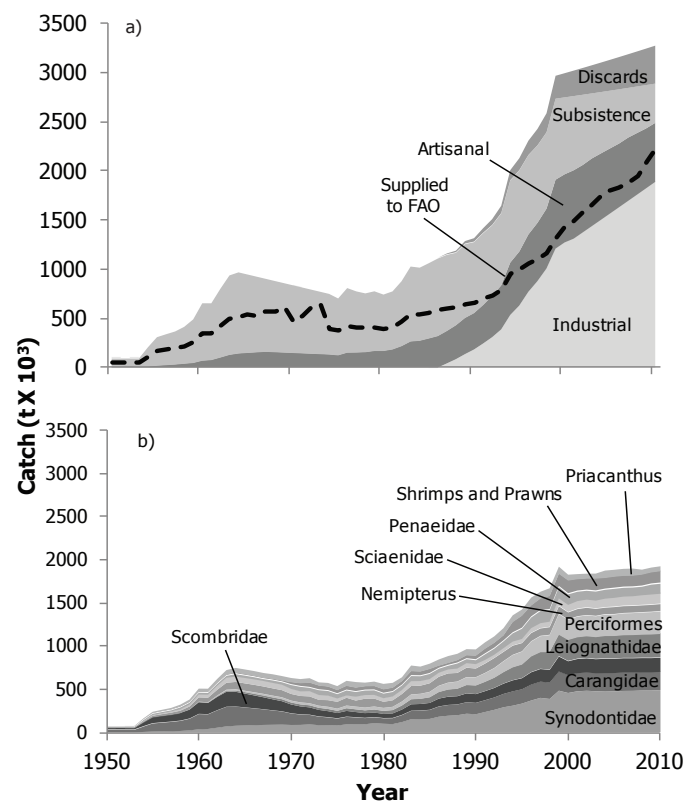


Figure 2. Reconstructed catches for Vietnam from 1950-2010. a) showing contribution of different sectors. The solid line represents FAO reported landings. b) top taxa in total reconstructed marine catches

⁶ E.g., Saltwater Fishing Forums. <http://forums.sportfishingmag.com/showthread.php?560562-fishing-Viet-Nam> [Accessed Sept. 19, 2013].

⁷ Thanh Nien News "2 dead, 1 missing as sportfishing boat sinks off southern Vietnam" 26 March 2012. <http://www.thanhniennews.com/index/pages/20120326-three-feared-dead-as-boat-sinks-on-fishing-trip.aspx>. [Accessed Sept. 19, 2013].

sectors. Therefore, we did not account further for sources of IUU catches in the industrial, artisanal, and subsistence sectors. This step is supported by anecdotal evidence from Nam Dinh Province. Here, a small driftnet fishery, whose catch is not consistently recorded, is thought to contribute up to a quarter of the province's total inshore fishery catch (van Zwieten *et al.* 2002). This is fully within the range of the unreported catch ratio, whereby we raised reported landings by a factor of 1.9 to account for unreported catches.

The steep increase observed in reported landings starting in the 1990s can be attributed to the rapid growth in the number of fishing vessels in Vietnam, particularly of more powerful offshore fishing vessels. From 1990-2002, the number of motorised boats in Vietnam increased by 87% from 41,266 vessels in 1990 (Long 2003) to 77,000 vessels in 2002 (MoFI and WorldBank 2005), while offshore fishing vessels rose by 170% between 2000 and 2010. While overall catch may have been increasing, catch per unit effort (horsepower) has been on a decline even before 1990 (van Zwieten *et al.* 2002; DERG and MoPI 2010). This trend suggests declining fish biomass in Vietnam's waters (Watson *et al.* 2012), and continued total catch increases may be driven by continuously increasing effort and spatial expansion of the offshore fleet (Swartz *et al.* 2010; Watson *et al.* 2012). This condition is corroborated by fisher interviews, whereby interviewees believed that fish stocks had declined, and that increase in catches seen in the 2000s were "...mainly caused by the use of more efficient fishing gear and the growth of the number of fishing boats" (Boonstra and Dang 2010).

Alternatively, the linear growth in reported landings in the last two decades may indicate systemic over-reporting, a situation that could arise if fisheries officials have a personal interest in attaining production targets (Watson and Pauly 2001). Either way, reported marine landings statistics should not be taken at face value. Given these reasons, our decision to flat-line marine capture at 2.5 million t from 1999 to 2010 appears reasonable. First, the value accounts for unreported catches in Vietnam. Second, with uncertainty over the status of Vietnam's fish stocks, but strong indications that biomass may well be at a reduced and declining level, we avoid over-estimating actual marine fisheries catches by eliminating the exponential growth pattern in our reconstruction.

Discards were estimated at around 4.7 million t from 1989-2010, overwhelmingly from offshore vessels that do not return to port daily (Long 2003). Otherwise, there is a ready market for low-value fish that would otherwise be discarded, for processing into fish meal, fermented fish and animal feed. Discards increased almost 50 fold from 7,700 t-year⁻¹ in 1987 to 387,000 t-year⁻¹ in 2010. This trend reflects the rapid growth in the number of offshore vessels in Vietnam since 1990, and the proportional increase of low-value fish in total catches.

Illegal fishing by foreign vessels is an additional stress on Vietnam's fisheries. According to Butcher (1999), Thai trawlers were already fishing off the coasts of South Vietnam as far back as 1964. More recently, 300-500 foreign boats are thought to fish illegally in Vietnam's EEZ every year, taking an estimated 100,000 t-year⁻¹ of marine catch annually (see also Pauly *et al.* 2013). This translates to a potential 5% additional catch in Vietnam's EEZ in 2010, representing a socio-economic loss to Vietnamese society as fish catches taken illegally by foreign vessels do not contribute to Vietnam's food security nor generate financial returns.

Vietnam's inshore zone up to 5 nm from shore is heavily exploited, and is threatened by land-based pollution, destructive fishing methods, and unregulated fishing effort (Pomeroy *et al.* 2009). Although fisheries regulations exist, lack of adequate monitoring and enforcement effort essentially makes Vietnam's marine fisheries an open access resource. Overcapitalisation in both nearshore and offshore sectors has to be addressed urgently—uncontrolled growth in boat numbers and engine capacity has to be addressed and stricter delineation of, and access controls over, inshore and offshore fishing zones have to be implemented. To do so, fisheries managers have to reconcile their dual mandates of marine production and resource conservation, a task which will require a broader ecosystem-based management approach than that currently demonstrated. The performance of the offshore fleet has not met expectations (Pomeroy *et al.* 2009; DERG and MoPI 2010), as high fishing costs and lack of institutional monitoring and enforcement have allowed offshore vessel owners to remain fishing in shallower waters, where they stress already overused nearshore resources and create conflict with small-scale fishers. Clearly, Vietnam's fisheries regulations have to address socio-economic issues, not least the poverty of small-scale fishing communities.

A series of fisheries management capacity building projects in the 2000s indicate that Vietnam is developing expertise to improve its fisheries management system. For example, co-managed marine protected areas and buybacks have been attempted in some locations (Pomeroy *et al.* 2009), and steps can be taken to strengthen and adapt the traditional *van chai* system to current conditions (Ruddle 1998). Yet, large gaps in knowledge of Vietnam's marine fisheries will continue to hinder management efforts unless the underlying issues are resolved. This study highlights the shortcomings of past and present marine fisheries statistics, and should act as a catalyst for more stringent and comprehensive accounting of extractive pressures on Vietnam's marine resources before the resource base is pushed to the point of collapse.

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

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Discard
1950	50,000	95,000	-	2,900	92,000	-
1951	50,000	95,000	-	2,900	92,000	-
1952	50,000	95,000	-	3,800	91,000	-
1953	50,000	95,000	-	4,800	90,000	-
1954	110,000	209,000	-	12,600	197,000	-
1955	164,000	312,000	-	21,800	290,000	-
1956	179,600	342,000	-	27,300	314,000	-
1957	194,400	370,000	-	33,300	336,000	-
1958	219,000	416,000	-	41,600	375,000	-
1959	259,000	493,000	-	49,300	443,000	-
1960	345,000	656,000	-	72,200	584,000	-
1961	344,900	656,000	-	78,700	577,000	-
1962	422,390	803,000	-	104,400	699,000	-
1963	493,690	939,000	-	131,400	807,000	-
1964	509,970	970,000	-	145,500	824,000	-
1965	532,960	948,000	-	151,700	796,000	-
1966	530,740	926,000	-	157,400	769,000	-
1967	566,110	904,000	-	162,800	742,000	-
1968	573,870	882,000	-	158,800	724,000	-
1969	615,010	861,000	-	154,900	706,000	-
1970	466,550	839,000	-	151,000	688,000	-
1971	529,440	817,000	-	147,000	670,000	-
1972	608,670	795,000	-	143,100	652,000	-
1973	634,650	773,000	-	139,200	634,000	-
1974	395,080	751,000	-	135,200	616,000	-
1975	370,640	705,000	-	126,900	578,000	-
1976	426,100	810,000	-	154,000	656,000	-
1977	408,480	777,000	-	155,400	621,000	-
1978	397,740	756,000	-	158,800	598,000	-
1979	408,850	778,000	-	171,100	606,000	-
1980	391,460	744,000	-	171,200	573,000	-
1981	408,346	777,000	-	186,400	590,000	-
1982	462,758	880,000	-	220,000	660,000	-
1983	541,088	1,029,000	-	267,500	761,000	-
1984	535,029	1,017,000	-	274,700	743,000	-
1985	558,860	1,063,000	-	297,600	765,000	-
1986	583,812	1,110,000	-	322,000	788,000	-
1987	599,339	1,147,000	34,000	331,700	774,000	7,700
1988	605,980	1,168,000	69,000	346,600	737,000	15,700
1989	647,265	1,256,000	111,000	369,600	750,000	25,300
1990	653,236	1,277,000	149,000	371,700	722,000	34,300
1991	694,248	1,366,000	198,000	392,800	729,000	46,000
1992	729,953	1,447,000	250,000	421,200	717,000	58,400
1993	785,304	1,567,000	314,000	448,300	731,000	73,900
1994	946,322	1,902,000	432,000	533,400	834,000	102,600
1995	990,250	2,005,000	508,000	549,900	825,000	121,800
1996	1,058,708	2,159,000	624,000	583,500	806,000	145,800
1997	1,098,736	2,257,000	710,000	593,000	786,000	167,700
1998	1,155,154	2,391,000	813,000	609,000	775,000	193,800
1999	1,314,593	2,733,000	975,000	701,500	824,000	233,500
2000	1,419,612	2,747,000	1,025,000	693,200	782,000	246,600
2001	1,481,175	2,760,000	1,050,000	696,000	754,000	259,900
2002	1,575,640	2,773,000	1,100,000	686,000	714,000	273,300
2003	1,647,133	2,787,000	1,150,000	688,500	662,000	286,900
2004	1,733,434	2,801,000	1,200,000	676,000	624,000	300,700
2005	1,791,100	2,815,000	1,250,000	662,500	587,000	314,700
2006	1,823,700	2,829,000	1,300,000	648,000	552,000	328,800
2007	1,876,300	2,843,000	1,350,000	644,000	506,000	343,100
2008	1,946,700	2,858,000	1,400,000	627,000	473,000	357,600
2009	2,091,700	2,872,000	1,450,000	609,000	441,000	372,200
2010	2,220,000	2,887,000	1,500,000	600,000	400,000	387,000

Appendix Table A2. Reconstructed total catch (in tonnes) by major taxa, for Vietnam, 1950-2010.

Year	Synodontidae	Carangidae	Scombridae	Perciformes	Leiognathidae	Nemipterus	Sciaenidae	Penaeidae	Shrimps & prawns	Priacanthus
1950	1,900	28,800	22,400	-	-	3,000	2,200	7,100	2,800	1,900
1951	2,100	28,100	21,800	-	-	3,400	2,500	7,100	2,800	2,200
1952	2,400	27,400	21,300	-	-	3,800	2,800	7,100	2,800	2,400
1953	2,600	26,700	20,800	-	-	4,100	3,100	7,100	2,800	2,700
1954	6,600	61,100	47,600	-	-	10,600	7,900	14,300	5,300	6,800
1955	11,200	92,500	71,900	-	-	17,800	13,300	14,300	5,500	11,500
1956	13,200	100,000	77,800	-	-	21,000	15,700	14,300	5,500	13,500
1957	15,300	106,600	82,900	-	-	24,400	18,100	14,300	5,500	15,700
1958	18,000	115,600	89,900	-	-	28,600	21,300	21,400	7,900	18,400
1959	24,500	133,800	104,100	1,200	1,200	35,800	27,100	21,400	7,900	23,100
1960	37,200	175,300	136,400	3,300	3,100	50,700	38,800	21,400	7,900	32,600
1961	41,000	168,200	130,800	5,000	4,700	52,400	40,600	21,400	7,900	33,700
1962	55,500	200,100	155,700	8,200	7,800	67,000	52,500	21,400	7,900	43,200
1963	70,700	225,400	175,300	12,100	11,500	81,100	64,300	21,400	8,000	52,200
1964	77,800	220,900	171,800	14,900	14,100	85,300	68,300	28,500	10,400	54,900
1965	81,600	206,900	161,000	17,000	16,100	85,700	69,200	26,600	9,700	55,200
1966	84,900	193,200	150,300	19,000	18,000	85,700	69,900	25,000	9,100	55,200
1967	87,500	179,500	139,600	20,900	19,800	85,300	70,100	21,900	8,700	54,900
1968	89,300	165,200	128,500	22,400	21,200	84,000	69,700	28,200	10,900	54,100
1969	90,800	152,000	118,200	23,800	22,600	82,800	69,200	28,700	11,400	53,300
1970	87,200	132,200	102,900	23,800	22,600	77,100	64,900	44,500	25,300	49,600
1971	87,900	119,200	92,700	24,500	23,200	75,000	59,500	52,600	34,000	48,800
1972	93,600	109,500	85,200	25,600	24,300	79,100	67,000	38,900	51,300	53,300
1973	84,900	97,900	76,100	26,000	24,600	68,100	62,100	56,000	45,500	38,300
1974	84,100	90,000	70,000	27,000	25,600	77,200	58,600	53,900	42,500	43,900
1975	81,200	79,600	61,900	27,000	25,500	79,400	44,900	50,200	39,200	47,300
1976	94,200	86,000	66,900	32,800	31,100	90,500	33,200	57,600	45,300	59,400
1977	96,300	77,400	60,200	33,300	31,500	70,300	50,700	54,500	42,700	65,900
1978	95,600	70,700	55,000	34,200	32,400	102,800	48,900	52,300	40,800	43,600
1979	107,600	67,800	52,700	37,000	35,000	92,200	48,700	53,100	41,500	52,500
1980	101,100	62,600	48,700	36,700	34,800	70,900	47,700	53,100	41,600	64,400
1981	97,300	67,700	52,700	40,400	38,300	75,700	50,600	52,200	41,000	58,000
1982	120,200	80,300	62,400	48,800	46,300	87,100	52,500	52,400	41,500	46,500
1983	153,300	96,200	74,800	59,700	56,600	97,100	62,500	59,500	48,000	67,200
1984	155,400	97,100	75,500	61,500	58,200	93,900	60,200	55,600	46,000	58,700
1985	157,100	103,000	80,100	66,600	63,100	99,200	55,000	59,900	49,100	62,600
1986	182,700	117,100	91,100	77,400	73,300	103,800	52,800	46,300	26,700	73,600
1987	193,900	123,200	95,800	84,600	80,100	106,100	52,600	42,300	23,600	81,900
1988	199,800	123,200	95,800	88,000	83,400	98,800	57,500	58,700	29,500	75,800
1989	217,100	132,000	102,600	98,000	92,800	107,100	60,100	45,800	36,400	72,900
1990	210,700	131,000	101,900	101,200	95,900	99,700	57,800	45,000	44,000	74,500
1991	236,800	135,700	105,500	109,200	103,500	106,600	49,500	64,800	56,100	75,600
1992	261,900	142,500	110,900	119,400	113,100	114,000	45,700	69,600	58,500	77,200
1993	291,700	154,200	119,900	134,300	127,200	105,900	50,200	78,700	59,700	86,200
1994	310,100	165,700	128,900	152,200	144,100	104,700	54,200	95,500	122,100	79,500
1995	334,300	166,000	129,100	159,800	151,300	94,900	54,900	118,000	141,300	74,300
1996	369,900	185,300	144,100	184,800	175,000	92,800	64,300	122,900	130,100	93,100
1997	400,400	189,400	147,300	197,300	186,900	84,300	67,600	140,300	135,700	81,300
1998	387,900	190,800	148,400	208,700	197,600	87,300	70,100	133,400	154,200	92,200
1999	483,300	225,200	175,200	254,100	240,600	85,000	97,100	130,500	145,400	84,400
2000	456,800	209,100	162,700	248,100	235,000	80,100	93,900	121,100	152,900	68,600
2001	476,800	212,500	165,300	253,900	240,400	81,600	98,700	108,400	137,000	60,300
2002	482,500	213,700	166,200	257,400	243,700	82,600	100,600	102,200	133,400	57,800
2003	477,200	211,200	164,200	257,400	243,700	79,800	101,600	104,600	142,600	58,600
2004	473,400	216,400	168,300	264,900	250,800	73,300	110,600	102,900	129,200	86,200
2005	476,200	214,600	166,900	265,700	251,600	79,100	113,300	104,200	132,300	81,100
2006	480,600	215,400	167,500	269,000	254,700	77,600	117,000	101,800	130,700	81,700
2007	481,400	214,800	167,000	271,000	256,600	76,600	118,200	100,900	129,200	83,500
2008	485,300	214,100	166,500	273,000	258,400	76,600	123,500	98,500	132,200	58,400
2009	485,500	213,800	166,300	275,300	260,600	78,000	126,300	114,100	134,000	56,500
2010	490,800	213,400	166,000	277,600	262,800	78,100	126,100	115,700	137,100	58,000