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Historical Ecology of the Raja Ampat Archipelago, Papua Province, Indonesia

Fisheries Centre, University of British Columbia, Canada

Historical Ecology of the Raja Ampat Archipelago,
Papua Province, Indonesia

by
Maria Lourdes D. Palomares and Johanna J. Heymans

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DIRECTOR'S FOREWORD

In a paper[1] whose importance cannot be over-emphasized, Dr Jeremy Jackson, of the Scripps Institution of Oceanography, and his numerous co-authors, demonstrated that humans have impacted on the diversity of the oceans for thousands of years. However, these impacts were limited to vulnerable coastal species which could be readily hunted or collected. Although their local extirpation and sometimes extinction had long-term consequences reaching into the present, it is only with the onset of modernity that humans and the first wave of globalization –the global colonial enterprises conducted by European powers from the 16th century onwards – that widespread impacts on marine biodiversity became visible. This is not only because this globalization encouraged the international trade of products obtained from the exploitation of coastal areas, but also because the sailing vessels which the European powers deployed in this period carried onboard alert observers of nature, i.e., captains and naturalists, whose narratives of their voyages contain a wealth of observations on the biodiversity they observed.

This contribution is the second of a series which uses 'content analysis' to convert these observations into numbers that can be analyzed using various statistical methods. The first, pertaining to the Falkland Islands[2], clearly indicated that over time, observations on various animal groups in those remote islands used the word 'abundance' or 'common' (or their equivalent) less frequently, while those indicating rarity became more frequent. The same results were obtained here, thousands of miles from the Falkland Islands, in a totally different cultural and biological context – one subjected, however, to the same drivers of change.

In both the Falkland Islands and the larger Raja Ampat Archipelago, local population increase and the increase of its footprint appear to have a strong effect on local biodiversity. However, in both cases, the biggest impact is due to the external (international) demand for certain products, e.g., fur seal skins and whale oil from the Falklands, for consumption in Europe and North America, and *tripang* (i.e., sea cucumber), pearls and turtles from the Raja Ampat Archipelago, consumed in both China and Europe. Though exploitation rates were to increase tenfold and more in the second half of the 20th century, the earlier exploitation rates, e.g., those prevailing in the 19th century, already had an impact on biodiversity, as demonstrated here.

This report, thus, confirms that content analysis can indeed be applied at various scales, and that well-stocked libraries, such as UBC's, can be used to reconstruct aspects of the history of biodiversity of far-away lands and seas. It is ironic that this conceptual tool is being successfully deployed in the 21st century, in which, it seems, we will be finishing off the biodiversity that we should, instead, be handing over to the next generations.

Daniel Pauly
Director Fisheries Centre, UBC
09 October 2006

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[1] Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Cooke, R., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293, 629-638.

[2] Palomares, M.L.D., Mohammed, E., Pauly, D., 2006. European expeditions as a source of historic abundance data on marine organisms. Environmental History. 11 (October), 835-847.

Historical Ecology of the Raja Ampat Archipelago, Papua Province, Indonesia[1]

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ABSTRACT

This report presents a review of the status of marine resources of the Raja Ampat Archipelago, Papua Province, Indonesia based on narratives of early European expeditions in various museums and libraries in Europe and also local archives in Papua. More than 500 documents on the study area were identified and located in various museums in the Netherlands, the UK, and France, and at the University of British Columbia library. Some of these were available in electronic format and some were photocopied. Not all the documents were available for consultation and some were 'off limits', notably those in special and rare book collections.

Of these 500 documents, 350 were obtained and more than 250 were processed (25,000 pages scanned), of which only 50% (in 900 pages of text or 4% of the total number of pages scanned) contained abundance observations and observations on the impact of the human population on the ecosystem within the geographic bounding box established at 2° North and 2° South between 127 and 132° East.

In general, these observations suggest: 1) a decline, of 50%, of the perceived occurrences of turtles, fish and invertebrates; 2) a general decline in the perception that turtles, fish and marine plants were abundant; 3) a sharp increase in the perception of populousness in coastal kampongs (i.e., villages); 4) a sharp decrease in the perception that marine resources are fished only for subsistence; 5) a decrease in the perception that marine resources are fished extensively; and 6) a slow increase in the perception that marine resources are fished for commercial purposes at medium and low levels of activity. These results corroborate those of data from independent sources of time series trends of catches of fresh fish, dried and salted fish, and shrimp as well as time series trends of exports of fish products, e.g., *tripang*, *trassi*, turtle shells, mollusk shells, crocodile skin, shark fins and jellyfishes.

The data used for this exercise can be accessed through the 'Historic Expeditions and Scientific Surveys' link of the *Sea Around Us* Project website (www.seaaroundus.org). They will gradually be complemented with data from documents so far not accessed. The results of this study will feed into the ecological modelling of the Bird's Head functional seascape, a component of the Seascapes Program of Conservation International (www.conservation.org).

INTRODUCTION

Over the past decade, scientists and resource managers have realized the dangers of the 'shifting baseline' phenomenon, whereby our perspective of 'what is natural and pristine' is blurred by the increasing overexploitation of reefs over the last half-century. We have 'forgotten' what a truly healthy reef or fish stock looks like; a reef that today seems healthy and dense with fish may actually be only a vestige of its former self. A 'good catch' for a fisherman using a motorized dugout canoe today might actually be tiny compared to what a fisher used to be able to catch twenty years ago by simply fishing from the beach with a bow and an arrow. Accounts from the late 1700s and early 1800s which mention seas swarming with big fish and beaches packed with turtles are nowadays hard to believe. However, we are coming to understand that this really was the way that reefs naturally existed – but sadly we have greatly reduced the numbers of most large marine life over the past 100 years.

The main objective of this study is to reconstruct, to the extent possible and from these narratives, a broad picture of the status of the living marine and coastal resources of the Raja Ampat group of islands prior to the onset of commercial fishing and logging to demonstrate how the perception of population size changed over time. A secondary objective is to show how the impact of human extractive activities has changed over time, by looking at the perceived changes the density of human populations and their perceived impact on the ecosystem. The results of this study will feed into the ecological modelling of the Bird's Head functional seascape, a component of the Seascapes Program of Conservation International (www.conservation.org). Before addressing these objectives, it is necessary to first provide a historical background of the Raja Ampat Archipelago which we attempt in the following sections.

In order to set appropriate management targets for maintenance and restoration of fish stocks and ecosystem integrity in the Raja Ampat Archipelago, it is imperative to reconstruct, as best we can, what this ecosystem looked like before the onset of commercial fishing and logging. Fortunately, the Maluku and other parts of the region was visited by at least five major naturalist expeditions in the early to mid 1800s, including the French ships the *Uranie* (1818-1819), the *Coquille* (1823), the *Astrolabe* (1826), the British ships the HMS *Samarang* (1843, 1846), the HMS *Challenger* (1874-1875). Naturalists conducting research on marine life in the area included the Dutch ichthyologist Peter Bleeker's comprehensive studies on Indonesia's fish fauna throughout the 1860s, and the British Alfred Russel Wallace whose travels within the Malay Archipelago in the early 1860s introduced us to the concept of the center of biodiversity. At the turn of the century, the area was again visited by the *Siboga* expedition (1899-1900) and later by the *Snellius* expedition (1929-1930). Additionally, there is a wealth of information collected by Dutch colonial administrators (recording volumes of fisheries products landed and traded, etc) and the Allied Forces during World War II, all of which can be mined for information on the original state of fish stocks and reefs in the Archipelago.

THE SPICE TRADE AND THE EAST INDIES

The first European accounts of the East Indies can probably be attributed to Marco Polo, who stayed in Sumatra in 1292 (Robequain, 1958:1). This was followed by various accounts related to the flow of spices, i.e., nutmeg (*Myristica fragrans*), cloves (*Eugenia aromatica*) and cinnamon from the East Indies (India, the Malay Archipelago and the Moluccas) to Europe. As the demand for spices increased in Europe, merchants established agencies and correspondents, mostly Indians, Chinese and Arabs, in the East Indies which encouraged active trade and the growth of 'middlemen' peddling these goods between Europe and the East Indies. As the cost of spices increased due to Venetian, Arab and Indian middlemen, many European powers, notably the Portuguese, strove to ensure control of the spice production itself and "for about 100 years the Moluccas were the centre of European activity in the East Indies" (Robequan, 1958:2).

"As early as 1512 the Portuguese established a royal agent in Sumatra, and a Portuguese squadron under the command of Abreu reached the Moluccas, though all but one ship was lost on the voyage" (Robequain, 1958:2). In 1526-1527 the Portuguese Jorge de Meneses landed on the west coast of New Guinea and 10 years later some sailors of a Spanish vessel was shipwrecked on the north coast (Utrecht, 1978). In 1545 the Spaniard Ynigo Ortiz de Retes landed with his ship the *San Juan* at the mouth of the Mamberamo river and noticed the similarity of the population to that of Africa (Utrecht, 1978). The Spaniard Magellan's expedition (without him, as he died on one of the St. Lazarus Islands, i.e., the Philippines) reached the Moluccas and was received by King Almanzor at Tidore. The Portuguese were established on the neighboring island of Ternate, and the Spice wars started (Robequain, 1958:3). The Portuguese were driven back to Amboina in 1575 (Robequain, 1958:3).

"Of the European settlers the huge Portuguese carracks could accommodate at least six hundred men and the Dutch ships even more" (Robequain, 1958:301). The voyage from Western Europe to the East Indies seldom lasted less than a year and often took longer (Robequain, 1958:301). The voyages avoided the north-east monsoon by passing around the west of Buru and sailing between Halmahera and New Guinea (Robequain, 1958:304).

The Dutch, "increasingly dissatisfied with their position as middlemen as their own economy expanded" (Robequain, 1958:3), joined in the struggle to control the spice trade and production. Jan Huyghen van Linschoten returned from a trip to Goa carrying copies of Portuguese nautical maps which enabled Cornelius Houtman to complete a voyage to Bantam on the west coast of Sumatra on June 5, 1596 (Anon, 2006a). This broke the 16th century Portuguese monopoly of the spice trade.

After this expedition, thirteen more were sent by the Dutch East India Company to the East Indies between 1598 and 1602 (Robequain, 1958:3). Jacob Cornelis van Necq of Amsterdam arrived in the Moluccas in 1598 and was welcomed at Amboina by the natives, after which some Dutch settled in Banda to cultivate nutmeg (Robequain, 1958:254). In 1605 the Dutch established themselves in Amboina and in 1610 they became the masters of Ternate (Robequain, 1958:3). In 1619 Jan Pieterzoon Coen seized Jakarta from the Portuguese and founded Batavia. It was from here that the Dutch East Indian Company succeeded in controlling most of the trade (Robequain, 1958:3). By 1768, the Dutch who were exporting cloves from plantations in Ambon were faced with overproduction as cloves were "grown in such quantities, that the government at Batavia, sometimes order a large number of clove-trees to be extirpated, and that no more than a certain fixed number shall be planted. [...] the propagation of the clove-trees should cease, till their number was reduced to 550,000; the number of trees, both young, and fruit-bearing, was then 759,040" (Stavorinus, 1798:330).

After the expedition by merchants from St. Malo, Vitré and Laval to Sumatra and Java in 1529-1530 (the voyage of Jean Parmentier to Sumatra in 1529), hardly any French ships visited the East Indies until the end of the 18th century (Robequain, 1958:4). However, "recent researches indicate that Jean Parmentier's expedition to Sumatra was the means by which the discovery of Java-la-Grande became known" (Wallis, 2006). The Spaniards and Portuguese also did not advance, but the English did; although they were unsuccessful in their attempts to settle in the Moluccas at the beginning of the 17th century, their factory at Bantam lasted until 1682 (Robequain, 1958).

English freebooters including William Dampier often succeeded in cheating the Dutch; Great Britain seized the Dutch territories during the Napoleonic Wars and held on to them until 1816 (Robequain, 1958:4). Dampier sailed past the north coast in 1700 on his ship the *Roebuck* and James Cook sailed past the south coast through the Torres Strait in 1770 (Utrecht, 1978). The Anglo-Dutch treaty (or the Treaty of London) signed by Hendrik Fagel and Anton Reinhard Falck for the United Kingdom of the Netherlands and by George Canning and Charles Watkins Williams Wynn for the Great Britain on March 17 1824, officially divided the region into the British Malaya (Malaysia) and the Dutch East Indies (Indonesia). This treaty was ratified by the Great Britain on April 30 1824 and by the Netherlands on June 2, 1824 (see Anon, 1824).

The Dutch retained control of the Dutch East Indies until Indonesia became independent in 1945. However, West Irian (now Papua) did not (Mintz, 1961). Papua was run by Indonesia from 1962 under a United Nations mandate and was finally taken over by Indonesia in 1969 (ICG, 2002:1). The demographic balance has changed dramatically since the Indonesian takeover. There has been an influx of settlers under Indonesian rule, mostly ethnic Malay Muslims, often Javanese or Bugis, though some are from Maluku, a Malay-Melanesian region with Christian and Muslim inhabitants (ICG, 2002:9).

Explorations in New Guinea

The oldest written information on New Guinea is from the Chinese merchants who, in the 8th century, gave the king of the Sumatran Sriwijaya kingdom a "black curly haired *Sen-k'i* girl" from New Guinea. In the 12th century the Chinese trade dignitary, Chau Ya-kua, described New Guinea as an area subjected to

Javan rule (Utrecht, 1978). In 1365 the East-Javanese historic work *Nagarekerta-gama* mentions that New Guinea was part of the greater Indonesian kingdom of *Majaphahid* (Utrecht, 1978).

The first Dutch ship that arrived on the New Guinea coast was the *Kleine Zon* in 1606. It was attacked and returned back to Banda in 1607 (Utrecht, 1978). In the meantime, Willem Zansz made a short stop at the Kei and Aru Islands with the *Duyfcken* and toured the south coast of New Guinea, although he did not land on the island itself, but on the north coast of Australia (Utrecht, 1978). At the same time Luis Vas de Torres sailed through the strait that divides Australia and New Guinea, which now bears his name (Utrecht, 1978). The VOC ship *Eendracht* under Captain Isaac le Maire and first mate Willem Cornelisz Schouten was the second Dutch ship to land on New Guinea, and landed on an island which was then called New Ireland (i.e., Schouten Island), on the eastern side of New Guinea (Utrecht, 1978).

In January 1623, the *Arnhem* and *Pera* under the command of Jan Carstenz sailed to north Australia. The *Arnhem* landed in New Guinea and was attacked by the Papuans (Utrecht, 1978). Between 1636 and 1824 the Dutch stayed away from New Guinea (Utrecht, 1978) and because the Dutch were not really interested in New Guinea, they recognized the Sultan of Tidore as the sole leader (Jansen-Weber *et al*., 1997).

In 1773, the English East Indian Company claimed the eastern part of New Guinea and in 1824, the Dutch and English decided to divide New Guinea in two (Jansen-Weber *et al*., 1997). In 1824, the Dutch sent the *Dourga* under the command of D.H. Kolff to West New Guinea where it landed at the Aru Islands and then at Prins Frederik Henderik Island, up the west coast and onto the north. Finally, in 1826, the *Triton* was sent to southwest New Guinea (Utrecht, 1978).

OCEANOGRAPHIC AND MARINE BIOLOGICAL STUDIES

In spite of the long ascendancy of European powers in the area, cartographical, hydrographical, geographical and biological studies became of interest only towards the end of the 19th century. The tight control of the Dutch East India Company prohibited the exploration, notably for cartographical purposes (the offense of which was punished in extreme cases by death), of all areas under its rule (de Freycinet, 1829). The spice trade and the economic benefit from it were all that interested the Company because the islands "can never be expected to yield any advantage, besides that derived from the spice-trade" (Stavorinus, 1798:335). However, 19th century European officials in the region, notably the *Resident*, were learned individuals who occasionally dealt with describing the lush nature of the region. "As they were first and foremost, civil servants – colonial bureaucrats [...] not highly paid, but the cost of colonial living was low, and they had solid pensions [...] many of their studies were financed out of the colonial budget and moreover, it was not of great matter to their employers whether or not they published a great deal [...]" (Anderson, 1992:26). They had time to 'indulge' in studies of natural history, sometimes being able to collect specimens (as Bleeker did in the mid 1800s), and at the same time fight the boredom of their jobs.

The earliest biological accounts from the region were published by Georg Everhard Rumphius, a German-Dutch botanist employed by the Dutch East India Company, who described plants from the island of Ambon in a catalogue, entitled *Herbarium Amboinensis* published in 1741, 39 years after his death (see Rumphius, 1999; www.museumboerhaave.nl). Rumphius' work was followed by a long lull in organized scientific voyages until in June 1759 the botanist, Vitaliano Donati, was sent by the Italian King on a scientific and commercial mission to Egypt and the East Indies to collect samples for the museum and the Botanical Garden, and to observe in those countries the processes of mineral extraction, agricultural cultivation, and livestock breeding. Donati's voyage was unfortunately ended when he died near the Indian coast of Mangalore in February 1762 (see Anon, 2002). Another botanist, the Swedish Carl Peter Thunberg was sent by the Dutch East India Company to collect specimens for the Dutch botanical gardens in 1771. He stayed 3 years in South Africa where he was able to learn Dutch and collect many botanical specimens from inland Africa. He finally got to Java in 1775 and stayed in Jakarta for only 2 months (see www.wikipedia.org). The French naturalist and explorer, Pierre Sonnerat published an account of his voyages to Southeast Asia and the Moluccas (see Sonnerat, 1776, 1782). In the 1776 account of his voyage to New Guinea, he described many terrestrial plants, trees and birds including 3 species of 'penguins' (which probably was an error). The British Joseph Banks joined the first joint scientific expedition of the British Royal Navy and the Royal Society to the South Pacific Ocean on the *H.M.S. Endeavour* in 1768-1771, the first of James Cook's voyages to the region. Banks is credited with several species of plants which now bear his name (see Bank's Endeavour journal at www.southseas.nla.gov.au).

This trend in studies of the terrestrial fauna, flora and paleontology of the region continued until the late 1800s leading to the Dutch expedition to the center of Sumatra in 1877-1879 and Vorderman's ornithological studies in Jakarta (Weber, 1902:2-3). Marine biological studies, of which there were few, were still to be organized. The French, during their period of 'Enlightenment' sent vessels of the Royal Navy to perform oceanographic explorations even before the start of the 19^{th} century. The first real scientific expedition, however, can probably be attributed to the circumnavigation of the *Géographe* and the *Naturaliste* commanded by Nicolas Baudin with François Péron and Jean Baptiste Louis Claude Théodore Leschaunault de la Tour as naturalists and Charles Alexandre Lesueur as artist (Péron, 1807; Freycinet, 1811). This expedition was the first of its kind to carry scientists and private citizens, among its crew; in those days, naturalists on board were mostly surgeons of the royal navy. Baudin and his crew sailed through the Timor Sea and on their way to Australia in 1801, anchored at Kupang (Timor Leste) where some fish specimens (about 200 species) were obtained.

It took more than 10 years before the French could send another expedition of this type. Louis Claude de Freycinet who sailed with Baudin as commander of the *Naturaliste* undertook his own circumnavigation in the *Uranie* (and later in the *Physicienne* which sailed under the command of Dumont D'Urville) in 1817-1820 with Jean René Constant Quoy and Joseph Paul Gaimard as naturalists (Freycinet, 1825; 1829). Freycinet and his crew (which included his wife, Rose de Freycinet) anchored at Kupang (Timor Leste) and later set up an 'observatory' on the island of Rawak (probably Balabalak) to observe the marine life of the islands Vaigiou, Boni and Manouaran (all in Waigeo, Papua Province). The many specimens obtained along the way were mostly lost in the shipwreck of the *Uranie* in the Falkland Islands on February 4, 1820. A total of 164 fish species were brought back, 137 described, 62 illustrated in the Atlas of the expedition, drawn either by Jacques Étienne Victor Arago or by Quoy himself. The infinite patience and determination of Charles Gaudichard-Beaupré in retrieving his herbarium from the shipwrecked *Uranie* (he washed the plants in freshwater and dried them again) and thus saving two-thirds of the shipwrecked botanical collection is here noteworthy of the dedication of voyageur-naturalists of the time (Bauchot *et al.*, 1990).

Louis Isidore Duperrey commanded the *Coquille* in 1822-1825 with Prosper Garnot (royal navy surgeon) and René Primevère Lesson (pharmacist) as naturalists (Duperrey, 1825; 1826; 1830). This expedition sailed through the Torres Strait to New Ireland (Schouten Island), Waigiu (Waigeo), and the Moluccas and finally anchored in Port Jackson (Sydney, Australia). Prosper Garnot was left in Sydney, being ill with dysentery, and later embarked on the *Castle Forbes* with several cases of the material gathered. The *Coquille* sank near the Cape of Good Hope, South Africa and the collections were lost. The expedition, noted by Cuvier as 'scientifically exemplary', successfully brought back specimens representing 288 fish species preserved in spirits of wine, 70 of which were illustrated by Lesson. More than 100 of them were to be described in the report of these travels (see Bauchot *et al.*, 1990).

The zoologists of the *Uranie*, Quoy and Gaimard, went on another circumnavigation passing through the 'southern seas' with the *Astrolabe* commanded by Dumont D'Urville in 1826-1829. In the region, they visited New Ireland (Schouten Island), Ambon, Celebes and Batavia (Jakarta). Quoy and Gaimard (who helplessly watched the *Uranie* go down with most of their collections) insisted on sending partial shipments, five in all, to the Museum of Natural History, Paris. Despite the diseases (malaria, dysentery and scurvy) that prevented some explorations and killed ten men (an ill Gaimard disembarked at Réunion), a considerable collection was brought back to France, along with 6,000 drawings (with a copy of each in case the original should be lost - an average of 12 drawings executed each day). A total of 49 fish species, 8 of which were new, were described in 1834 (see Bauchot *et al.*, 1990).

Dumont D'Urville commanded a second circumnavigation in 1837-1840 with the *Astrolabe* and the *Zelée*, the results of which were published between 1833 and 1848 with 10 volumes of narratives, 3 volumes of atlases, 2 volumes on hydrography, 2 on geography, 2 on botany and 5 on zoology.[1]

Other scientific initiatives also published reports of studies in the region. The British vessel the *H.M.S. Samarang* under the command of E. Belcher visited the area between 1843 and 1846 with the zoologist Arthur Adams (Adams, 1848). This expedition resulted in important documents furthering the understanding of the marine fauna of the Celebes Sea and the coast of Borneo (see online collection of historic narratives at www.dlxs.library.cornell.edu). From 1854 to 1862, Alfred Wallace traveled through

[1] We unfortunately run out of time to fully integrate the results of D'Urville's second expedition in this report. However, we believe that inclusion of these results would increase the usefulness of this study.

the Malay Archipelago to collect specimens and stayed for some time in the Raja Ampat area (Wallace, 1869). The *H.M.S. Challenger* undertook its major study of the area between 1874 and 1875 (Tizard *et al.*, 1885), the *Siboga* visited the area between 1899 and 1900 (Weber, 1902) while the *H.M.S. Snellius* visited the area in 1929-1930 (Kuenen, 1941). Between 1843 and 1861 Pieter Bleeker, a Dutch medical doctor and ichthyologist, conducted independent research and 'field trips' in the area. He collected well over 12,000 specimens (many are held at the Natural History Museum in Leiden and some in the Natural History Museum in Paris) and described more than 500 fish genera and about 2,000 species in more than 500 papers, many from the Dutch East Indies and specifically from the Raja Ampat area and some from his voyage to the Moluccas in the *Minahassa* (Bleeker, 1856e). His *Atlas Ichtyologique* published in 36 volumes between 1862 and 1878 remains a precious resource for today's ichthyologists.

The Second World War introduced another long lull in the string of scientific expeditions in the area and not much followed after that. Modern expeditions and surveys, unlike their 19th century (and earlier) counterparts, are now organized over shorter periods and with a specific hypothesis to test, not just to conduct surveys of the natural history. Purely oceanographic surveys focusing on physical measurements of the oceans were conducted in New Guinea waters in the second half of the 20th century by joint efforts of groups of international research institutions (see historical review in Cresswell, 2000). Biodiversity surveys were restarted in the region in the mid 1980s, notably the extensive fish samples from the trawl surveys of Gloerfelt-Tarp and Kailola in 1984, which, together with the already accumulated and older specimen collections, have improved our knowledge of Indonesian and Southeast Asian fish diversity. The Smithsonian Institution's ongoing support to biodiversity studies permitted an inventory of the abyssal Pacific Ocean sea cucumbers in the late 1990s led by D.L. Pawson and L. Parenti's study of Indonesian mangrove and coastal fishes.

In 1999, the Biodiversity Conservation Network published a report on the linkages between business, the environment and local communities (BCN, 1999) and found that in 1998 there was an increase in community capacity to address various issues related to marine resource management, conservation activities and ecotourism management. Monitoring of the project's socioeconomic and biological impacts began with baseline data collection in early 1997. Biak (in Geelvink Bay, now Teluk Cenderawasih) is the headquarters of their project and awareness resulted in a number of local agreements, including:

- A ban on blast and cyanide poison fishing;
- A village law was drafted to protect local coral reefs as a tourism resource and the law was validated by the local government;
- An agreement was reached with local fishermen on the use of only large-mesh nets (BCN, 1999).

The Biodiversity Conservation Network reported that, as a result of this project, the blast fishing by locals was at an all time low and improvements can be seen in areas that were damaged in the past by blast fishing or by the earthquake and tsunami of 1996. Recovery is particularly rapid near Runi Island, the site of extensive earthquake damage (BCN, 1999). Similarly, Severin (1997:53) found that in some distant corners of the Moluccas the natural world did survive largely intact.

Concern for the region's biodiversity was put in the limelight after a series of workshops on *Managing Potential Conflicts in the South China Sea* (WMPC-SCS) hosted by the Indonesian Department of Foreign Affairs. The various non-government organizations, who participated in the workshops, published a declaration to "renew efforts to secure support for and continue implementation of the agreed co-operative projects, particularly those focusing on biodiversity" (Ng *et al.*, 2004:2). This led to the Natuna-Anambas Archipelago 2002 expedition on the Indonesian research vessel *Baruna Jaya VIII* conducted by regional scientists who explored 60 sites in coastal habitats and obtained over 3,000 specimens of plants and animals both marine and terrestrial (some of which are still being processed; see Ng *et al.*, 2004, for the various contributions resulting from this expedition).

Now, at the start of the 21st century, we are conducting this historical review of what we know about the marine biodiversity of the region. Much has been done, but much has to be done in order to put both textual and numerical data into a synthesis that might, after all these centuries, make us better understand not only the richness but also the ephemerality of this biodiversity.

MATERIALS

THE STUDY SITE: KEPULAUAN RAJAAMPAT (RAJA AMPAT ARCHIPELAGO)

Geography

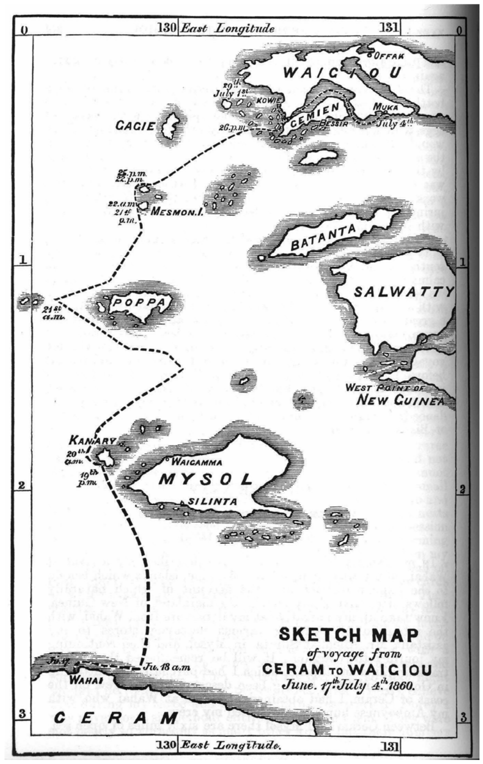
The Raja Ampat Islands encompass over 4 million hectares (Erdmann and Pet, 2002) or 43,000 km² (McKenna *et al.*, 2002) of land and sea area off the far northwestern tip of the Papua Province of Indonesia. This area includes the four large islands of Waigeo, Batanta, Salawati and Misool (also known as Batanme) and hundreds of smaller islands scattered amongst these (Erdmann and Pet, 2002). McKenna *et al.* (2002) define the Raja Ampat area as occurring between 0°20' N and 2°15' S latitude and 129°35' E and 131°20' E longitude. Erdmann and Pet (2002) noted that this boundary definition of the Raja Ampat islands includes the peripheral islands of Sayang in the north and Gag, Kofiau and the Bambu Islands to the west, but specifically excludes the Ayu and Asia Islands to the north and the Boo Islands to the west. The area so defined is entirely within the administrative boundaries of Sorong Regency (Kabupaten), with Sorong city as the regency seat. Included within this regency are the five districts (kecamatan) of Salawati, Samate, Misool, South Waigeo and North Waigeo, with a combined population of approximately 50,000 residents occupying 89 villages (McKenna *et al.*, 2002).

For this study, we included the areas surrounding the Raja Ampat Islands (bounded roughly at 2°N to 2°S and 127° to 132°E; Figure 1), including the Bird's Head peninsula, the Halmahera Islands and the Moluccas. The Bird's Head peninsula (Vogelkop), which is part of the Raja Ampat study site, has mostly rough ground, with foothills rising quickly to the limestone mountain ranges close to the coast and forming the watershed divide (Anon, 1944). The northeastern section of Bird's Head (the Manokwari area) is exposed to northerly and southerly winds and to swells entering Geelvink Bay (Anon, 1944:6). Depths generally range between 20-100 m close inshore, and there are several well-charted shoal banks and a dry reef although the coast is mostly reef-free. The sea approaches from the east, and the coast is exposed during the NW monsoon when there is usually a heavy swell (Anon, 1944:6).

The Moluccas include all the islands between the Sula group on the west and New Guinea in the east and from the Philippines in the north to the eastern part of the Sunda arc on the south (Robequain, 1958:249-250). It has a moister climate than the southern parts and has luxuriant vegetation, with the rainfall exceeding 102 cm and up to 351 cm in Amboina (201 days per year; Robequain, 1958:250). The Moluccas were known as the 'Spice Islands' of lore (Mintz, 1961:5).

To the south of the Sunda arc, Indonesia is bounded by a deep trench parallel with the arc and marking the region as belonging wholly to the Pacific (Robequain, 1958:13). At the eastern end of Indonesia between Australia and New Guinea the Arafura Sea masks the Sahul shelf similar to that of Sunda is very shallow (101 m). The Sahul shelf is named after a large sandbank stretching from Timor to New Guinea (Robequain, 1958:14).

To the east of the Wallace line the Sunda shelf gives way to a series of deep basins where submarine relief is uneven over relatively small areas (Robequain, 1958:14). The deepest part of the area is in the eastern part of the Banda Sea at a depth of 7,470 m (Robequain, 1958:15). The Banda Sea is subdivided into several secondary basins and has very complex ocean currents. Water from the Pacific Ocean reaches the Banda Sea from the north by a very narrow trough which skirts the west coast of Halmahera and swings around Buru, and the influence of the Pacific water prevails throughout these deep-sea basins (Robequain, 1958:15). In eastern Indonesia, the greatly varying depth of deep-sea basins is accompanied by a very uneven uplift of the folds along the island arcs and therefore the islands are smaller and the coasts generally steeper and more broken (Robequain, 1958:16).



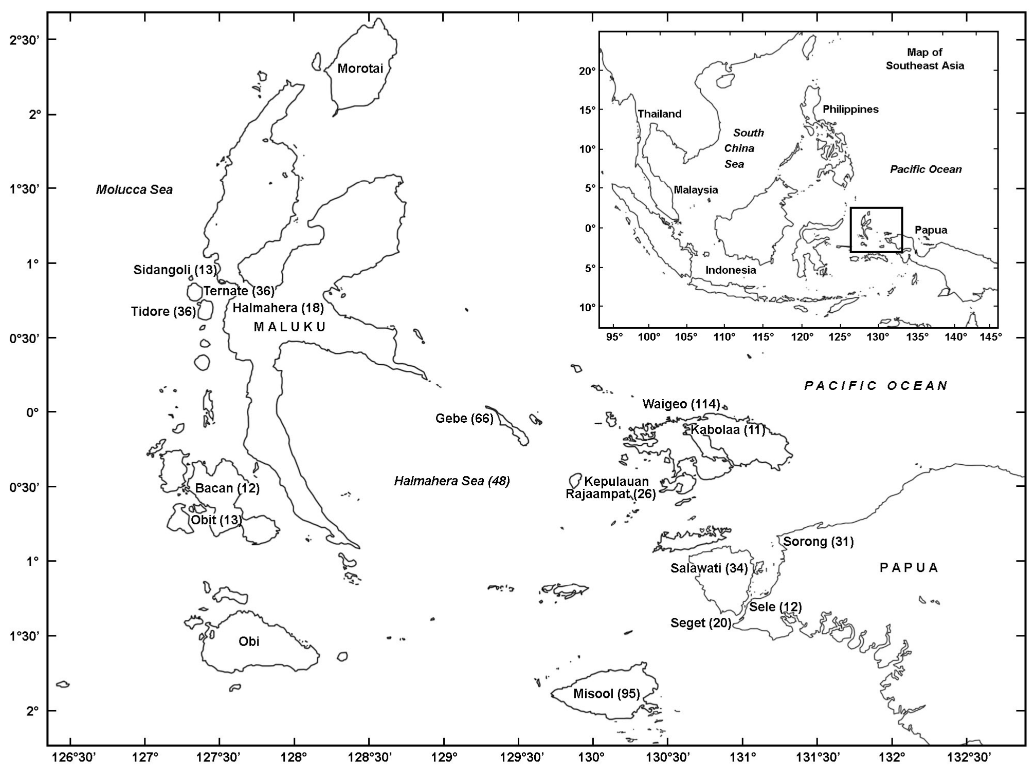


Figure 1. Maps depicting the study area; above: Wallace's voyage to Kepulauan Rajaampat in 1860; below: study area bounded by 2° North and 2° South between 127-132° East showing some of the place names (and number of observations in brackets) used in this analysis; the complete list of place names and number of observations available for the region is presented in Appendix A. Map drawn by A. Atanacio (Los Baños, Laguna, Philippines).

Physical environment and oceanography

The physical environment of our study area was described by MacKenzie (1962). Usually the winds are quite light and it is hot with substantial rainfall, especially on the coast, which is also subjected to monsoon winds. The southeast monsoon on the north coast starts in May with light easterly winds. From June to October, the monsoon is more defined, but it is affected by the high central mountains of New Guinea (MacKenzie, 1962). The northwest monsoon is more substantial with higher winds and it starts in November at full force until March. It causes large swells that are the source of large waves (MacKenzie, 1962). April to May and November to December have less wind from various directions. Although the coast is outside the typhoon belt it does sometimes get large north-east swells, rain and wind associated with typhoons in the Philippines (MacKenzie, 1962). The rainfall is more than 20-30 cm per year with average humidity of 87 % in January and 78 % in August to September, and humidity is usually highest at night, while being reduced during the day by heat (MacKenzie, 1962).

The average temperature at sea is usually about 1.5°C higher than on land, and the average sea temperature is about 28°C, varying by about 0.25°C (MacKenzie, 1962). Salinity, temperature and chemical tracer data suggest that, while it represents only a minor component of the Indonesian throughflow, there is a general southerly flow of water from the westerly-flowing South Equatorial Current (SEC), past the Raja Ampat area and into the Halmahera and Seram seas (Gordon and Fine, 1996, in Erdmann and Pet, 2002). These data also suggest that some of this westerly flowing SEC water is entrained in the Halmahera Eddy to the north of Raja Ampat, looping to the NE and joining the easterly-flowing North Equatorial Counter Current (Gordon and Fine, 1996 in Erdmann and Pet, 2002).

In the Birds Head area, tides are mixed, with semi-diurnal dominant, and tidal streams are weak (Anon, 1944:7). Sea currents are affected by the monsoons, with the main currents being east in the west monsoon, and west in the east monsoon. The average speed of the current at the coast is about 2.32 km per hour, with top speeds of 4.63 km per hour (MacKenzie, 1962). Visibility varies between 0.56 and 7.41 km but outside of the coastal areas the water is deep blue and secchi-disc readings were clear until 35 m. At the coast the visibility is about 15-20 m (MacKenzie, 1962).

MARINE BIODIVERSITY

The main materials used for this study were historical documents of voyages and expeditions by the various colonial nations, notably the Dutch, the French and the English, to the East Indies. Appendix B enumerates the different narratives of voyages and expeditions and other historical documents we obtained for this study. Reference materials encoded in the historical database (and included in the analyses) are differentiated from those references which were not processed but which we obtained as electronic or paper copies, and which will be processed at a later date.

The materials we chose to process first were those we felt would lead us to obtaining species lists and descriptions containing abundance observations as well as inferences on the human population and their impact on the marine environment. Thus, many of the materials we listed in Appendix B are either narratives of voyages, scientific expeditions or surveys, but some are ethnographic or economic studies. Such material was linked to an 'expedition record' as it involved specific details of stations or trip itineraries and thus linked to geographic coordinates. Other materials we obtained, e.g., memoires of individuals, historical and scientific reviews, and checklists of species, were also encoded, but not linked to a specific expedition. This meant that we had to assign standardized place names to these abundance records, where possible, and also assign assumed geographic coordinates (e.g., for the standardized place name) in order for us to include them in our analyses. Appendix B also includes recent information that we were able to obtain for the region. Note that studies focusing solely on Kepulauan Rajaampat (Raja Ampat islands) are minimal (2 % of the total number of observations obtained; see Appendix A for standard place names used in the analyses and the corresponding number of abundance observations obtained), thus justifying the expansion of our documentary research on the neighbouring areas, e.g., Laut Halmahera (Halmahera Sea), Kepulauan Kei, Kepulauan Boo, Kepulauan Aru and Laut Arafura (see Figure 1).

METHODS

BIODIVERSITY OF MARINE ORGANISMS

Abundance observations

Carpenter and Springer (2005) reiterated the hypothesis that the Indo-Malay-Philippines Archipelago is a “biodiversity hotspot”, i.e., a center of “extreme biodiversity”. This alone justifies our interest in establishing the species composition of the area. Reconstructing the make-up of the marine ecosystem, though a more tedious and honestly daunting task is doable, however, given the many scientific expeditions and surveys we have already enumerated above. Records of specimens brought back by these expeditions are currently mostly available in digital format. However, the related geographic information, though extractable from the original expedition logs, is most often captured incompletely or even erroneously. Still, with the help of the various species databases available online, we could construct a checklist of species in the region based on specimen records ‘reacquired’ from these expedition and survey reports. The caveat, however, and we reiterate, is that these records must be extracted and encoded in a database format.

The study of biodiversity is not only limited to knowing what species occur in the area but also how much of it was and is there. However, it appears that, at least in Southeast Asia, “we have no way of estimating the abundance of fish, shrimps, oysters, and other marine animals in the middle of the nineteenth century, as the first systematic surveys did not take place until after World War II. We therefore have to rely entirely on anecdotal evidence to gain an impression of the abundance of marine life at this time, but this at least gives us a base from which we can judge the great changes that began to take place in the middle of the twentieth century” (Butcher, 2004:28). Granting that abundance data is not easily accessible, we can again envision to ‘reacquire’ such data from records of specimens and descriptions of these organisms from the same expedition and survey reports we mentioned above.

Palomares *et al.* (2006) presents a methodology which allows for such textual and qualitative data to be transformed into semi-quantitative form, and thus used to plot trends in relative abundance of marine organisms over time. Moreover, data on relative abundance, size, habitat, and feeding behaviour of marine organisms, as well as uses and trade by the local people, can also be extracted from these observations.

Following the methodology of Palomares *et al.* (2006), we extracted accounts of marine organisms and encoded these into the Historic Expeditions and Surveys Database, a relational MS Access database hosted within the *Sea Around Us* Project website (see www.seaaroundus.org). Each observation or ‘anecdote’, *sensu* Pauly (1995), comprising of one or several sentences or paragraphs, was ranked according to the perceived abundance of a group of species, using the multi-level system in Palomares *et al.* (2006), viz: extremely abundant; abundant; very common; common; rare; absent; and ‘occurrence’ when no inference on abundance was possible.

Coding was based on words used in the descriptions indicating relative amounts of observed marine organisms. For example, ‘fish abound along the coast’ was coded as abundant, while ‘enormous quantities of’ was coded extremely abundant (see Table 1). Note that coding can be repeated independently by one or more researcher(s) in order to reduce subjectivity.

Table 1. Definition for and example of the coding system used in this study.

Code	Example
Very abundant	"Enormous quantities of small fish swarmed under the drift-wood, and troops of Dolphins (*Coryphaena*) and small Sharks (*Carcharias*), three or four feet long, were seen feeding on them, dashing in amongst the logs, splashing the water, and showing above the surface, as they darted on their prey. The older wood was bored by a *Pholas*" (Moseley, 1892: 374-375).
Abundant	"The coral banks, though abundant, were not so easily accessible at Amboina as at Banda, being in deeper water, and specimens of most of the species could only be procured by deep wading and diving" (Moseley, 1892: 335).
Very common	"The cliffs appear as if formed of a stratified ferruginous red rock. Here and there were conspicuous white patches on the cliffs, the nesting-places of Boobies, of which large flocks were seen flying to roost as evening came on" (Moseley, 1892: 316)
Common	"It is evident that a wide area of the sea off the mouth of the Ambernoh River is thus constantly covered with drift-wood, for the floating wood is inhabited by various animals, which seem to belong to it, as it were. […] A *Lepas* was common on the logs" (Moseley, 1892: 374-375).
Rare	"Les îles que j'ai citées se trouvent sur un banc étendu, qui unit la Nouvelle-Guinée à Misool et devient progressivement plus profond en se rapprochant de cette dernière île, […]. On n'y rencontre presque pas de *Lithothamnion*, en dépit de la faible profondeur (18 mètres), à laquelle il se trouve placé" (Weber, 1902: 72).
Absent	"Entre Sulu et Kapul, nous avons rencontré, à 275 m. (Station 105), […] Un second coup de filet (Station 95), exécuté plus au Nord, ne nous fournit aucun autre exemplaire de cet Ascidien; […]" (Weber, 1902 : 53).
Occurs	"Entre Sulu et Kapul, nous avons rencontré, à 275 m. (Station 105), […] parmi lesquels il faut aussi signaler quatre exemplaires du remarquable *Chelyosoma*, connu surtout dans les mers arctiques. La présence de ce Tunicier dans cette région torride du globe fit sur nous une impression profonde" (Weber, 1902: 53).

Each observation was assigned to the functional group being described (marine mammals, seabirds, turtles, fish, invertebrates, seaweed, algae, others). Scientific names of the species when mentioned or footnoted were encoded in the remarks field, and the phylum, class and order were obtained from the Catalogue of Life (2006 annual checklist; www.sp2000.org). Biological information (e.g., size, feeding and spawning behaviour) were also encoded in the remarks field. If the description includes several groups of species in one sentence, separate records were created to account for each functional group (including the name of species when specified). Each observation was linked to the following information:

- the 'sampling station', i.e., the spatial coordinates (most of the time from details of stations but sometimes estimated using MSN Encarta or Google Earth), time of arrival and departure, the country and locality names of the 'station';
- the expedition details;
- the source and online links to the entire text, if available;
- the specimen accession number, if identified, and online links to the website of the museum that holds the specimen, if available.

The observations were separated by functional groups and arranged chronologically. Observations for each functional group were further subdivided into time periods with similar number of observations and plotted on the chronological axis at the value corresponding to the mean of the years with observations. The total number of observations per rank was obtained for each time period (represented by its mean year). This permitted the plotting of the 'perceived' abundance (in % per rank) of each functional group over time.

Checklist of species

Documents of species surveys and descriptions were obtained and used to collate a list of species found in the area (see Figure 1). The resulting list of specimens, which includes 'dated' scientific names, was compared to global species databases – FishBase (see www.fishbase.org) for fish, Catalog of Life (2006 annual checklist; www.sp2000.org) for invertebrates and AlgaeBase (see www.algaebase.org) for seaweeds and other water plants – in order to obtain the currently-accepted names of species figuring in these lists.

EXOGENOUS IMPACTS TO THE ECOSYSTEM

A methodology similar to that described above was employed for exploitation of natural resources, e.g., fishing and trade, and human population accounts. Observations describing intensity of fishing and fishing practices, amount extracted, trading, etc., were ranked according to the level of intensity of the activity using four qualitative levels, *viz.*: low, medium and high for commercially important activities and subsistence for non commercial activities. Thus, for example, de Clercq's (1999) description of the Bajorese at Ngaai ma-Dodera, which "has a small beach where a few Bajorese from Kayoa Islands have temporarily settled and whose main occupation is collecting *tripang* (sea cucumbers) and turtles; both are harpooned with a pointed instrument" is ranked as 'high' since this was probably a 'boom and bust' operation; the Bajorese traded seasonally with the Chinese.

These observations on exogenous impacts to the marine ecosystem were grouped according to the type of activity, sorted in increasing chronological order and expressed as percent of the total for each year class. They were then plotted in a line graph to infer trends of population level, extraction and trade of natural resources in the area. Finally, they were compared to fishing trends obtained from other sources.

Results and Discussions

Documentation

Appendix B includes more than 350 documents that we obtained for this study, of which more than 250 were processed, i.e., slightly over 25,000 pages of text read in a span of 4 months (6 person-months). This does not include over 140 additional documents of material we identified, but have not been able to obtain due to time constraints (see Appendix C). Of these, 100 documents (roughly 50 % of those processed) contained abundance information in about 900 pages of text or 4 % of the total number of pages scanned.

We gathered a total of 1,950 observations for Indonesia. Of these, 1,243 (64 %) pertained to the Papuan region, 586 (30 %) to the Maluku region and 121 (10 %) to other areas in Indonesia. Table 2 summarizes the observations obtained for Papua and Maluku, by functional group. It also indicates the percentage of these groups used in the trends analyses. Note that we only used observations for which we had geographic coordinates from station details and/or reasonable estimates (from plausible descriptions of localities) that fall in the bounding box for the study site (see Figure 1).

As mentioned above, the materials we gathered exist either in electronic (pdf) format, as paper photocopies or reproduced from digital pictures. A large percentage of these documents were obtained from various European libraries. The rest were obtained from the special and rare books collection of the University of British Columbia (Vancouver, Canada). Most of the electronic and digitally reproduced copies are protected with copyright from the holding libraries. However, some can be accessed for free via the Internet, notably from the online library of the Bibliothèque Nationale de France (www.gallica.bnf.fr).

We plan to scan some of the better copies we have at hand and make these documents in pdf format available in a CD-ROM for later use. However, making them available via the Internet through the Historic Expeditions and Scientific Surveys website (see www.seaaroundus.org) would be a better avenue for a wider and more general dissemination, and we shall explore this option in the near future. A recommendation is thus needed in order to get a copyright waiver for our database and website.

Table 2. Summary of abundance observations and reference to human impact in the Papua and Maluku provinces of Indonesia obtained from over 250 documents (25,000 scanned pages) processed and encoded in the Historic Expeditions and Scientific Surveys database of the *Sea Around Us* Project (www.seaaroundus.org). Observations in study area are those which had good estimates of geographic coordinates falling in the study area (see Figure 1).

Functional group	Papua	Study area	Maluku	Study area	Total available	Total study area	%
Fishes	253	73	252	61	505	134	26.5
Invertebrates	562	295	200	116	762	411	53.9
Marine mammals	8	0	5	5	13	5	38.5
Other animals (e.g., crocodiles)	18	0	1	0	19	0	0.0
Sea snakes	7	0	0	0	7	0	0.0
Seabirds	18	8	6	2	24	10	41.7
Turtles	68	25	5	0	73	25	34.2
Other plants (incl. mangroves)	54	21	20	12	74	33	44.6
Sea grass	8	3	7	0	15	3	20.0
Seaweed/algae	39	9	16	5	55	14	25.4
Total for marine plants	101	12	43	5	144	17	11.8
					0		
Exogenous factors (e.g., fishing)	107	107	31	31	138	138	100.0

MARINE BIODIVERSITY

Historic trends in abundance of marine organisms

One of the earliest statements that indicates the wealth of natural resources in Indonesia is that made in a report by Stavorinus (1798:331) who wrote that the inhabitants of Ambon were “in alliance with the Company, and furnish a considerable quantity of provisions, consisting of wild boars, stags, sea-cows and other articles of food, which they barter at Neira for piece-goods and other necessaries” (this observation is actually the only one we have that mentions dugongs, i.e., ‘sea-cows’). Later, on one fine morning in 1801, François Péron (1807:146) went to the landing area in Kupang and observed the abundance of marine life, then already exploited by the Malays – “fish, mollusks, urchins, crustaceans, and most spectacularly that of Madrépores which the Malays used to line the shore on which they worked and walked”. In 1818, de Freycinet (1829:46) made a similar remark, i.e., on the abundance and variety of fishes, while setting up his observatory on a sand bank in Waigeo where “tous les genres de poissons que nous nous procurâmes; ils sont en grand nombre et excellents; plusieurs offrent des formes singulières et les couleurs les plus variées”. He also remarked that the sea provided them with many diverse forms of beautiful crustaceans, some shells and almost every day with turtles (de Freycinet, 1829:46). However, the earliest statement that identifies the region as a center of biodiversity, well before the term ‘biodiversity hotspot’ was coined, is Wallace’s (1869) judgment that “there is perhaps no spot in the world richer in marine productions, corals, shells and fishes than the Ambon harbour”.

Another remarkable point was the generally larger size of marine organisms observed between the 1700s and 1800s. In Lumu-lumu, Weber (1902:46) observed that fishers of this region were “très habiles à prendre au harpon de grands poisons”. He further explains that he was able to obtain a specimen of *Urogymnus asperrimus* (Bloch & Schneider, 1801) (Rajiformes, Elasmobranchii) from a fisher who harpooned it. The photograph (Weber 1902:46) of the specimen shows that the ray without its tail was about 2/3 as tall as the European holding it in the photograph. Thus, if the average European man was 165 cm tall, then the ray would have measured 111 cm to its caudal peduncle corresponding to a body width of 80 cm. Note that the largest size so far recorded for this species is 100 cm body width (Michael, 1993). In addition to large rays, Weber (1902:22) also observed several individuals of eagle and manta rays and requiem sharks whose stomachs were full of cuttlefish in Lombok. He subsequently observed, on various other occasions, squalid sharks purposely hunting for cuttlefish in the coral reefs. This observation tells us that sharks and cuttlefishes were frequently seen in the area and were therefore probably very common.

Furthermore, observations of marine mammals, though few (we only obtained 5 observations), indicated that marine mammals were not only present, but also provided good hunting. Thomas Forrest (1969:128) who wrote that on the “9th of March [1775], by break of day, Pulo Pisang bore N. E. eight leagues; and Pulo Lyong (an insland near Ouby, appearing with an even outline) bore W. N. W. about ten leagues. [...] The water was smooth, and many porpoises blowing near us”. This gives us an indication that dolphins were very common if not abundant in the area. Weber (1902) wrote that marine mammals, from small species of dolphins and *Kogia* spp to the bigger species of Balanopteridae and sperm whales were harpooned by the inhabitants of Lamakera and Lamararap; note that Weber (1902:32) also deduces that the locals learned to harpoon cetaceans from the Europeans. It is interesting to note that none except two voyager's narratives tell of whaling: Baron van Lynden, resident of Timor described the whaling by the inhabitants of these two kampongs in 1851; and a short note from an anonymous observer published in 1849 (Weber 1902:31-33) recorded the same observation.

Turtles seemed to figure regularly in the daily life of people in the area. Forrest (1969:86) wrote that Papuans, “in their boats, continued to bring us abundance of excellent fish; also turtle, which my Mahometans would not eat; but they ate the eggs. The natives had a way of stuffing the guts of the turtle, with the yolks of its eggs. So filled, they rolled it up in a spiral form, and roasted it, or rather dried it over a slow fire; it proved then a long sausage”. Not only were turtles used for food, but were also an item to barter with; de Freycinet (1829:22) wrote while anchored in the observatory in Waigeo in 1818 that “nous avions tous les matins autour de nous un marché assez bien approvisionné; il nous offroit une grande varieté de poissons, des tortues, des langoustes, quelquefois aussi des cochons sauvages, des ananas, des citrons, &c.” In the 1770s, Forrest (1969:112) observed that tortoise shells can be obtained at ‘Krudo’ and the islands near it, “as indeed every where on this coast; but it requires to me to collect a quantity and the merchant must advance the commodities of barter. This the Chinese do, and are seldom cheated by the Papuas”.

Seabirds seemed to be less frequently seen by the voyagers; we obtained but 10 observations on terns, gulls, sandpipers, king fishers and a sea eagle (Van Musschenbroek 1883:30, 42, 51, 60, 61, 69, 84, 127; Cheeseman 1949:115; Maurenbrecher 1956:8; de Clercq 1999:30). Sonnerat (1776:178-181) lists three species of 'penguins', which seems suspicious as penguins are not known to occur in tropical regions. Maurenbrecher (1956:8) describes that the best time to go fishing is when the tuna is hunting; they drive schools of baitfish, silverwhite sardines, towards the surface and there they attract gulls and terns which form a bank of white wings, that can be seen at a distance by the Papuas and draw them to the fishing grounds.

Mollusks and crustaceans were likewise diverse and abundant and generally used for the inhabitants' daily sustenance. Forrest (1969:124) wrote that in 1775 cockles were in quantity in the islands of 'Bo' and 'Popo' where a "Banguey corocoro went to a smooth landing place, and picked up a great many excellent kimas (cockles) about the bigness of a man's head; nor failed to give us our share". Cockles nowadays can be described to grow as big as a man's hand, but not a man's head. The kima, which was consumed with fresh bread made of sago flour (Forrest, 1969:43), were "found in abundance, of all sizes, at low water, during spring tides, on the reefs of coral rocks. And the kima stewed, is as good as most fish, nor does one tire of it. Its roe will sometimes weigh six pounds; the fish altogether, when cleared of the shell, weighing twenty or thirty pounds". Undoubtedly, the kima was none other than the giant clam, *Tridacna gigas*, which though still found in the region, is not as abundant as it was in the 1770s.

Such a richness and diversity of marine life supported fishing not only as a means of subsistence but also as a means of earning a living. It became, as observed by the Resident of Ternate, de Clercq, in 1890, "as one of the three most important branches of industry in the region" third to weaving of sarongs and tobacco cultivation. He described "rich fishing grounds" which contributed to the decision of some Ternatese locals to move to Sidangoli where they can engage in "*calalang* (tuna, skipjack) fishing which [p. 46] pays well since that kind of fish is in great demand with the Alfurus from the interior" (de Clercq 1999:30). Oyster beds became highly exploited "as everybody took whatever he can find from the oyster beds, without giving the pearls time to develop properly, [...] since the divers never [...] receive any pay and are only rarely sufficiently fed, it is natural for the rulers to receive very little remuneration from the activity. They are therefore inclined to hand over the advantages of the exploitation to others, as has happened a few times during the last several years" (de Clercq 1999:39). De Clercq further noted that this practice was "not conducive to the proper growth of pearl oysters" and this led to fewer profits which forced the divers to "occupy themselves with collecting nacre". Thus, in 1890, signs of overexploitation, especially in the shallower coastal zones, began to appear.

We can infer from such observations that, in the region, from the late 1700s up to the mid 1800s, sealife was not only very diverse, but also abundant. There are few descriptions that say otherwise. However, some suggestions of overexploitation, such as de Clercq's observations in the late 1890s, lead us to believe that such abundance and diversity could not sustain the growing pressures exerted on it by a growing population and an increase in the demand for sea products.

Results of our abundance trends analyses seem to corroborate this. Figures 2 to 4 illustrate the trends of perceived abundance of turtles, fish, invertebrates (mostly mollusks, crustaceans and echinoderms) and Figure 5 of aquatic plants (seagrass, seaweeds, algae) in the study area. These plots were based on the data in Table 3 which treated all coded observations for the study area except observations that only mentioned occurrence of a functional group. The perceptions that these organisms abound or are common in the waters of the region appear to generally decline.

Table 3. Number of observations of perceived abundance for Papua and Maluku provinces falling in the study area (see Figure 1). Note that invertebrates include mollusks, crustaceans, scleractinian corals and sea cucumbers while aquatic plants include seagrass and seaweeds/algae. Note also that 'abundant' includes 'extremely abundant' and common includes 'very common'.

Functional group	Year lower limit	Year upper limit	Year mid class	Abundant	Common	Rare	Absent	Occurs	Totals
Turtles	1800	1819	1810	2	5				7
	1820	1839	1830						
	1840	1859	1850						
	1860	1879	1870					8	8
	1880	1899	1890		1			2	3
	1900	1919	1910					1	1
	1920	1939	1930		1			2	3
	1940	1959	1950		1			1	2
	1960	1979	1970			1			1
	1980	1999	1990						
			Subtotals	2	8	1		14	25
Fishes	1800	1819	1810	4				2	6
	1820	1839	1830						
	1840	1859	1850			1		71	72
	1860	1879	1870			1		5	6
	1880	1899	1890	1	10				11
	1900	1919	1910						
	1920	1939	1930	7	2			8	17
	1940	1959	1950	1	4			9	14
	1960	1979	1970		2			2	4
	1980	1999	1990	1	1			2	4
			Subtotals	14	19	2		99	134
Invertebrates	1800	1819	1810	5	8				13
	1820	1839	1830						
	1840	1859	1850					2	2
	1860	1879	1870	1	4	3	2	23	33
	1880	1899	1890	12	18	3		249	282
	1900	1919	1910					1	1
	1920	1939	1930	2	19	1		36	58
	1940	1959	1950	3	4			10	17
	1960	1979	1970		2			1	3
	1980	1999	1990	1				1	2
			Subtotals	24	55	7	2	323	411
Aquatic plants	1800	1819	1810	0	0				
	1820	1839	1830				0		
	1840	1859	1850	0					
	1860	1879	1870	0	0			2	2
	1880	1899	1890	4	2	1		2	9
	1900	1919	1910						
	1920	1939	1930		0		1	2	3
	1940	1959	1950	1	2				3
	1960	1979	1970						
	1980	1999	1990						
			Subtotals	5	4	1	1	6	17
			Totals	45	86	11	3	442	587

Note that the upward trend in Figure 4 of the perception that invertebrates abound and/or are common might be an artifact of scientific surveys, conducted in the late 1800s and early 1900s, which sampled the whole range of the ecosystem and included the deep sea flora and fauna with emphasis on invertebrates. Palomares *et al.* (2006) suggested that before the advent of scientific surveys of the marine environment, observations tended to focus on larger and economically more important organisms such as marine mammals, sharks, large species of bony fishes, birds, turtles and other remarkable species. Invertebrates, which usually were consumed for subsistence and were smaller, compared to, e.g., marine mammals and sharks, were often not the subject of descriptions. It seems that this also is the case for Kepulauan Rajaampat. With the exception of pearl oysters, *tripang*, and probably giant clams – which were the subject of some of the descriptions we mentioned above – most mollusks and crustaceans gleaned from shallow waters and consumed for subsistence by the Papuans and the Malukans did not 'capture the eye' of voyagers. This might explain the discrepancy of the trendlines for observations in Figure 4.

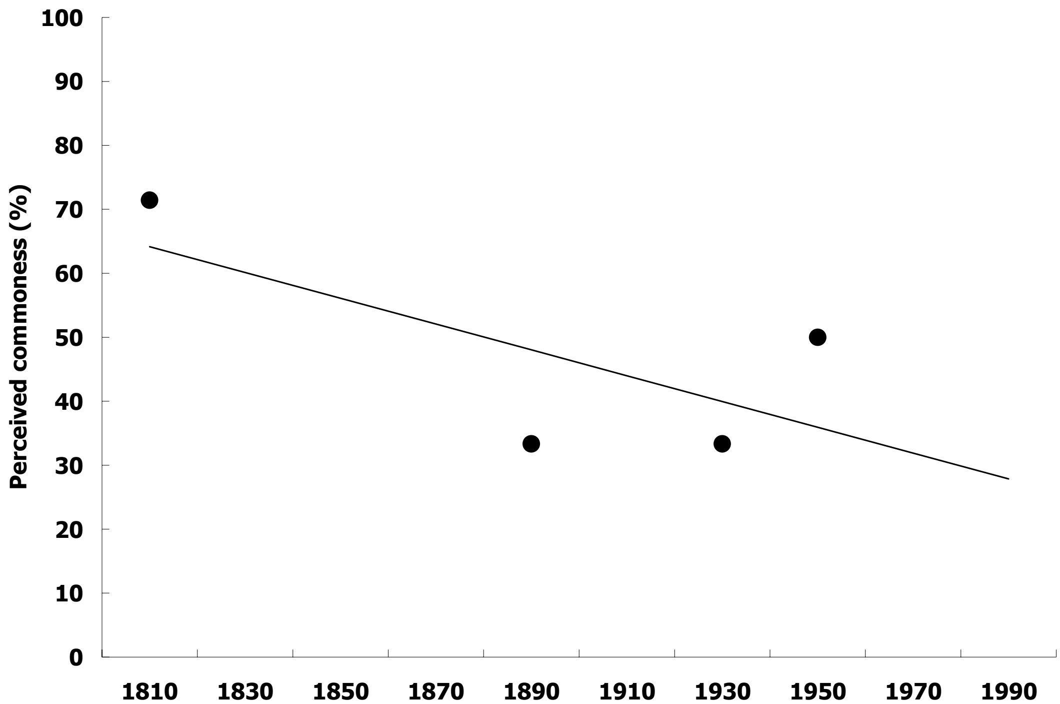


Figure 2. Observations of commoness of turtles in the study area (see Figure 1) in % of all observations of each 20-year period (see Table 3). Although based on only 4 data points (r=0.69), the trend is validated by the fact that the only 2 observations coded 'extremely abundant' fall into the 1810 class and the only observation coded as 'rare' falls into the 1970 class.

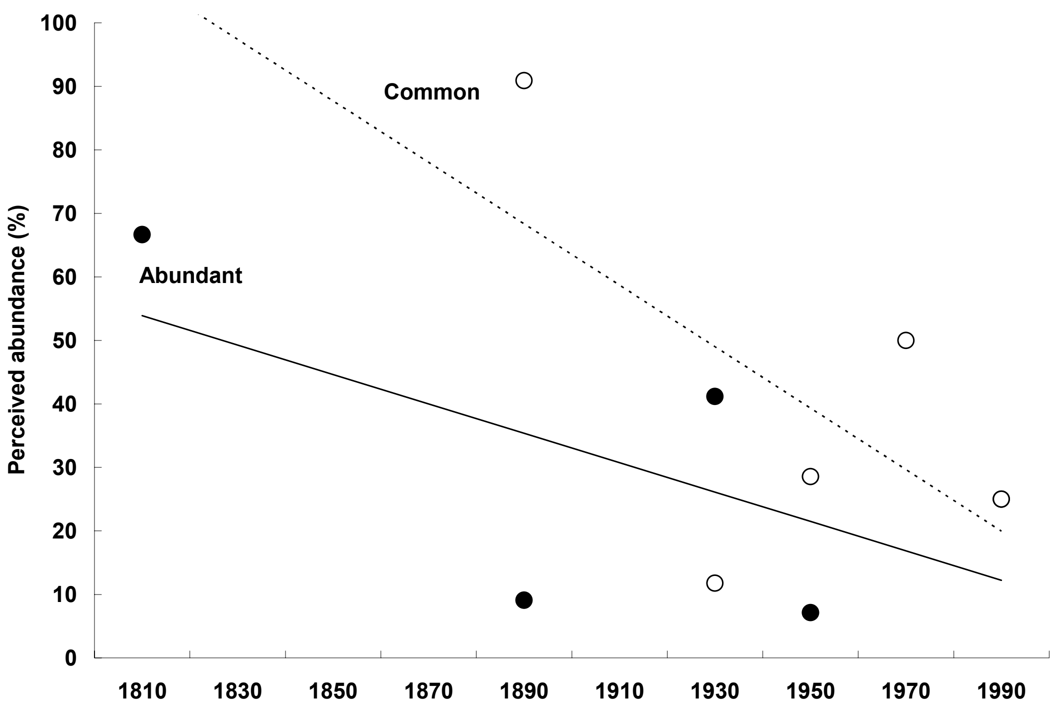


Figure 3. Perceived abundance of fishes in the study area (see Figure 1) in % of all observations of each 20-year period (see Table 3). Although based on few groups of observations ($r_{abundant}$=0.64; r_{common}=0.60), the two trend lines confirm each other.

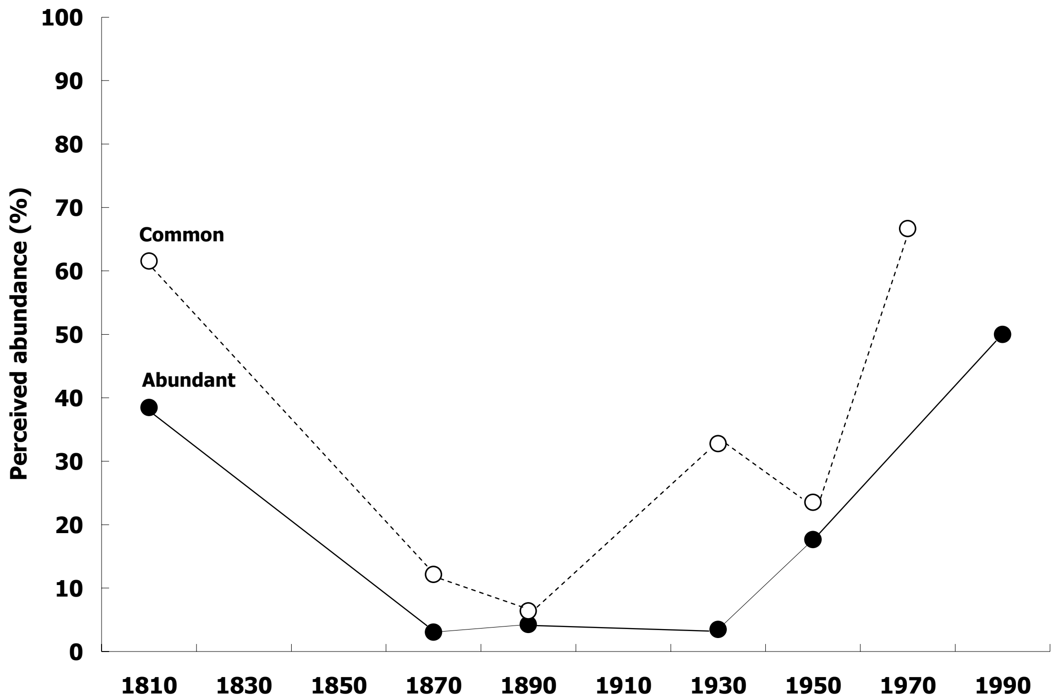


Figure 4. Observations of abundance of invertebrates (mostly mollusks, crustaceans, scleractinian corals and sea cucumbers) in the study area (see Figure 1) in % of all observations of each 20-year period (see Table 3). The seeming increase in abundance of invertebrates may be an artifact due to the improved coverage of benthic and coastal organisms by more recent scientific surveys.

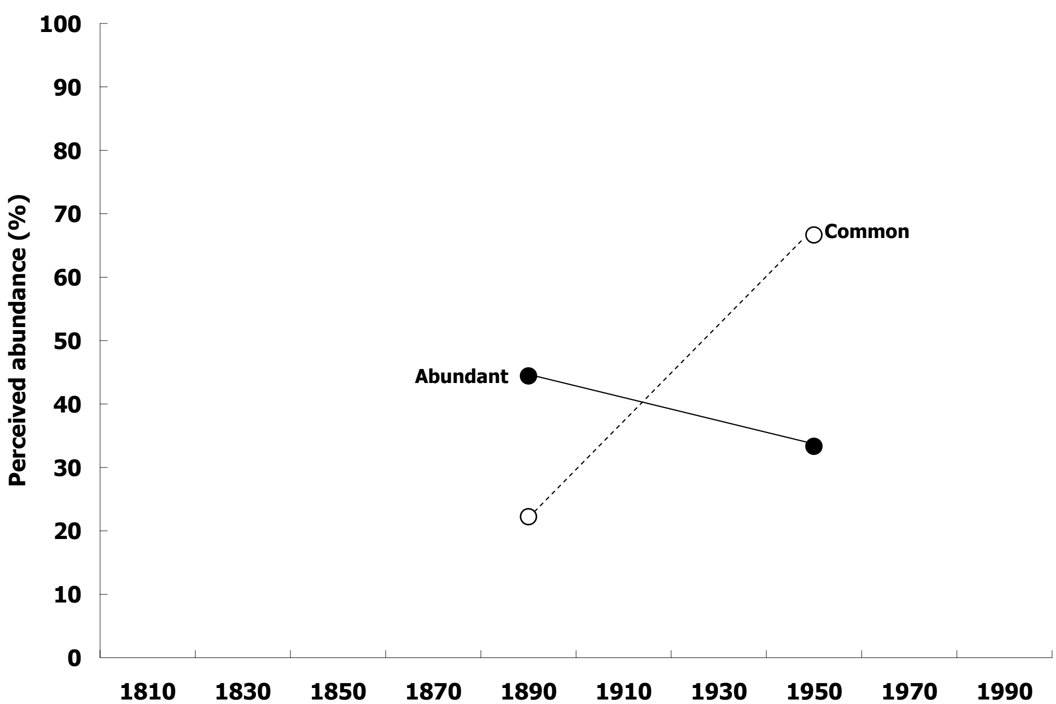


Figure 5. Observations of abundance of aquatic plants (seagrass and seaweeds) in the study area (see Figure 1) in % of all observations of each 20-year period (see Table 3). Though based only on 4 data points and 2 year classes, this suggests a decrease in the perception of abundance from 'abundant' to 'common'.

We do not claim for these results to be conclusive. However, we can infer that abundances of marine organisms have generally declined in the area. We can perhaps even venture to propose, given the trend of perceived occurrences of, e.g., turtles, fishes and invertebrates (Figures 6), that the abundance of these animals was probably 50% higher in the early 1800s than what it was in the late 1990s.

We can not take this analysis further to give quantitative estimates of biomasses as our analysis is based only on qualitative data.

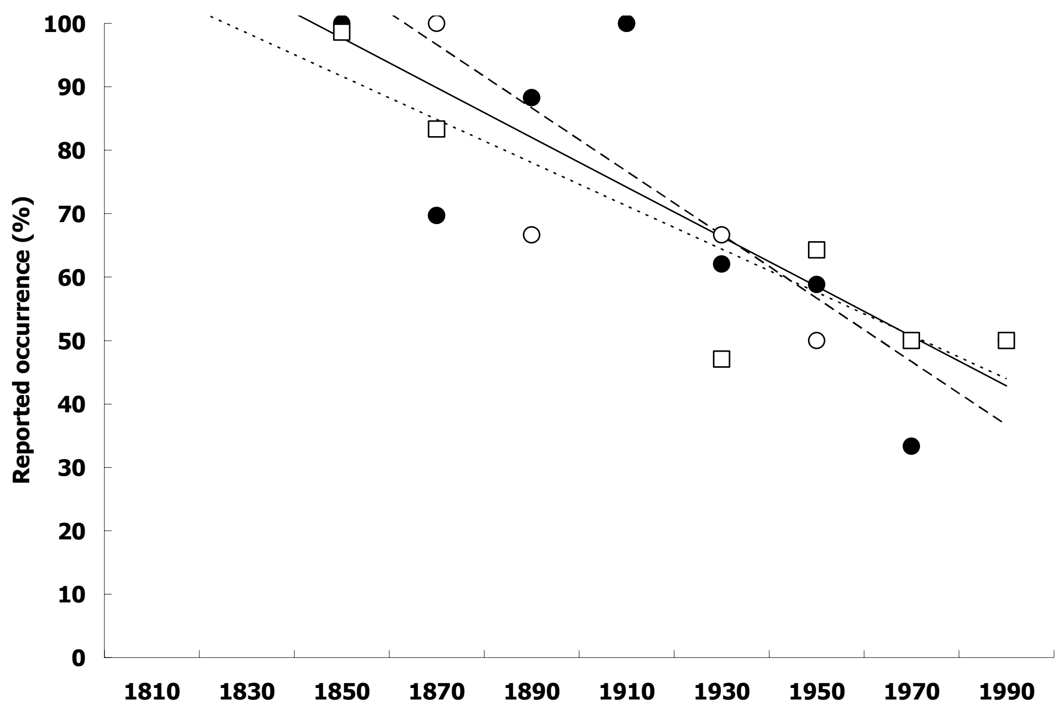


Figure 6. Reported occurences of turtles (white dots, dashed line), fishes (white squares, dotted line) and invertebrates (black dots, solid line) in Papua and Maluku provinces plotted using the data in Table 3. This shows a continous decrease in reports of occurrence ($r_{turtles}$=0.71; r_{fishes}=0.90; $r_{invertebrates}$=0.80) of these organisms in the study area (see Figure 1).

Species lists from historic expeditions and surveys

As has been mentioned above, comprehensive scientific surveys of the area are a product of the late 1800s and are few. Due to lack of time, we were only able to collate parts of the available documents. Thus, we included in this analyses the reports of the expeditions of the *Challenger*, *Coquille*, *Curaçoa* and Bleeker's specimens described in 1872-1873. Table 4 summarizes the specimens we obtained from these expeditions by kingdom, phylum, class and order. These partial results indicate that in our study area, at the end of the 1800s, the numbers of species known to science were 8 sharks, 168 bony fishes, 208 mollusks, 183 crustaceans, 119 echinoderms, 140 other invertebrates (mostly hard corals and sponges) and 23 species of algae, fungi and bacteria (Table 4).

Compiling the list in Table 4 from these expeditions and survey results was not an easy task. The major hurdle was identifying valid scientific names based on the old scientific names or the common names used by scientists of the time. This was facilitated by global species databases, without which, the task would have been almost impossible to complete.

Online and searchable global species databases exist for fish (FishBase; www.fishbase.org), invertebrates (Catalogue of Life 2006 annual checklist, www.sp2000.org) and algae (AlgaeBase; www.algaebase.org). The Catalogue of Life, which is based on two major database initiatives, Species 2000 (www.sp2000.org) and ITIS (www.itis.usda.gov), contains a large number of scientific names but has little coverage of marine organisms. Thus, of the 852 species we found in Table 4, we can attribute only 273 species to valid scientific names, of which 161 are fishes and 12 are algae. Given that the Catalogue of Life will not give us a complete coverage of marine invertebrates, we then also compared our invertebrate specimen list with the SeaLifeBase database, a new (only since December 2005) joint database initiative of The *Sea Around Us* Project (Vancouver, Canada), the Oak Foundation (Geneva, Switzerland) and the World Fish Center (Los Baños, Philippines). From these two databases, we were able to identify another 140 valid species names.

Table 4. Summary of specimens collected by the *Challenger* (1873-1876), *Coquille* (1822-1825), *Curaçoa* (1865) expeditions and by Bleeker in 1872-1873 compared with global species database (FishBase, www.fishbase.org; Catalogue of Life 2006 annual checklist; AlgaeBase, www.algaebase.org; and SeaLifeBase) to obtain current accepted/valid scientific names.

Group	Kingdom	Phylum	Class	Order	Specimens	Species	Valid names
1	Animalia	Chordata	Actinopterygies		34	31	28
2	Animalia	Chordata	Actinopterygies		33	29	26
32	Animalia	Chordata	Actinopterygies		82	82	81
33	Animalia	Chordata	Actinopterygies		26	26	26
34	Animalia	Chordata	Chondrichthyes		3	3	3
35	Animalia	Chordata	Chondrichthyes		5	5	4
3	Animalia	Chordata	Ascidiacea		4	4	2
4	Animalia	Echinodermata	Echinoidea		17	13	0
5	Animalia	Echinodermata	Asteroidea		35	30	0
6	Animalia	Echinodermata	Ophiuroidea		39	36	3
7	Animalia	Echinodermata	Holothuroidea		2	2	0
8	Animalia	Echinodermata	Crinoidea		48	38	0
9	Animalia	Mollusca	Cephalopoda		18	13	10
36	Animalia	Mollusca	Cephalopoda		1	1	1
10	Animalia	Mollusca			140	93	2
11	Animalia	Mollusca	Gastropoda	Thecosomata	13	10	1
37	Animalia	Mollusca	Gastropoda	Opisthobranchia	3	3	3
12	Animalia	Mollusca	Bivalvia		91	73	3
13	Animalia	Mollusca	Polyplacophora		18	15	0
14	Animalia	Arthropoda	Malacostraca	Decapoda	65	56	20
15	Animalia	Arthropoda	Malacostraca	Decapoda	26	23	4
16	Animalia	Arthropoda	Malacostraca	Decapoda	49	43	5
17	Animalia	Arthropoda	Isopoda		4	4	1
18	Animalia	Arthropoda	Copepoda		7	7	1
19	Animalia	Arthropoda	Cirripedia		2	2	0
20	Animalia	Arthropoda	Ostracoda		49	41	3
21	Animalia	Annelida	Polychaeta		7	7	2
22	Animalia	Bryozoa			42	30	2
23	Animalia	Cnidaria	Hydrozoa	Hydroida	3	2	0
24	Animalia	Cnidaria			24	21	9
25	Animalia	Cnidaria	Anthozoa	Actiniaria	2	2	1
26	Animalia	Porifera	Demospongiae	Hadromerida	10	10	1
27	Animalia	Porifera	Demospongiae		21	19	9
28	Animalia	Porifera	Demospongiae		13	12	0
29	Animalia	Porifera	Demospongiae	Verongida	1	1	0
30	Animalia	Porifera	Demospongiae	Dictyoceratida	1	1	0
31	Protozoa	Protozoa	Granuloreticulosea	Foraminiferida	84	42	7
	Plantae	Chlorophyta			1	1	0
	Plantae	Rhodophyta			6	6	5
37	Chromista	Ochrophyta			7	7	7
	Fungi	Ascomycota			8	8	4
	Bacteria	Cyanobacteria			1	1	0
Totals	6 kingdoms	13 phyla	23 classes	6 orders	1044	852	273

It would be preferable to include all available lists of specimens, e.g., from the *Siboga* and the *Snellius* expeditions and from Bleeker's ichthyological atlas and extend this analysis to obtain a full review of what has been identified in the region. Thus, we will continue to encode the list of specimens into the specimen database and report on this elsewhere.

Current biodiversity

According to the rapid assessment done of Raja Ampat in 2001, the region supports the world's richest marine biodiversity, concentrated in the extensive coral reef, mangrove and seagrass habitat (McKenna *et al.*, 2002). Although the area is sparsely populated, destructive fishing practices such as cyanide and blast fishing have had an impact with illegal logging also being seen within the reserve on Waigeo Island (McKenna *et al.*, 2002).

The Marine Rapid Assessment Program (RAP) assessed 45 sites over a 15 day period in 2001, and they did underwater inventories at each site for three faunal groups that were selected because they serve as indicators of overall reef biodiversity, namely: scleractinian corals, mollusks and reef fishes, while observations on reef fisheries were also made (McKenna *et al.*, 2002). The results of this assessment included 456 species of scleractinian corals, 699 species of mollusks and 828 species of reef fishes, increasing the total known species of the islands to 970 (McKenna *et al.*, 2002). The reef fisheries targeted 59 genera and 19 families (McKenna *et al.*, 2002).

In addition, Conservation International has recently undertaken a new assessment of the Papua province, including Teluk Cenderawasih (Geelvink Bay), the FakFak-Kaimana area and areas to the east and south of Raja Ampat. These two surveys utilized the same experts as the previous assessments (Erdmann and Pet, 2002; McKenna *et al.*, 2002) and their objectives were to compare the species of these three areas to get an overall Bird's Head Seascape species list (Mark Erdmann, Conservation International, *pers. comm.*). The results of the fish, corals and stomatopod mantis shrimp species include the lists obtained by Erdmann and Pet (2002), McKenna *et al.* (2002) and others thus giving the most up to date species list for corals, fish and stomatopods (Mark Erdmann, Conservation International, *pers. comm.*). The total number of species in this study is given in Table 5. In addition to these data, McKenna *et al.* (2002) also indicated that there were 699 species of mollusks and 196 species of fish targeted for reef fisheries in the Raja Ampat area, although no estimates are given for the Teluk Cenderawasih and FakFak-Kaimana areas.

Table 5: Known number of species in the total Birds Head Seascape (data from Mark Erdmann, Conservation International, *pers. comm.*).

Area	Reef fishes	Stomatopods	Corals
Raja Ampat	1105	38	533
Teluk Cenderawasih	716	26	456
FakFak/Kaimana	861	37	456
Total Birds Head Seascape	1230	56	565*

EXOGENOUS IMPACTS TO THE ECOSYSTEM

Historic trends in human populations

In the 1950s, the density of people in the Raja Ampat area was estimated at below 5 individuals per km² (Robequain, 1958:91). The least densely populated districts were not merely those to which nature was unfavorable to humans, but also those that had not had time to be affected by the most intensive type of exploitation (Robequain, 1958:89). Of the 138 observations we collected which indicated the number of inhabitants in the region, 54 fell within our geographic area (Figure 1; see also Table 6). Figure 7 illustrates the results of these observations, suggesting a steady increase in the number of inhabitants in the Papua and Maluku provinces. The 1998 census estimated the population of Raja Ampat at 48,707 inhabitants or 7 individuals per km² of land (McKenna *et al.*, 2002). If we accept the annual increase in the number of inhabitants suggested in Figure 7 (i.e., 2.5%), the number of inhabitants in the area in the 1700s would have been 9,700 inhabitants or 1.4 individuals per km² of land. This increase in the number of inhabitants implies an increasing impact of the human population on the marine environment, notably on the shallow coastal zone. This is corroborated by the implied change in importance of marine organisms in the study area suggested by a decrease in subsistence fishing and a corresponding increase in commercial extraction of marine resources through shallow water fishing and gleaning of coastal reef flats (see Figure 8).

Table 6. Perceived density of human inhabitants in Papua and Maluku provinces within the study area (see Figure 1).

Year lower limit	Year upper limit	Year mid class	Un-inhabited	Sparsely inhabited	Inhabited	Populous	Totals
1750	1799	1775					0
1800	1849	1825	2	3		2	7
1850	1899	1875	1	5	5	24	35
1900	1949	1925		3		4	7
1950	1999	1975				5	5
		Totals	3	11	5	35	54

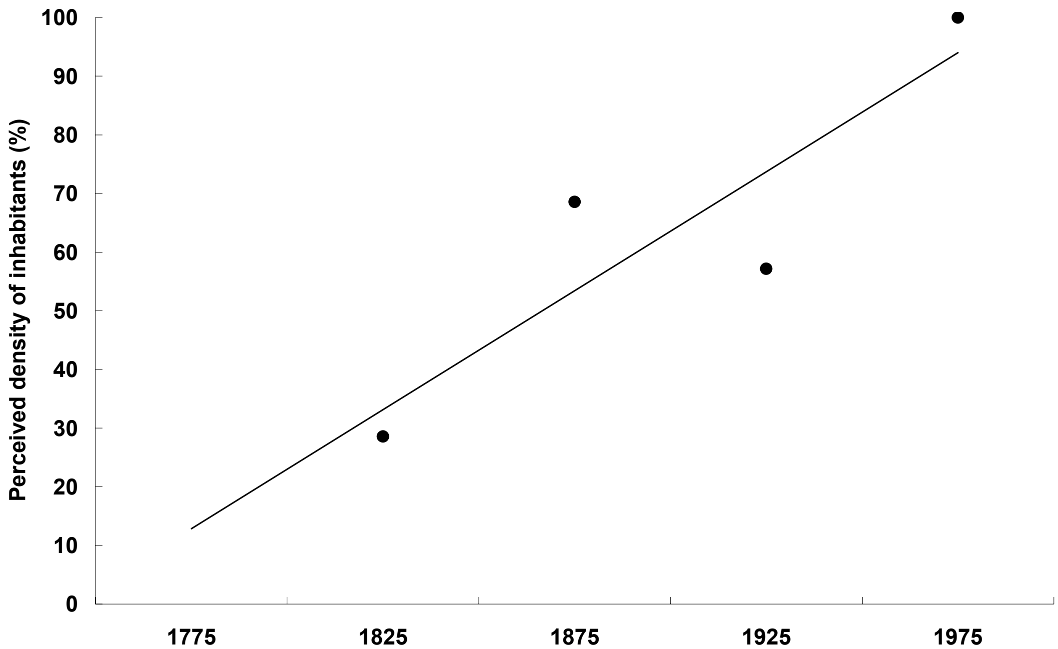


Figure 7. Perceived density of inhabitants in Papua and Maluku provinces plotted from data in Table 6. The slope (r=0.87) of the regression, though based only on 4 data points, suggests a 2.5% annual increase in the number of inhabitants in the study area (Figure 1).

Table 7. Perceived extraction by fishing and gleaning of marine organisms in shallow coastal zones of Papua and Maluku provinces in the study area (see Figure 1).

Year lower limit	Year upper limit	Year mid class	Commercial	Subsistence
1750	1799	1775	0	0
1800	1849	1825	0	4
1850	1899	1875	11	9
1900	1949	1925	6	7
1950	1999	1975	6	5
		Totals	23	25

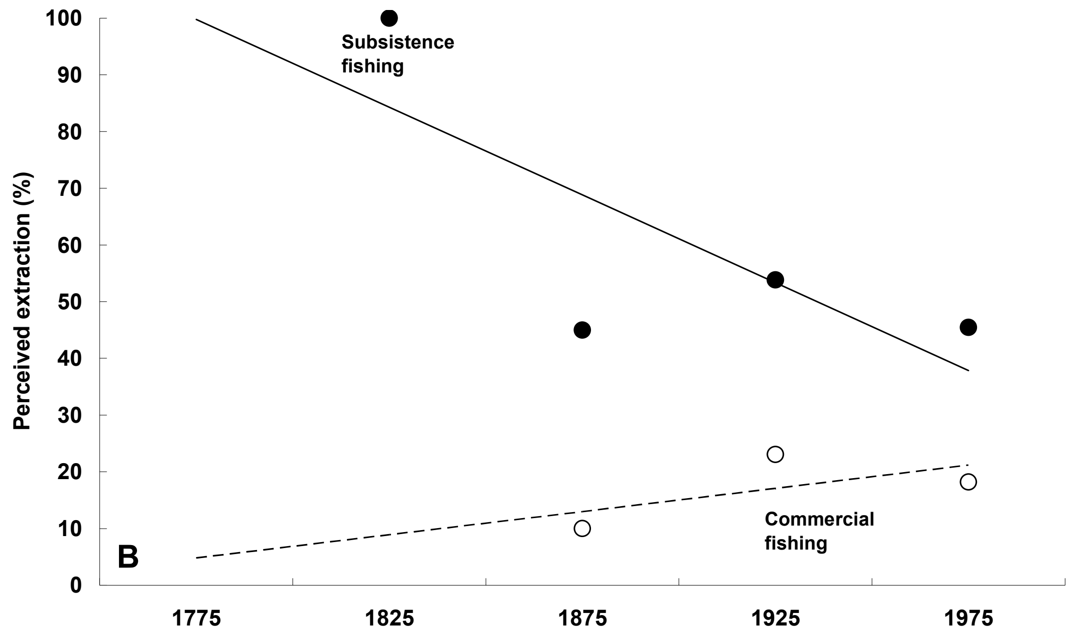


Figure 8. Perceived extraction of marine organisms by kampongs in Papua and Maluku provinces plotted from data in Table 7. The suggested decrease in subsistence fishing/gleaning (r=0.77) and the suggested increase in commercial fishing/gleaning (r=0.62) imply a change in the economic importance of marine resources in the study area (see Figure 1) and thus an increasing impact of the human population on the marine environment.

Historic trends in fishing

In the 19th century, the Kawe people of Raja Ampat frequently went to Gag Island to the west of Waigeo Island to look for fish and other sea life (Berry and Siswanto, 1998:19), although very little else is known about the subsistence fisheries of Netherlands New Guinea. On Chinese trade, Brunel wrote in his memoirs that the Chinese valued "fish fry, the fins of sharks and sea priapus, crabs, tripam and certain kinds of Molucca beans" (Brunel, 1792). Thus, they traded with the Moluccas even in the 1700s.

The Bugis, Bajorese and Makassarese who were expert fishers and boat makers living off the sea and making their business from sea products, were nomadic peoples who set-up camp in areas where they can fish (Weber 1902:24). As fish and other sea products, e.g., *tripang* (sea cucumbers), mollusk shells, pearls, have become trading commodities, the market at Makassar offered a venue for these fishers to sell their goods. The Chinese traded regularly with these fishers. In 1890, there was a "lively trade with Chinese from Makassar and Bugis from Kendari and with other areas which belong to the government of Celebes" (de Clercq, 1999:95). It is therefore not impossible to imagine that these people went as far east as Yapen Island on the northern Papuan coast or as far south as the northern coast of Australia to fish. Robequain (1958) observed a change in the groups of people that live almost exclusively by fishing, namely the *Orang Laut* or 'sea gypsies'. Their house boats were usually moored under a sheltering roof and a lighter craft is used for moving about and fishing. They sold part of their catch to the Chinese to buy cassava and tapioca (Robequain, 1958:93).

Whale fishing was also practiced in the Archipelago as Weber (1902:34-35) deduced from the skulls that were offered to him once the inhabitants understood that it was of value to the scientist; the number of cetaceans harpooned in the kampongs of Lamararap and Lamakera (Solor, Nusa Tenggara Timur) must have been considerable. He further observed that these animals were captured to be consumed, *in toto*. It also became apparent that the capture, notably of the smaller species, of whales and dolphins was very important to these inhabitants. He mentioned that all of the Malay Archipelago, only the inhabitants of these two kampongs practiced whaling. However, he could not conclude if cetaceans were more abundant in the Solor Strait than in other areas of the archipelago with similar conditions as the *Siboga* did not capture any specimens of cetaceans outside of the Solor Strait.

Gleaning the shore line for sea products was also a daily occupation. Weber (1902:29-30) described how the locals of Savu constructed 'dams' of corals on the reef flats which were totally submerged at high tide, more or less parallel to the reef, their heights decreasing towards the shore. These 'dams' divided the surface of the reef into compartments of different dimensions, which slowly dried up at low tide and served to filter the animals brought in with the high tide (Weber, 1902:29). The locals then captured these animals (fish, mollusks, crustaceans, sea cucumbers, etc.) easily with harpoons and nets or with their hands. These artificial parks also served the zoologist as an excellent field of exploration as, presumably, the scientific crew of the *Siboga* joined the locals in hand-picking their specimens from these dams (Weber, 1902:30).

Mollusks were already the object of a fishery, notably of the pearl fishery. Forrest (1969:144) described that the Sultan (presumably of Misool) claimed Obi for his own but "makes no farther use of it, than fishing for pearls on its coasts, where no doubt any stranger may do the same"[5]. In the 1770s, the Dutch East India Company made a profit of "one hundred thousand rixdollars, annually. [...] The fishery, however, does not take, for certain, every year, for this depends upon the condition in which the beds are found. [...] the number of boats and men, to be employed in it, are determined upon: the number of divers, is, at present, usually fixed at ninety-six" (Stavorinus, 1798:353).

By 1931, the Japanese were showing interest in exploiting shells (*keong lola*, i.e., *Trochus niloticus*) and sea cucumbers (Klein, 1934), which already in the 8th century were much prized by the Chinese who paid Bugis fishers to go as far as northern Australia to harvest and dry them (see Chen, 2003, Cawte, 1996; Anon, 1986); and they were doing so without any control (see discussion on shell fishery below). Klein (1934) was worried that this would have a bad effect on the population of the islands around New Guinea that are dependent on the export of *lola* shells and *tripang*. In April 1931, the authorities in Ternate suggested an election board against the exploitation by Japanese, which came into being later that year (Klein, 1934). In 1930-1931 both *lola* shells and *tripang* were exported from Fak Fak and Kaimana and it was more important as an export product than yellow wood, bamboo or bark (Klein, 1934). Between 1928 and 1933 exports of both species were made from Sorong; and Misool exported large quantities (Klein 1934). By 1934-35 the export of *tripang* from the territory of Papua was 40 tonnes (see Figure 9B) (Boschma, 1937).

In 1941 the Institute for Sea Fisheries in Batavia sent a small vessel to southern New Guinea to research the fish potential between Merauke and Frederik Hendrik Island, which found that there were many currents, and the fish fauna was similar to that found on Sumatra (Van Eeckhoud, 1954).

Before the second World War (WWII), mollusks, turtle shells, *tripang* and *trassi* (dried shrimp paste) were exported (Van Pel, 1958). The Japanese were then very active, fishing in all areas of New Guinea (Van Eeckhoud, 1954). In addition, the Japanese government had stationed a research vessel in Nanyo with some scientific staff on board (Van Eeckhoud, 1954). From documents found after the war it seems that the Japanese estimated about 154 tuna per km^2 (mainly yellowfin tuna, *Thunnus albacares*) in the 960 km north of the Mapia islands (Van Eeckhoud, 1954).

Robequain (1958) suggested that fishing was profitable on the extensive sand and muddy shallows of the local seas. There was far less fishing off the coasts facing the Indian and Pacific Oceans. However, some villages, much like in the 1770s, lived entirely by fishing and fishing villages generally consisted of wretched huts or piles where life is often squalid (Robequain, 1958). The greatest catches were obtained by the Asian immigrants, with the Chinese exploiting the coastal waters of the Straits of Malacca and the Japanese using motorized trawlers to catch deep water fish (Robequain, 1958:101).

After WWII, the first fishing station opened on Doom, an island close to Sorong where the first fishery surveys were done, mainly fishery inventories, line fishing, bait fisheries, and fisheries on small tuna, although the bait and tuna fisheries were not very spectacular (Van Pel, 1958). In 1948 they were catching 600 kg per day (MacKenzie, 1962). After that, Hollandia (now Jayapura) was chosen as a basis, Doom was abandoned and Manokwari was opened as a second station (Van Pel, 1958).

[5] Malthusian overfishing in the 1770s?

By 1951 two technicians were stationed in Manokwari and Sorong and their main duty was to see if the tuna and trawl fisheries were possible (Anon, 1951). They found that the main fishing methods were very primitive and on Merauke, Saonek, Aju Islands, Biak and Seroei dried/salted fish were produced to trade, while the main production of salt fish and *trassi* was at Merauke (Anon, 1951). On the coral islands to the west and north of New Guinea the fishery for *lola* shells was prevalent. Two small fishing boats were obtained and one was used at Sorong, while the other was rented to a fisherman in Hollandia, although they were not useful to go out into the open ocean (Anon, 1951).

In 1952 the *Hollandia* was brought in for tuna long-lining and stationed in Manokwari (Anon 1952). In 1953, the Fisheries Department tried to improve the shell fishery, by improving the diving equipment of the fishermen (Anon, 1953). From Kaimana to Salawati, in the Raja Ampat islands, and minimally in Geelvink Bay (now Teluk Cenderawasih) they dove for mother-of-pearl and troca shells (Trochidae, Gastropoda), and the fish caught were sold in Hollandia, Sorong and Manokwari, while smaller numbers of fish were sold from Biak (Anon, 1953). Research cruises were undertaken at Noemfoor, the Ambai islands and Merauke in long line and trawl fisheries. A trawler, the *De Goede Hoop*, arrived in June 1953, and was used for trawling experiments on the north coast of New Guinea, the Selé Strait and at the mouth of the Mamberamo River (Anon, 1953). A United Nations report on Netherlands New Guinea suggested that there were no indications of overfishing, but they did find that in the Humboldt Bay area the fisheries were less consistent. Only one instance of explosive fishing was recorded in that year (Anon, 1953).

By 1954 most of the fisheries were still subsistence based and only the left over fish was sold (Anon, 1954). The fishery was mostly run by outrigger *prauws*, with or without sails (Anon, 1954). During 1954 other products such as mother of pearl, *tripang* and turtle shells became more important (Anon, 1954). Two research vessels were used to study the fishing possibilities in Netherlands New Guinea, with troll and trawl possibilities being researched in Geelvinkbaai, the Raja Ampat islands, Maccleur Gulf and the areas west of the Mamberamo river mouth (Anon, 1954). The troll fishery showed promise at Geelvink Bay and Raja Ampat islands, with average CPUEs of 55-95 kg per hour (Anon, 1954). The trawlers did not do as well, with only the Kaboei bay fishery on Waigeo being feasible (Anon, 1954). Zwolle (1956) found that the most fish occurred in areas too shallow and coastal for the *De Goede Hoop*. Fishing was not impressive and the best catches were made in a bay of Waigeo Island, where catches of 1 tonne per hour were possible (Zwolle, 1956). However this bay was too small for a permanent trawl fishery (Van Pel, 1958). Many sawfish and sharks were caught and most of the catch was uniform, except for around the south coast from Merauke to Fredrik-Hendrik Island, where a larger percentage of small fish, crabs, sea snakes, sharks, saw fish, etc. were caught (Zwolle, 1956). The fisheries around Hollandia and Manokwari were found to be not viable (Anon, 1954). In 1954, aboriginal fishermen were being trained on the longliner *Hollandia* but the longline fishery was shut down due to problems with the boat. Also, the local fishermen did not want to stay at sea for long periods (MacKenzie, 1962).

In 1955, the Fisheries Department was encouraging motorized fishing vessels to the subsistence fishermen in Hollandia and Manokwari and they studied the viability of trawl fishing around Merauke and the shallow seas around the south coast (Anon, 1955). Fewer troca shells were exported but most of the fishery production was very similar, while *tripang* export was in decline (Anon, 1955). Research cruises were undertaken on the southeast coast of Japen, and the Waropen coast in northern Geelvink Bay, while the *De Goede Hoop* was trawling around Frederik Hendrik Island and at the Tami mouth a smaller vessel was trawling in shallower water to look for fish (Anon, 1955). The longline and hand line fishery around Geelvink Bay was promising but the trawl fishery was found to be generally not viable, although the area was suitable for trap fishing. Longline fisheries only caught 4 kg of fish per hour (Anon, 1955) and were also deemed to be not productive. Motorization of fishing *prauws* were still being suggested and tens of these motorized *prauws* were found around Sorong and Hollandia (Anon, 1955).

By 1956, the trawl fishery was still being researched south of Merauke while reef and bottom trawl fisheries in Humboldt and Jotefa bays were found to lead to minimal yield as the reefs were too small and had been overfished over the years (Anon, 1956b). The local fishery for mother-of-pearl in Geelvink Bay and the Raja Ampat islands was very similar to the previous years (Anon, 1956b). The *De Goede Hoop* still tested for commercial fisheries south of Merauke and found one area of 65 km^2 that had a catches of 0.2 tonnes per hour. Only 5.8% of the catch was marketed as fresh fish and the rest were salted (Anon, 1956b). Fish traps at the Waropen coast were more viable and with relatively small traps catches of up to 30 kg was possible (Anon, 1956b).

The fishery did not get above subsistence to commercial fisheries (MacKenzie, 1962) and both the trawl and long line fisheries were suspended in 1956 (Van Pel, 1958). The *De Goede Hoop* was then employed to look into the mother-of-pearl fishery in Geelvink Bay and night fishing with lamps was introduced in 1957 (Anon, 1957b). During 1957, 146 tonnes of fresh fish was exported from Humboldt and Jotefa Bays, including Indian mackerel (*Rastrelliger kanagurta*), horse mackerel (*Megalaspis cordyla*, *Gnathanodon speciosus*), tengiri (*Scomberomorus guttatus*), tuna and bonito's (Anon, 1957b). At Sorong, 50 tonnes of fish were dried, most of which was *Lutjanus* spp (Anon, 1957b).

By 1957, the trawl fishery at Merauke is stopped due to bad results and the personnel moved to Manokwari. The results of the *De Goede Hoop* mother-of-pearl fishery were very poor due to lack of interest by the local people (MacKenzie, 1962). The motorized fishery on the island Isobabie on the Soepiori coast was improved in 1958, with a Dutch boat stationed there that fishes on a profit share basis, and there were plans to add another 5 such boats in Humboldt and Geelvink Bays in 1959 (Anon, 1958). Shrimp fisheries were explored at the Mataboor area of the Waropen coast (Anon, 1958).

Van Pel (1958) believed that New Guinea was not ready for industrial fisheries, and that industrial fishing could only be conducted by foreigners catching pelagics and selling it outside of New Guinea. He found that the best fishing grounds were at the coast, but it did not yield enough to be commercially viable. Most fish and shrimps were prevalent near beaches and close to river mouths (Van Pel, 1958). There was also some part of the year that they couldn't fish due to bad weather and even when they could catch lots of fish, there were problems with selling it, due to lack of markets. The best results were given with trolling, handlines and traps (Van Pel, 1958). Beach seines sometimes yielded good results in the area of Manokwari, but not enough to make the fishery viable (Van Pel, 1958). It was decided to try and improve the coastal fishery, which is much smaller and is more subsistence based (MacKenzie, 1962).

Van Pel (1958) describes the different fishing gears that are used for coastal and reef fishing in Netherlands New Guinea:

- *Kustsero* (coastal trap), set perpendicular to the coast on sandy or muddy bottoms, 2°-5° incline;
- *Kustkamer* (coastal trap), a trap that is set on steeper shores (6-10°);
- reef traps;
- *bodem-boeboe* – a cylindrical trap used on the bottom;
- *rif-boeboe* – a rectangular trap used on reefs;
- *kustbarricade* – coastal barricade, a net on the beach and mangroves;
- *handlijn* – handline;
- *beuglijn* – longline (bottom);
- *pelagische beuglijn* – pelagic longline;
- *sleeplijn* – troll;
- *bodem kieuwnet* – bottom gillnet;
- *drijvend kieuwnet* – floating gillnet;
- *basnignet* – a boxlike net used in the Philippines and using lamps;
- *Ophaalnet* – scoopnet, rectangular net that is placed down and then pulled up. Used close to the coast and in rivers;
- *kruisnet* – crossnet two crossed sticks keep the net open and is used from coast, or boat;
- *hoepelnet* – hoopnet attached to a hoop, used for crab fishery;
- *strandzegen* – beach seine.

The local fishery (*bevolkingsvisserij*) used vessels that were 8 m long and 2.4 m wide and had a 20 HP engine (MacKenzie, 1962). (Van Pel, 1958) suggested that a vessel of ±7.5 m long and ±2.4 m wide and a maximum depth of 0.75 m would be good for fishing in Netherlands New Guinea. He described the types of boats used as:

- *prauw* – hollowed out tree stump - useful for gear 7, 8, 10, 15 and 16 on short distances;
- *uithouder prauw* – outrigger *prauw* – useful for gears 7-17;
- *kleine motorvissersboten* – small motorized fishing boat, used for commercial fishery, *prauws* with outboard motors fall in this category, useful for gear 1-4 and 6-13.

The search for mother-of-pearl fishing grounds ended in 1959, but a trap fishery for spiny crayfish was researched at Superiori-Ranirif and the shrimp study continued on the Waropen coast (Anon, 1959). By 1960 the Fisheries Department still had the use of the *De Goede Hoop* as well as a Dutch vessel used for education at the Waropen coast, a 13 m long motorized vessel for technical studies and three 8 m long motorized fishing vessels (Anon, 1960b). In 1960, vessels were exchanged between the Dutch and Australian parts of New Guinea, test fisheries were run on shrimp and mackerel and the fishing in the Waropen Coastal area is expanded to the Moor islands (Anon, 1960b). By 1961, all fishery management activities in Geelvink Bay were consolidated in Seroei on Japen. The *De Goede Hoop* ceased to be available. However, 13 m and 8 m vessels were still available (Anon, 1961). Fisheries for pelagic fish with ring and gill nets as well as demersal fishes with bottom nets were tested in 1961 (Anon, 1961).

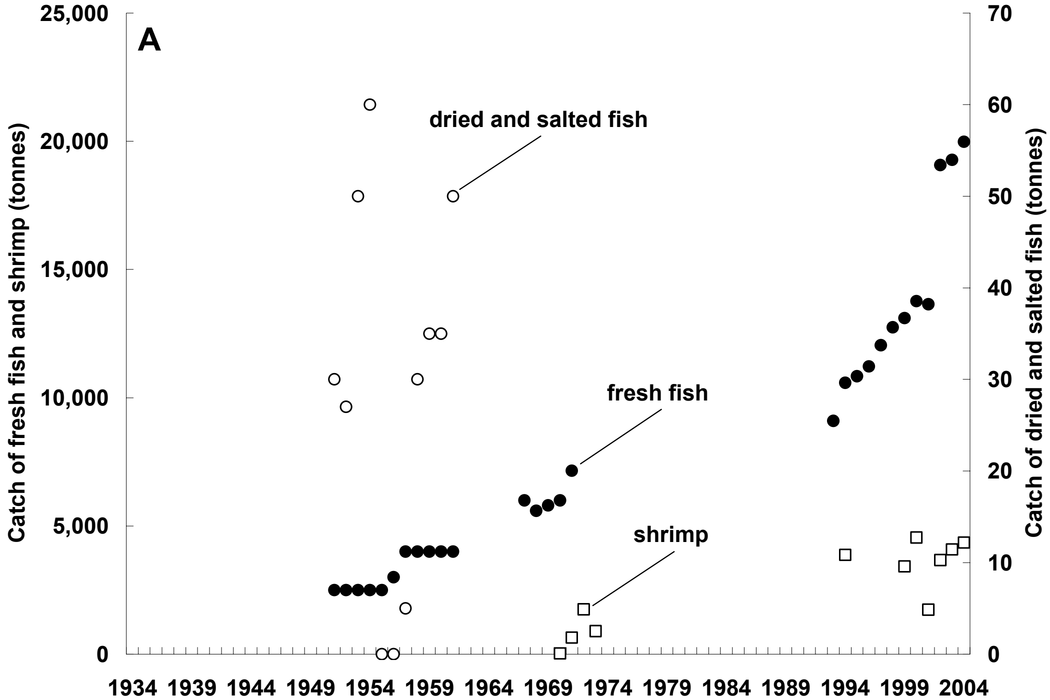
Catch statistics for the Netherlands New Guinea were given in the Reports on Netherlands New Guinea from 1951-1961 (Anon, 1951; Anon, 1952; Anon, 1953; Anon, 1954; Anon, 1955; Anon, 1956b; Anon, 1957b; Anon, 1958; Anon, 1959; Anon, 1960b; Anon, 1961) and are presented in Figure 9A.

By 1962, the fishery still mostly consisted of subsistence fisheries, while near the cities, where it was possible to get outboard engines, the fisheries were motorized and commercial (MacKenzie, 1962). There was enough fish to feed the subsistence farmers on the coast, but not in the cities or inland, which imported large quantities of frozen and canned fish, although the importation of salted/dried fish was reduced markedly (MacKenzie, 1962). The Department of Sea Fisheries had provided three fishing vessels which were used by fishermen, and they got 40% of the profits, but the Department was paying for all the exploitation costs. One of the vessels was given to the fishery cooperative at Dormena (Demta), one to a good fisherman from Seroei (both operated from Hollandia) and one to a fisherman in Insobabi (MacKenzie, 1962). The vessel at Insobabi was taken back because the fisherman did not know how to use it, and the two vessels in Hollandia was not making a profit yet (MacKenzie, 1962).

The bottlenecks for the fishery included the fact that the seas around Netherlands New Guinea were very different, with the coasts that lie close to the ocean only being useful for high-sea fisheries (MacKenzie, 1962). Reefs were not close to the coast, so processing and transport made fisheries there difficult and the low lying coastal areas in the south that are unprotected from the sea were only fishable for a short period during the year, and required specific fishing methods (MacKenzie, 1962). The small scale coastal fishery did not contribute to the general economy although they were dependent on that economy (MacKenzie, 1962). The market for fish from Netherlands New Guinea was also not very well developed and only depended on local fish markets. Export of marine products included tuna (yellowfin, *Thunnus albacares*; albacore, *Thunnus alalunga*) shrimp and lobsters (MacKenzie, 1962).

Unfortunately, no data was available for catches and/or exports of fish in the Papua province from 1961-1967 nor from 1874-1992; Rabanal (1974) reported on the export of fish, shells, jellyfish, crocodile skins and shrimp from Irian Jaya. Data from 1993 to 2004 were obtained from the Sorong Regency Office and these together with estimates of export obtained from Rabanal (1974) of fish, shrimp, shells, crocodile skin, tuna and jellyfish for 1967-1973 are shown in Figure 9A (catches of fish, tuna and shrimp), Figure 9B (export of mollusk shells, *tripang*, shark fin, *trassi*, turtle shells jellyfish, crocodile skin).

Van Pel (1958) found that shell collection was one of the best fisheries in Netherlands New Guinea (Van Pel, 1958). Five commercial species of shells occurred: *Trochus niloticus* (Linnaeus, 1767), *Trochus obeliscus* Gmelin, 1791, *Turbo marmoratus* Linnaeus, 1758, *Pinctada maxima* (Jameson, 1901) and *Pinctada margaritifera* (Linnaeus, 1758) (Van Pel, 1958). The most important commercial species was the *lola* shell, *Trochus niloticus*, that usually doesn't occur deeper than 12 m. However, the blacklip (*Pinctada margaritifera*) and goldlip (*Pinctada maxima*) pearlshells were found in shallow water and fished by the local population, but not in large quantities. They occurred down to 55 m, but at those depths the results were not good (Van Pel, 1958). Blacklip pearl and *lola* shells were collected and sold to Chinese middlemen, who buy not just from Yapen Island but from everywhere else in Netherlands New Guinea (Van Pel, 1958).



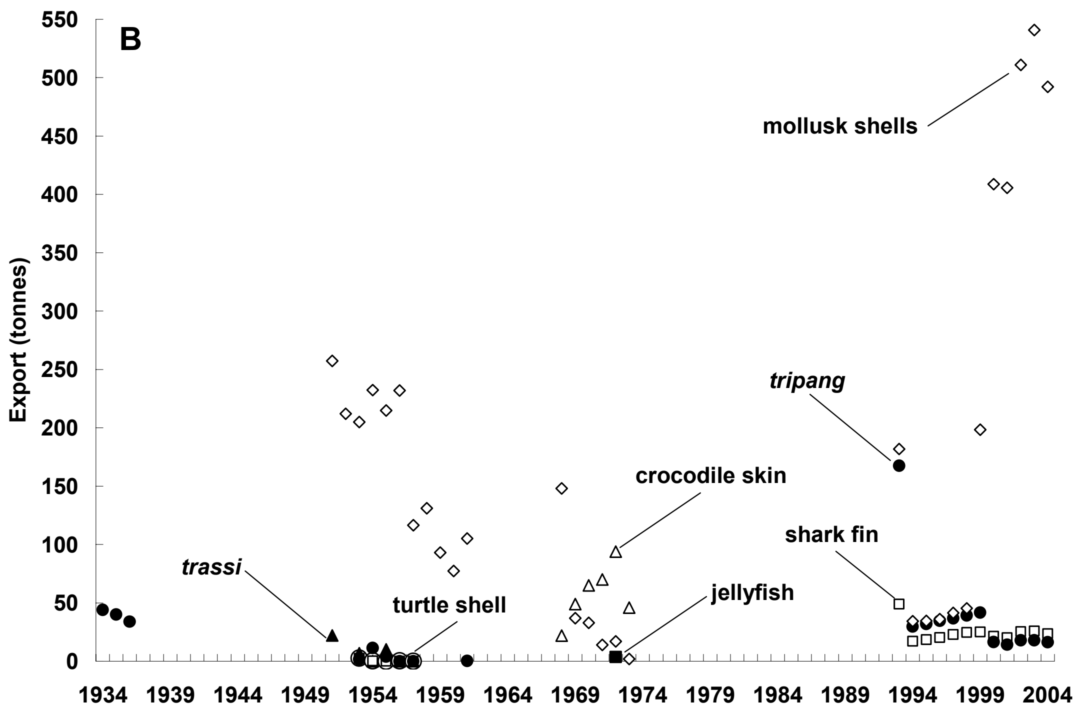


Figure 9. Catches and exports made in Netherlands New Guinea. **A**. Fresh and dried/salted fish, as well as shrimp catches. **B**. Export of *trassi* (dried shrimp paste), *tripang* (sea cucumber), shark fin, turtle shells, jellyfish, and crocodile skin.

The earliest estimates of shells exported from Netherlands New Guinea are from 1910 to 1932 when shells were being exported in *lasten* (= ± 3 m^3, see Figure 9B; Klein 1934). Boschma (1937) gave estimates of shell exported from Netherlands New Guinea between 1933-35, while Van Pel (1958) gave estimates from 1952-1957 and the estimates for 1958-1961 were obtained from the United Nations reports on Netherlands New Guinea (Anon, 1958; Anon, 1959; Anon, 1960b; Anon, 1961). Finally, Rabanal (1974) estimated exports for 1968-1973 (Figure 9B). The export of shells were declining and the prices reduced even by 1957 when 92.4 tonnes of troca, 8 tonnes burgos (*Turbo* spp) and 16.1 tonnes black and goldlip pearl shells were exported bringing in f490,200.00 (Van Pel, 1958). "Radja Ampat was the most imported shell area and there seemed to be no limitations to the amount of shells there [..] The fisheries are quite primitive but important to the native people" (Van Pel, 1958).

Conclusions

This review generated interesting and sometimes conflicting conclusions. It seems that indeed, Kepulauan Rajaampat forms the eastern base of the triangle of the world's center of marine biodiversity. Abundance observations and fishery records attest to the diversity and abundance of marine organisms in the area. It also seems that the inhabitants of the islands and the surrounding areas, notably of the Maluku province, have since ancient times practiced fishing for subsistence. In addition, fishing for trade has been practiced since the 8th century as encouraged by the profitable business with the Chinese and later on under the control of the Dutch East Indies Company.

There is a lack of quantitative records of extraction during the period when the Dutch East Indies Company ruled; "exact quantities of products were unknown since traders in a free port never disclose true figures" (de Clercq, 1999:14). The impact of these exogenous factors on the marine ecosystem since the 18th century is thus difficult to assess. However, the scientific surveys from the 19th century onwards might help in establishing, at least from the late 1800s, the changes which have occurred in this ecosystem. Our results seem to suggest a 50 % decline in sightings of turtles, fishes and invertebrates which might be due to increasing pressure exerted by a steadily increasing number of inhabitants.

There are indications of continuing commercial extraction of invertebrates, e.g., mollusk shells and *tripang*, in spite of signs of overexploitation. However, recent fishery expansion studies suggest that subsistence fisheries can be supported by the current fish, shellfish and echinoderm stocks. Commercial, e.g., trawl, fisheries seem to be a generally unprofitable enterprise. The unprofitability of commercial fisheries might be a blessing in disguise for the Kepulauan Rajaampat ecosystem. As the larger species of fish, crustaceans, mollusks and echinoderms, though considerably reduced in abundance, have not been extirpated, discouraging commercial trawling in a largely shallow water zone would be beneficial to what is still left of this ecosystem. Thus, emphasis must be placed on the proper management of subsistence and small-scale fisheries.

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APPENDICES

APPENDIX A: LIST OF PLACE NAMES WITH OBSERVATIONS ON ABUNDANCE OF MARINE ORGANISMS OR ON EXOGENOUS FACTORS IMPACTING ON THE MARINE ECOSYSTEM

Place name	Obs.	Place name	Obs.
Unspecified	13	Gag, Kepulauan Rajaampat, Papua	3
Adi, Maluku	4	Gam, Kepulauan Rajaampat, Papua	2
Aiduma, Nusa Tenggara Timur	3	Gani, Halmahera, Maluku	2
Ajawi, Biak, Papua	1	Gebe, Halmahera, Maluku	66
Ambon, Seram, Maluku	58	Gisser, Laut Seram, Maluku	15
Amurang, Sulawesi Utara	1	Halmahera, Maluku	18
Andai, Papua	1	Hansisi, Samau, Nusa Tenggara Timur	1
Angra Meos, Papua	1	Har, Kai Besar, Kepulauan Kai, Maluku	2
Ansus, Papua	16	Igi, Papua	1
Argoeni, Papua	2	Insobabi, Biak, Papua	1
Aru, Kepulauan Aru, Maluku	6	Jayapura, Papua	18
Atjatuning, Fak Fak, Papua	3	Jedan, Kepulauan Aru, Maluku	1
Atti Atti Onin, Papua	2	Jef Lie, Misool, Papua	1
Aurora bank, Laut Halmahera, Maluku	2	Jodio, Kepulauan Tapok, Papua	1
Awek, Yapen, Papua	1	Kaap de Goede Hoop, Papua	1
Bacan, Maluku	12	Kabarei, Waigeo, Papua	2
Bajowe, Sulawesi Selatan	3	Kabia, Sulawesi Selatan	1
Bamboe, Kepulauan Fam, Papua	1	Kabolaa, Waigeo, Papua	11
Bandanaira, Banda Besar, Maluku	21	Kai Besar, Kepulauan Kai, Maluku	3
Bantaeng, Sulawesi Selatan	1	Kaimana, Papua	1
Batanme, Papua	1	Kanjungan ketjil, Laut Celebes, Kalimantan Timur	3
Batanta, Kepulauan Rajaampat, Papua	4	Kasonaweja, Papua	5
Batu Pangal, Kalimantan Timur	1	Kassim river, Batanme, Papua	3
Beeuw, Waigeo, Papua	7	Kau, Halmahera, Maluku	1
Beo, Kepulauan Talaud, Sulawesi Utara	3	Kayuangin, Kepulauan Sunda	1
Biak, Papua	20	Kayumerah, Papua	2
Binongka, Kepulauan Tukangbesi, Sulawesi Tenggara	1	Kepulauan Aru, Maluku	3
Bira, Papua	1	Kepulauan Auri, Papua	1
Bitsyaru, Papua	1	Kepulauan Ayu, Papua	4
Bomberai, Teluk Berau, Papua	1	Kepulauan Banda, Maluku	15
Borneo bank, Selat Makassar, Kalimantan Timur	2	Kepulauan Banggai, Sulawesi Tengah	10
Bukisi, Papua	1	Kepulauan Boo, Halmahera, Maluku	5
Bulukumba, Sulawesi Selatan	1	Kepulauan Gorong, Maluku	1
Buru, Maluku	25	Kepulauan Kai, Maluku	4
Busu, Halmahera, Maluku	1	Kepulauan Kumamba, Papua	4
Damar, Maluku	8	Kepulauan Lucipara. Maluku	2
Danau Amaru, Papua	1	Kepulauan Mapia, Papua	7
Deer, Kofiau, Papua	6	Kepulauan Obi, Maluku	2
Digoel, Papua	2	Kepulauan Padaido, Papua	9
Dobo, Kepulauan Aru, Maluku	7	Kepulauan Penyu, Maluku	1
Dona Carmelita Bank, Kepulauan Boo, Papua	1	Kepulauan Podena, Papua	1
Fafanlap, Misool, Papua	3	Kepulauan Rajaampat, Papua	26
Fak Fak, Papua	22	Kepulauan Rombombo, Salawatti, Papua	1
Fam, Kepulauan Fam, Papua	8	Kepulauan Sangihe, Maluku	7
Faur, Papua	4	Kepulauan Scouten, Papua	1

Place name	Obs.	Place name	Obs.
Flores, Nusa Tenggara Timur	5	Kepulauan Sula, Maluku	1
Kepulauan Tapok, Papua	1	Morotai, Halmahera, Maluku	4
Kepulauan Tobelo, Maluku	1	Mumi, Papua	2
Kepulauan Wakde, Sulawesi Utara	1	Namatote, Papua	2
Kepulauan Widi, Maluku	2	Nangamesi, Sumba, Nusa Tenggara Timur	2
Kofiau, Torobi, Papua	2	Noemfoer, Papua	1
Kokas, Papua	1	Numfoor, Papua	1
Kupang, Nusa Tenggara Timur	1	Obi, Maluku	1
Kur, Kepualuan Kai, Maluku	11	Pacific Ocean, Point d'Urville, Papua	14
Kurudu, Yapen, Papua	5	Panai, Papau	11
Labuha, Maluku	2	Papua	246
Labuhanbajo, Nusa Tenggara Timur	3	Parang, Seram, Maluku	1
Lakahia, Papua	4	Patani, Halmahera, Maluku	2
Lake Sentani, Jawa Tengah	4	Patipi, Papua	1
Laluin, Nusa Tenggara Timur	2	Pidjot, Lombok, Nusa Tenggara Barat	3
Lamakwera, Solor, Nusa Tenggara Timur	7	Poeé, Papua	1
Lamalerap, Lomblen, Nusa Tenggara Timur	1	Pulau Taam, Kepulauan Kai, Maluku	3
Laut Arafura, Papua	1	Ram, Papua	3
Laut Banda, Maluku	22	Rani, Papua	1
Laut Banda, west of Gunungapi, Maluku	2	Roewata, Seram, Maluku	1
Laut Celebes, Sulawesi Utara	49	Roon, Papua	12
Laut Halmahera, Maluku	48	Sabuda, Papua	1
Laut Maluku, east of Ternate, Halmahera, Maluku	2	Sailolof, Salawati, Papua	8
Laut Maluku, Halmahera, Maluku	5	Sailus ketjil, Paternoster, Nusa Tenggara	7
Laut Sawu, Nusa Tenggara Timur	7	Saketa, Halmahera, Maluku	1
Laut Seram, Maluku	13	Salawati, Papua	34
Lenteng,Flores, Tenggara Timur	1	Salayar, Sulawesi Selatan	8
Libobo, Halmahera, Maluku	1	Samate, Salawati, Papua	9
Lilinta, Misool, Papua	5	Saonek, Waigeo, Papua	10
Lirung, Buru, Maluku	2	Saparua, Seram, Maluku	2
Lobo, Teluk Triton, Papua	4	Sarmi, Papua	3
Lumu-Lumu, Selat Makassar, Kalimantan Selatan	2	Sawan, Siau, Sulawesi Utara	2
Madorang, Seram, Maluku	1	Sawangan, Sulawesi Utara	1
Makasar, Sulawesi Selatan	34	Seba, Kepulauan Savu, Nusa Tenggara Timur	5
Mamberamo, Sulawesi Selatan	1	Seget, Papua	20
Manado, Sulawesi, Sulawesi Utara	16	Selat Dampier, Papua	2
Manipa, Seram, Maluku	3	Selat Lenna, Papua	4
Manokwari, Teluk Doreh, Papua	52	Selat Limbe, Sulawesi Utara	9
Mansinam, Manokwari, Papua	7	Selat Makassar, Kalimantan Timur	7
Mapi, Papua	2	Selat Patinti, Halmahera, Maluku	1
Mar Warsai, Papua	1	Selat Rabia, Waigeo, Papua	1
Masalembu Besar, Jawa Timur	1	Selat Sagewin, Salawatti, Papua	1
Mayalibit passage, Waigeo, Papua	6	Selat Samau, Timor, Timor Leste	2
Merauke, Papua	12	Selat Sele, Salawatti, Papua	12
Mesa, Halmahera, Maluku	1	Seram, Maluku	20
Middelburg, Papua	1	Serui, Papua	3
Miei, Papua	2	Sidangoli, Obit, Halmahera, Maluku	13
Mios Waar, Papua	1	Sigaroi-rivier, Papua	2
Misool, Papua	95	Sorong, Papua	31
Moearas Reef, Borneo, Kalimantan Timur	2	Sowek, Biak, Papua	2
Moetoes besar, Waigeo	1	Sulawesi Utara	2
Mois Indi, Papua	2	Sunam, Halmahera, Maluku	2
Sungi Digul, Papua	1	Teluk Wunoh, Waigeo, Papua	16

Place name	Obs.	Place name	Obs.
Sungi Karufa, Papua	1	Teluk Yos Sudarso, Papua	10
Sungi Lorentz, Papua	2	Teminabuan, Biak, Papua	1
Sungi Maros, Sunda Besar, Sulawesi Selatan	1	Ternate, Tidore, Maluku	36
Sungi Mimika, Papua	1	Tidore, Halmahera, Maluku	9
Sungi Muturi, Papua	1	Tire Lake, Papua	5
Sungi Weperar, Papua	1	Tondano Lake, Sunda Besar, Sulawesi Utara	1
Supiori, Papua	5	Tor River, Papua	1
Tamulol, Misool, Papua	1	Tsiof, Papua	1
Tanjung d'Urville, Papua	1	Tual, Kepulauan Kai, Maluku	10
Tanjung Saweba, Papua	1	Waar, Papua	2
Tanjung Yamursba, Papua	1	Wagoera rivier, Papua	1
Tare Lake, Papua	5	Wahai, Maluku, Maluku	12
Teluk Berau, Papua	8	Waigama, Misool, Papua	9
Teluk Bintuni, Papua	2	Waigeo, Papua	114
Teluk Cenderawasih, Papua	10	Wamar, Halmahera, Maluku	1
Teluk Demta, Papua	1	Wambong, Torobi, Papua	6
Teluk Dodinga, Bacan, Maluku	1	Warbal, Papua	4
Teluk Doreh, Papua	5	Warir, Salawatti, Papua	1
Teluk Etna, Papua	2	Wasior, Papua	2
Teluk Fofak, Waigeo, Papua	1	Wasir, Papua	1
Teluk Jailolo, Maluku	1	Wissel-meren, Papua	1
Teluk Kabui, Waigeo, Papua	6	Wokam, Aru, Kepulauan Aru, Maluku	6
Teluk Kaimana, Papua	3	Woropen, Papua	4
Teluk Kajumerah, Papua	1	Yamna, Papua	2
Teluk Kamrau, Papua	1	Yapen, Papua	10
Teluk Kawa, Seram, Maluku	2	Yauer-Manokwari, Papua	2
Teluk Kayeli, Buru, Maluku	1	Yobi, Yapen, Papua	1
Teluk Kema, Taliabu, Kepulauan Sula, Maluku	1		
Teluk Korido, Maradon, Biak, Papua	5		
Teluk Kwandang, Sulawesi Utara	1		
Teluk Lakahia, Papua	2		
Teluk Lilintah, Misool, Papua	4		
Teluk Majalibit, Waigeo, Papua	3		
Teluk Palos, Laut Celebes, Sulawesi Tengah	6		
Teluk Piapis, Waigeo, Papua	2		
Teluk Randowaja, Papua	1		
Teluk Sahu, Biak, Papua	1		
Teluk Saleh, Sumbawa, Nusa Tenggara Barat	2		
Teluk Sebakor, Papua	10		
Teluk Sekar, Papua	2		
Teluk Serui, Yapen, Papua	4		
Teluk Tolo, Sulawesi Tengah	9		
Teluk Triton, Papua	2		
Teluk Wagom, Misool, Papua	1		
Teluk Walckenaer, Papua	1		
Teluk Wandammen, Papua	1		
Teluk Waru, Seram, Maluku	2		
Teluk Wasai, Waigeo, Papua	2		
Teluk Weda, Halmahera, Maluku	1		
Teluk Wooi, Yapen, Papua	1		

Appendix B : List of documents obtained and consulted either in electronic or paper format containing narratives of or descriptions of voyages, expeditions, explorations and private, colonial or scientific surveys that visited the East Indies. The references used were fully extracted only for observations pertaining to the East Indies.

Years	**Voyage**	**Type**	**Used**	**Not encoded**
1500-1883	Haga, Netherlands New Guinea and Papua islands	Historical review		Haga (1884)
1581-1582	Miguel Roxo de Brito	Narrative		Boxer (1977); Gelpke (1994)
1595-1597	Phillip William to the East Indies	Narrative		William (1598)
1606-1765	Dutch discovery of Australia	Historical review		Heeres (1899)
1615?	John Darell - *Dragon* and *Katherine*	Narrative		Darell (1665)
1665?	Herbert's travels to Africa and Asia	Narrative		Herbert (1665)
1637-1677	Tavernier's voyages	Commented narrative		Tavernier (1677)
1638	Jean Hugues de Linschot's voyage to the East Indies	Narrative		Linschoten (1638)
1667-1670?	Glanius' voyage to the East Indies	Narrative		Glanius (1682)
1678	Johannes Keyts voyage to New Guinea	Narrative		Gelpke (1997)
1679-1859	Scientific circumnavigations	Review		Rogers (2001)
1685	Sx Jesuits' voyage to Siam	Relation		Tachard (1688)
1677	Fryke and Schewitzer's voyages to the East Indies	Relation		Fryke (1700)
1689-1698	Leguat's voyage to the East Indies	Narrative		Leguat (1708)
1699	Dampier's voyage to New Holland	Narrative		Dampier (1697); Dampier (1709)
1700-1899	Voyages to New Guinea and Papua	Review		Leupe (1875)
1707	Symson's voyage to East India	Narrative		Symson (1715)
1764-1766	Byron, around the world in the *Dolphin*	Narrative		Anon (1767)
1768-1771	Stavorinus' voyage to Batavia, Bantam and Bengal	Report to the Dutch East India Company		Stavorinus (1798)
1769	Sonnerat's voyage to New Guinea	Narrative and species descriptions	Sonnerat (1776)	
1768-1769	French discoveries SE of New Guinea	Historical review		Fleurieu (1797-1800)
1773	Banks on Bougainville's voyage around the world	Commentary		Banks (1773)
1774-1776	Forrest's voyage to New Guinea and the Moluccas	Commentary		Bassett (1969)
1781	Amasa Delano	Biography		Connolly (1943)
1790-1792	Etienne Marchand's voyage around the world	Historical review		Fleurieu (1797-1800)
>1792?	Rochan's voyage to Madagaskar and East Indies	Narrative		Brunel (1792)
1800-1804	Baudin's circumnavigation on the *Géographe*	Narrative		Péron (1807); Freycinet (1811)
1824	Bik's voyage to Kefing, Goram, Ke and Aru islands	Narrative		Bik (1928)

Years	Voyage	Type	Used	Not encoded
1825-1826	Voyages of the *Dourga*	Narrative		Kolff (1840)
1817-1820	Freycinet's circumnavigation on the *Uranie*	Narrative	Freycinet (1825; Freycinet (1829)	
1822-1825	Duperrey's circumnavigation on the *Coquille*	Narrative and species descriptions	Bory de St. Vincent (1846); Bory de St. Vincent (1828-1829); Duperrey (1825); Lesson (1826-30a); Lesson (1826-30b)	Duperrey (1826); Duperrey (1830);
1837-1840	D'Urville's second circumnavigation on the *Astrolabe and Zélée*	Narrative and species descriptions		D'Urville (1843); D'Urville (1844); Rosenman (1987)
1828	Modera's voyage to New Guinea on the *Triton* and the *Iris*	Narrative		Modera (1830)
1828-1836	Müller's voyage to the Indian Archipelago on the *Triton*	Narrative		Müller (1857)
1833	Voyage of the *Othello*	Narrative	Mitchell (1988)	
1843-1846	Voyage of the *H.M.S. Samarang*	Narrative and species descriptions		Adams (1848)
1847-1861	Bleeker's *Atlas ichtyologique*	Species descriptions	Bleeker (1847a-1847c); Bleeker (1849a-1849e); Bleeker (1850a-1850g); Bleeker (1852a-1852h); Bleeker (1853a-1853c); Bleeker (1854-57); Bleeker (1855a-1855i) Bleeker (1856a-1856j); Bleeker (1856-1857a and b); Bleeker (1857a-1857j); Bleeker (1858); Bleeker (1858-1859a to c); Bleeker (1859-1860a to h); Bleeker (1861a-1861c); Bleeker (1879)	
1847-1861	Bleeker's collected papers	Species descriptions	Lamme (1973); Lamme (1975a-1975c)	
1854-1862	Alfred Wallace's stay in the Malay Archipelago	Narrative	(Wallace 1869)	
1855	Bleeker's voyage on the *Minahassa*	Narrative		Bleeker (1856e)
1855-1873	Memories of the transfer of management from Tobias to Bosscher	Archival documents	Overweer (1995b)	
1858	Ethnography and natural study of New Guinea	Study		van der Goes *et al.* (1862)
1858	Papuas of Geelvinkbay	Study		Goudswaard (1863)
1858-1880	Archives relating to Netherlands New Guinea	Archival document	Overweer (1994)	
1860	Uprising on Ceram	Historical review		van Balen (1891)
1862-1887	Van Hasselt (missionary)	Study		Van Hasselt (1888)

Years	Voyage	Type	Used	Not encoded
1864-1865	Bernstein's voyage to New Guinea	Narrative		Van Musschenbroek (1883)
1865	The voyage of the H.M.S. *Curaçoa*	Checklist of species	Brenchley (1873); Günther (1873)	
1869-1870	Von Rosenberg's voyage to Geelvinkbaai and New Guinea	Narrative		Von Rosenberg (1875)
1871-1876	van der Crab, Teysmann, Coorengel, Langeveldt van Herert and Swaan	Narrative		Van der Robidé (1879)
1871-1873	D'Albertis'voyage to New Guinea	Narrative		D'Albertis (1880)
1871-1874	Wallace on D'Albertis' voyage to New Guinea	Commentary		Wallace (1881)
1871-1976	Description of the west and north coasts of Netherlands New Guinea and ethnography	Memoires of the resident of Ternate		De Clercq 1893; De Clercq and Schmeltz (1893)
1873	Meyer's voyage to New Guinea	Narrative		Meyer (1875)
1873-1876	The Voyage of the *H.M.S. Challenger*	Species descriptions	Agassiz (1886b); Allman (1886a); Bate (1886); Beddard (1886); Brady (1886a); Brady (1886b); Brady (1886); Busk (1886a); Carpenter (1886a); Günther (1886a); Günther (1886b); Haddon (1886); Henderson (1886); Herdman (1886a); Hertwig (1886) Hoek (1886); Lyman (1886); M'Intosh (1886); Mires (1886); Moseley (1886); Pleseneer (1886); Poléjaeff (1886); Ridley (1886); Schulze (1886) Sladen (1886); Smith (1886); Sollas (1886); Théel (1886); Watson (1886a); Watson (1886b)	Thomson (1880); Thomson (1881a-1881d); Thomson and Murray (1882a-c); Thomson and Murray (1883a-b); Thomson and Murray (1884); Thomson and Murray (1885); Tizard *et al.* (1885)
1876-1877	*la Corrèze,* Raffay	Narrative		Raffray (1880)
1876-1899	Willem L. Jens (missionary)	Study	Jansen-Weber *et al.* (1997)	

Years	Voyage	Type	Used	Not encoded
1879	Wallace on Australasia	Study		Wallace (1879)
1884	Haga's historical overview	Historical review		Haga (1960)
<1885	Dutch voyages to New Guinea	Historical review		Bonaparte (1885a); Bonaparte (1885b)
<1885	Mrs. Forbes	Voyage		Van Deventer (1888)
1889	Scientific study of Kei islands	Study		Planten *et al.* (1889)
1890	de Clercq, resident to Ternate	Report to the Dutch East India Company	de Clercq (1999)	
1898	Mapia Islands *Edi*	Narrative	Huizinga (1996)	
1899	The *Siboga* expedition	Scientific expedition and species descriptions	Alcock (1902); Billard (1913); Billard (1925); Boschma (1923); Burton (1930); Hickson (1916); Hickson and England (1905); Hickson and Versluys (1907); Ijima (1926); Lens and Van Riemsdijk (1908); Maas (1903); Maas (1905); McMurrick (1910); Moser (1903); Nutting (1910a); Nutting (1910b); Nutting (1910c); Nutting (1911); Stiasny (1935); Stiasny (1937); Thomson and Dean (1931); Tydeman (1903); Van der Horst (1921); Van der Horst (1922); Versluys (1902); Versluys (1906); Vosmaer (1911); Vosmaer and Vernhout (1902); Weber (1902)	Anon (1894); Weber (1899a); Weber (1899b)
1899	Mrs. Weber on *Siboga*	Narrative		Weber (1904)
1900	Mapia island description	Review		Heeres (1900)
1901	*H.M. Ceram*, van Asbeck	Narrative		Van Asbeck (1902)
1901-1904	*Tilikum,* Captain Voss	Narrative	Voss (1976)	

Years	Voyage	Type	Used	Not encoded
1903	Wichmann on *SS Zeemeeuw*	Narrative		Wichmann (1909); Wichmann (1910); Wickmann (1903a); Wickmann (1903b)
1903	Lorentz Humboldt Bay, geology	Study		Lorentz (1905)
1903	Results of voyage to New Guinea	Scientific results	Van der Sande (1907)	
1903-1916	Archives relating to Netherlands New Guinea	Archival document	Overweer (1995a)	
1903-1916	Military exploration	Study		Anon (1916)
1903-1914	Inventory of Dr. Lorentz' expeditions	List of species		Tempelaars (1983)
1904-1905	Southwest New Guinea Expedition	Review		de Rochemont (1909)
1905-1906	Hirschi, travels in Northwest New Guinea	Review	Hirschi (1908)	
1909-1912	3rd South New Guinea Expeditions	Scientific survey	Herderschee (1912)	Herderschee (1913)
1912	Van Muijlwijk (missionary)	Study	Van Muijlwijk (1913)	
1912	3rd Netherlands Expedition to Sneeuwbergte	Scientific survey		Pulle (1914)
1916	Pareau on *Siberg*	Narrative	Pareau (1917)	
1921	Description of the Indonesian part of New Guinea	Study		Van Eerde (1921)
1921	Violet Clifton's travels	Narrative	Clifton (1991)	
1922	Description of the seas of Netherlands East India	Review	Anon (1922)	
1925	Management memorandum on takeover of North New Guinea	Review	Van de Graaff (1991)	
1925	Vlemings description of the Chinese trade	Study	Vleming (1925)	
1929-1930	The *Snellius* expedition	Scientific survey		Anon (1929); Anon (1930); Fock and Luymes (1927); Kuenen (1941)
1933	Sailors' guide of Netherlands East India	Guide		Anon (1933)
1934	Economics of Netherlands New Guinea	Study	Klein (1934)	
1935	Fauna of New Guinea	Faunal list		De Beaufort (1935)
1935	Description of the exploration of New Guinea	Historical review		Le Roux (1935)
1937	Sea products of New Guinea and fisheries	Product list	Boschma (1937)	
1937	Canoes of Oceania	Review		Haddon (1937)
1938	Memories of the transfer of North New Guinea	Archival document	Beets (1991)	
1938-1939	Evelyn Cheeseman	Narrative	Cheeseman (1949)	
1939	Exploration to Central New Guinea	Study	Van Eeckhoud (1959)	
1939	New Guinea expedition of KNAG	Scientific survey	Le Roux (1939)	
1944	Terrain study of Radja Ampat	Study		Anon (1944)
1944	Terrain handbook Manokwari	Guide	Anon (1944)	
1945	Research on fish in Indo-Australia	Study		Herre (1945)

Years	Voyage	Type	Used	Not encoded
1947	Study on Manokwari	Study	Wehlburg (1947)	
1948-1949	Klein to Netherland- and Australian New Guinea	Narrative	Klein (1949)	
1949	Zaneveld on the *Fak-Fak*	Narrative	Zaneveld (1950)	
1949	Life on Biak described by Lillian Asimow	Study	Asimow (1991)	
1950	Marine gouvernment of New Guinea	Study	Hokke (1950)	
1951-1966	United Nations reports on fisheries	Report		Anon (1951); Anon (1952); Anon (1953); Anon (1954); Anon (1955); Anon (1956b); Anon (1957b); Anon (1958); Anon (1959); Anon (1960b); Anon (1961)
1952-1954	Contact with New Guinea: Fauna	Faunal list		Brongersma (1954)
1953	Fishing rights in Mimika	Study		Pouwer (1953)
1954	Fauna of New Guinea, Boschma	Faunal list	Boschma (1954)	
1954	Chronicle of New Guinea	Faunal list		McManus (1954)
1954	Tuna fisheries around New Guinea	Study		Van Eeckhoud (1954)
1954-1960	Manager in the heart of New Guinea	Study	Sneep (2005)	
1955	Subsistence fisheries	Study		Zwolle (1955)
1955	6th Infantry battalion in New Guinea			Nortier and De Leeuw (2000)
1956	Manual for Netherlands New Guinea	Guide		Anon (1956a)
1956	The Radja Empat Islands	Review	Edwoldt (1956); Maurenbrecher (1956a); Maurenbrecher (1956b)	
1956	Agriculture in Mappi area	Study		Perk (1956)
1956	Socio-economic structure of Jaqui	Study	Boelaars (1956)	
1956	Trawl fishery of New Guinea	Study		Zwolle (1956)
<1957	Bergman, through New Guinea	Review		Bergman (1957)
<1957	Scientific study of Ajamaru area	Study	De Haan (1957)	
1957	Oil in Netherlands New Guinea	Study	Anon (1957a)	
1957	Birds	Checklist		Coomans de Ruiter (1957a); Coomans de Ruiter (1957b)
1957	Forgotten Earth, Van Eeckhoud	Study	Van Eeckhoud (1957)	
1958	Poisonous shells of New Guinea	Checklist		Haneveld (1958)
1958	Malaya, Indonesia, etc.	Review		Robequain (1958)

Years	Voyage	Type	Used	Not encoded
1958	Raport on sea and inland fisheries	Report	Van Pel (1958)	
1958	Co-operatives	Review	Vesseur (1958)	
1958-1964	Sailor on the *H.M. de Ruyter*	Narrative	De Betué (1992)	
1959-1962	Coral reefs, poisonous fish and poisonous shellfish	Checklist		Coomans de Ruiter (1959-1962)
1960	American scientist in New Guinea	Review		Anon (1960a)
1960	Raport on development of Biak	Report	Le Roux (1960)	
1961	Jellyfish of New Guinea	Checklist		Coomans de Ruiter (1961a); Coomans de Ruiter (1961b); Coomans de Ruiter (1961c)
1961	Profile of Indonesia	Study	Mintz (1961)	
1961	Airport at Biak City	Review	van Reeken (1961)	
1962	Sea fisheries of Netherlands New Guinea	Study	MacKenzie (1962)	
1971	Fishes of Ambon	Checklist		Hutomo (1971)
1971	Brachyurans of Ambon	Checklist		Serene (1971)
1973	Surface schooling tuna	Study		Kearney *et al.* (1973)
1974	Brackish water fisheries	Study	Rabanal (1974)	
1975	Mangroves of Port Moresby	Checklist		Frodin *et al.* (1975)
1975	Sea grasses of Port Moresby	Checklist		Johnstone (1975)
1978	Uprising in Papua	Review	Utrecht (1978)	
1986	Meybrat fishery and Kain Timur complex	Study		Miedema (1986)
1989	Conservation in Irian Jaya	Study		Petocz (1989)
1991	Looking for their identity, West Papuas	Review	IMBAS/GPL (1991)	
1993	Empire of the east, travels in Indonesia	Review	Lewis (1993)	
1995	Management on New Guinea	Study	Huizinga (1995)	
1996	Wildlife in Indonesia	Checklist		Whitten and Whitten (1996)
1997	Severin in the footsteps of Wallace	Narrative	Severin (1997)	
1997	Ecology of Indonesian seas	Study	Tomascik *et al.* (1997)	
1998	Resource rights on Gag	Study		Berry and Siswanto (1998)
1999	Linkages between business and local communities	Study		BCN (1999)
2000	Wallace's line	Study	Barber *et al.* (2000)	
2000	Land and resource ownership	Study		Berry (2000)
2001	Raja Ampat languages	Review		Remijsen (2001)
2001	Cummunity conservation initiatives	Study		Schultze-Westrum (2001)
2001	Sea turtle harvests Kai islands	Study		Suárez (2001)
2002	Rapid marine survey of Raja Ampat	Scientific survey		Erdmann and Pet (2002)
2002	Resources and conflict in Papua	Review		ICG (2002)

Years	Voyage	Type	Used	Not encoded
2002	Marine rapid assessment of Raja Ampat	Scientific survey		McKenna *et al.* (2002)
2002	Underwater tailing placements	Study		Poling *et al.* (2002)
2003	Bull's eye of biodiversity	Study		Ivereigh (2003)
2004	Social and physical environment of Buyat Bay	Study		Anon (2004a)
2004	Sailing directions of New Guinea	Study	Anon (2004b)	
2004	Djief hunters, rainforest exploitation of Birds Head	Study		Pasveer (2004)
1893??2005	Journals and notebook of A.R. Wallace	Memoirs		Pearson (2005)
2006	Case study of Komodo National Park	Study		Pannell (2006)
2006	Lake Sentani background	Review	Moore *et al.* (2006)	

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