Managing Tourism in Bunaken National Park and Adjacent Waters, North Sulawesi, Indonesia

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TECHNICAL REPORT

Managing Marine Tourism in Bunaken National Park and Adjacent Waters, North Sulawesi, Indonesia

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This Technical Report was prepared by the Natural Resources Management (NRM III) Program's Protected Areas and Agriculture Team (PA&A). The NRM III PA&A Team works with Indonesian government and civil society on testing and strengthening decentralized natural resources management approaches at the field level, leveraging them for broad-based adaptation and replication at the regional to national level, and applying lessons learned to contribute to policy development favorable to strengthened and decentralized natural resources management. Particular emphasis is given to protected areas management, sustainable forest management, and agriculture and agroforestry development.

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Table of Contents

Annexes

List of Tables

List of Figures

List of Plates

Executive Summary

This report provides an assessment of present levels of use and impact of marine tourism, focused on recreational SCUBA diving, in Bunaken National Park (NP) and the surrounding reefs in North Sulawesi, including the Lembeh Strait and Bangka and Gangga Islands. The report also develops policy recommendations aimed at minimizing future impacts and thereby maintaining ecological and socio-economic sustainability of marine tourism in North Sulawesi.

Dive sites:

At present, North Sulawesi has approx. 120 known dive sites, in five main locations - Bunaken NP islands, Lembeh Strait, the North Sulawesi mainland to the north and south of Manado, the Gangga - Bangka - Talise islands and the southern mainland section of Bunaken NP, with more sites being 'discovered' regularly. Lembeh Strait and the islands of Bunaken NP host most dive sites (34 % and 27 % respectively), followed by the Manado mainland (including Tanjung Pisok within Bunaken NP, 19 %) and Gangga - Bangka - Talise Islands area (17 %).

Diver numbers:

At present, Bunaken NP entrance fee data indicate that at least 9,000 divers dive North Sulawesi's reefs each year. These are hosted by some 40 dive operators, who supply dive guides at an average ratio of one guide per four divers, for a total number of 'divers' of 11,250 per year. On average, each diver conducts 15 dives (ranging from four to > 30 dives) during his/her stay, in total performing between 110,000 and 225,000 dives per year.

Diving 'effort':

If the present diving effort were spread evenly over the 120 sites, present usage would equate to less than 2,000 divers per site per year, well within the recommended carrying capacity limits of 4,000 - 6,000 dives per site per year for other coral reef areas.

However, present (and presumably future) dive effort is not spread evenly among the 120 sites. For reasons of accessibility, logistics - economics, safety and 'divability' (manageable currents, suitability for training, tourist appeal / expectations etc.), approx. 30% of sites receive far more dive effort. Bunaken NP islands host a disproportionate

number of the most-dived sites, accounting for some 40% of all heavily dived sites. For many of these sites, diving by multiple operators occurs on a daily basis, with from three to a maximum of six boats operating at the same time in the busiest circumstances.

The most frequented dive sites are already receiving > 6,000 divers per year, which is above Carrying Capacity recommendations of the 'threshold' level for minimal reef damage. For most other sites, dive use is well below these limits.

At present, the maximum number of divers that can be accommodated in the approx. 40 recognized dive resorts and homestays and eight live-aboard dive boats in North Sulawesi at any one time is approx. 1,000, some 380 of whom can stay in homestay style cottages on the islands within Bunaken NP.

This maximum accommodation limit for divers is at present rarely if ever achieved, as different resorts experience different peaks in their accommodation cycle. However, with increasing dive tourism, the maximum will begin to be attained on a more frequent basis. If this maximum number of divers was maintained for much of the year, and assuming an average stay of two weeks per diver, then total divers could reach 25,000 annually. ***Based on international experience and present dive use trends, broad limits to overall marine tourism carrying capacity for North Sulawesi are already within reach.***

Diver interactions:

A total of 2,364 individual diver - substratum interactions were recorded during ca. 38 hours of behavioral surveys of 176 divers, with more than 60 interactions per diver per hour. Most interactions were caused by recreational divers who also formed more than half of the divers in the study. Highest rates of diver interaction were for touches (excluding standing) of the reef (27 touches per diver per hr), followed, in decreasing frequency by:

- standing by snorkelers (22 interactions per snorkeler hr^{-1});
- holding, mostly at the end of dives in strong current, and by photographers (13 interactions per diver hr^{-1});
- sediment disturbance (10 interactions hr^{-1});
- deliberate harassment (e.g. of cryptic fauna, anemone fish, turtles etc. - 8 interactions hr^{-1}); and
- bubbles contacting gorgonians and other attached reef-wall fauna (6 interactions hr^{-1}).

Accidental breakages of benthic organisms were less common (2 breakages per diver hr^{-1}), and there were just two deliberate breakages recorded. Nonetheless, ***harassment and breakages, with some 10 combined interactions per diver per hour, are major negative forms of interaction, particularly when considered in the context of overall dive use in North Sulawesi (11,000 divers per year performing in excess of 100,000 dives).***

There were wide ranges in both the numbers and types of interactions among different divers and different dive groups, and among and within operators. Even for the same operator, with high quality briefings and dive guide procedures, different dive groups behaved very differently.

There was also a wide range in 'quality' of dive guides, in relation to dive briefings, underwater supervision / dive guidance and levels of harassment. Some dive guides were among the worst offenders in terms of harassment, actively seeking out and manipulating organisms such as pygmy seahorses and other 'critters' for their clients. This practice is encouraged by some dive operations, as the dive clients have paid to see and photograph these particular animals, and the operators and their guides feel obliged to deliver.

Quality of Dive Briefings:

Dive briefings, on arrival of guests at the resort and / or pre-dive by dive guides, were assessed for six operators, all North Sulawesi Watersports Association (NSWA) members. Within this group, there were marked differences in the 'quality' of dive briefings delivered to guests on arrival and by dive guides before diving. ***Both arrival and pre-dive briefings ranged from the cursory to the detailed, and there is significant room for improvement, as detailed later.***

Dive boats:

Three incidents of boats striking reefs and anchoring on shallow reefs were observed, causing more damage to a dive site in several minutes than hundreds of divers can do in many hours. ***Control of anchoring, and more appropriate use of moorings will markedly reduce physical breakage at the dive sites.***

There was a wide range in the quality of boat handling and control of dive vessels, with significant safety concerns relating to duty of care for divers, particularly at the beginning and end of dives. A few boat handlers exhibit a high degree of skill and care, although many are placing their own customers, and those of other operators, at significant risk,

particularly where multiple operators conduct drift dives simultaneously (e.g. Lekuan II, III, Muka Kampung, Pangalingan). ***Many dive boats are travelling too fast in the immediate vicinity of surfacing divers, with significant risk of injury or death.***

Reef condition and impacts of diving:

Interviews with dive operators and guides from nine operations (all NSWA members) suggested that substantial diver-caused damage has already occurred at the heavily dived sites, notably to reef crest corals from anchoring, boat strike and snorkelers standing on the reefs. Damage had also occurred to the reef wall fauna, particularly gorgonian fan corals, from accidental and deliberate breakage, and possibly also from regular impacts of diver bubbles. There was also an initial decline in fish diversity, abundances and sizes during the late 1980s - early 1990s, probably attributable to increasing fishing pressure, and destructive fishing with explosives, nets and poisons. This has been followed by a marked recovery, and perhaps stabilization in abundances in many species of reef fishes, other than reef sharks, since the mid 1990s, attributable mostly to improved management. There is a consistent perception among long-term dive operators and guides that heavily-dived sites have declined in terms of their coral cover and fish and invertebrate life, mostly attributable to over-use by divers.

Quantitative data from four of the most heavily dived sites in Bunaken NP support the anecdotal accounts of damage, with generally ***high levels of dead coral rubble and very high levels of broken corals and coral fragments (1,000s of broken corals and fragments per site), consistent with high levels of dive-related impact***.

Species diversity and abundance of damaged corals:

The species diversity of fragments (representing some 200 coral species in total) and density of 'coraliths' (free-living coral colonies with living tissues on all sides because of regular over-turning) are the highest known to the present authors. Species exhibiting most impact (producing most fragments and broken attached corals) represented a wide range of coral genera of generally fragile branching and foliose growth-forms. Foliose species such as *Mycedium mancaoi* and *Montipora stellata* and branching *Acropora brueggmanni* were most susceptible, exhibiting very high levels of damage with relatively low overall percent cover (< 1% for each species). The branching poritids *Porites nigrescens* and *P. cylindrica* were also highly susceptible, and with respectively higher percent cover (2 - 3%). Other highly susceptible species included the branching *Montipora cactus*, digitate - encrusting *Montipora vietnamensis*, and ahermatypic

dendrophyllid *Tubastraea coccinea*. *T. coccinae* occurs predominantly on walls / overhangs, and high impact to this species is consistent with physical abrasion by divers and possibly also bubble impacts running up the walls. Other species, by contrast, had relatively high cover and low levels of damage, including massive colonies of *Porites* spp. and sponges.

Homestay accommodation within Bunaken NP:

Twenty accommodation providers on the islands within Bunaken NP were interviewed in relation to environmental management. Eighteen of the 20 homestays have septic wastewater treatment systems, only one of which is a modern, environmentally friendly system. ***Most septic units are within close proximity to the beach, with significant attendant risks of leaching / seepage and eutrophication.*** The closest septic systems in four homestays are within just 10 m of the beach, a further four homestays have units within 20 m of the beach, a further eight homestays have systems within 50 m and the remaining two homestays have systems within 100 m.

Most (14) homestays already make significant efforts in relation to minimizing physical impacts to the fringing reefs, transporting guests, loading / unloading supplies and accessing dive sites via channels in the reef, thereby minimizing further reef damage and coral breakage. Seventeen homestays also report that they provide instructions to tourists regarding appropriate snorkeling and reef-walking behavior and reef access via the defined channels (16 homestays).

Impacts to sustainable marine tourism:

Marine tourism development, and the setting of sustainable limits (through Carrying Capacity and / or Limits of Acceptable Change - LAC), are highly contingent upon the status / condition of the marine environment. Impacts affecting the quality of the marine environment will also impact on marine tourism, and its sustainability. Impacts include those that are a direct result of tourism itself, and those that are independent or not directly related to tourism, yet have a deleterious effect.

Tourism-related impacts include:

- diver damage;
- anchor damage;
- boat strike damage and propeller disturbance to shallow seagrass beds and fast boat speeds on shallow reefs and among divers;

- pollution from solid wastes;
- pollution from sewage - *eutrophication*;
- pollution from sediment mobilization during homestay construction;
- increased pressure on fisheries to supply tourists.

Non-tourism related impacts that can affect condition of the marine environment and thus marine tourism include:

- non-tourism related coastal developments;
- river flooding and run-off;
- storm waves;
- overfishing and destructive fishing - including blast and poison fishing;
- poison fishing to supply ornamental aquarium trade;
- pollution from Manado;
- coral predation by crown-of-thorns seastars or *Drupella* molluscs;
- coral bleaching from temperature fluctuations or other stressors.

Some of these impacts are amenable to local management, others are not. Nevertheless, all these impacts impinge on CC and LAC limits.

From ecological, socio-economic and aesthetic standpoints, Marine Tourism Carrying Capacity - the total number of divers an area can support - is directly related to the availability of 'high quality' dive locations - sites with high species diversity and abundances of corals, fishes and other organisms, and little human impact. With a finite, limited number of sites, damaged to heavily used sites will focus increasing pressure on the remaining high quality sites. In this regard, ***the importance of maintaining sites in good condition cannot be over-emphasized***.

To best address these impacts, a flexible model incorporating both CC and Limits of Acceptable Change (LAC) is recommended. ***Overall maximums for diver / visitor numbers and infrastructure should be regulated***, and fine-tuned through monitoring of LAC with amendments to regulation, in response to non-diving related, as well as diving related, impacts, to allow individual sites to recover from disturbances.

In practice, sites that have been badly damaged usually become less attractive to divers, facilitating / assisting reactive management measures such as temporary site closure.

Initial site assessment and ongoing monitoring are crucial in understanding site condition, setting realistic CC and LAC levels, and initiating appropriate reactive management responses.

Recommendations re Managing Marine Tourism

A precautionary approach to future marine tourism development and expansion is recommended, given the high rates of diver interactions, levels of damage at heavily-used sites and present levels of uncertainty in relation to actual diving pressure in the region. The recommended Carrying Capacity limit of < 6,000 divers per site per year derived for other reef areas is used herein for purposes of comparison, as an interim number until specific site monitoring can provide relevant numbers for North Sulawesi. Ultimately it will be necessary to define unacceptable level(s) of damage (e.g. the proportion of damaged colonies or the mean number of broken branches per colony exceeding that found at 'control' sites by 10%). Such figures would represent trigger levels for further investigation, rather than a rigid compliance level. The advantages of this approach are avoidance of the need to specify an absolute quantity, and that the trigger criterion can be updated to reflect extraneous factors such as climate variability that also affect 'controls'.

From the aesthetic (social / amenity) perspective, controlling the number of divers to maintain amenity value may be based on the mean maximum number of divers that distract from the enjoyment of a dive. For many divers this occurs when divers from more than one dive operator dive the same site simultaneously. NSWA members already have a form of self-regulation at individual dive sites in this respect, which may be more formally regulated. This would also help to control maximum numbers of divers at the busiest sites.

Site opening - assessment and monitoring:

1. Great care should be taken in opening new sites to diving, with initial assessment, regular monitoring and dive use restrictions put in place:
    a. Individual dive site use-limits should be based on an initial site assessment and evaluation of the particular sensitivity of the proposed site to diving-related damage (e.g. types / morphology of corals etc.).
    b. Diving activity may be capped at present levels by licensing operators currently using the NP. Licenses should list the sites/reefs which operators may visit.

c. Surveillance and regulatory measures may be developed in relation to the deliberate exceeding of CC limits by dive operators.

d. Marine Park zoning schemes are a useful way of controlling / regulating the opening of additional dive sites.

2. A standard, simple site assessment and monitoring protocol should be developed and implemented, based on Global Coral Reef Monitoring Network protocols and the field methods employed during the present study. Variables to be monitored include levels of coral damage (i.e. numbers of fragments, numbers and proportions of broken colonies).

3. For sites to be maintained in good condition, a high degree of cooperation among dive operators (as already exists within NSWA) is required, in relation to the setting of realistic Limits of Acceptable Change (LAC).

   a. LAC may be measured in terms of the levels of coral damage (i.e. numbers of fragments, numbers and proportions of broken colonies) and cover of living / broken / dead coral and rubble; fish diversity and abundance (and other indicators as appropriate), and by developing detailed, specific site inventories (e.g. notable features - spectacular fan corals etc.).

   b. Reactive management decision criteria need to be developed in relation to exceeding of LAC limits.

   c. In respect to LAC, careful vigilance / monitoring and reactive management will be required. The statistical detection and definite assignment of diver-caused change can be complex, in relation to within-site variability -natural changes.

   d. The use of 'control' or reference sites that are closed to diving, yet have similar community structure and other attributes is useful in terms of understanding source and impact of diving-related damage. However, in North Sulawesi there are significant difficulties associated with this approach (see Methods).

   e. This can also be expensive and a realistic monitoring and management budget needs to be allocated.

f. Some aspects of monitoring and management can be achieved by the dive operators themselves, in association with Park management staff. This is particularly important, not just for diving related impacts, but also for other disturbances that may affect quality of dive sites (e.g. coral predation by crown-of-thorns seastars).

g. Sites that have been badly damaged (i.e. exceeding LAC limits), should elicit reactive management measures, such as temporary site closure to allow for regeneration, and a review of CC limits.

Dive briefings and guidance:

4. A standard audio-visual dive briefing presentation should be developed for use by all operators. The presentation should provide insights into the unique diving experiences of North Sulawesi (currents, walls, fragile corals etc.), and educate divers towards appropriate dive behavior. The presentation need not be long (5 - 10 mins.) or 'heavy', but rather should be informative, 'light' and insightful, providing arriving divers with a sense of awe and wonder, respect and stewardship for the Park. This presentation should, however, be mandatory viewing, with the option for an immediate question / answer session, prior to the signing of the Environmental Awareness Statement. Taken together, these simple steps should improve diver behavior substantially.

5. Because guests staying on island homestays frequently snorkel from the beach without guide oversight, an eye-catching and informative poster should be developed that instructs such snorkelers as to proper coral reef snorkeling behavior – centered upon a “Swim, don’t Stand” theme. This poster should include a map showing channels in the reef that should be used for access to the reef crest during extreme low tides. The poster should include both English and Indonesian text, and should be distributed in sufficient quantity for posting in each homestay room and all dive centers. It should also be distributed, perhaps in laminated form, to catamaran/glass bottom boat and local snorkel charter boat operators.

6. Dive guides should be trained and licensed to operate within Bunaken NP waters, particularly in relation to underwater supervision and harassment. At present, some guides are among the most destructive of all divers in North Sulawesi, while others are exemplary. A standard training course, with a certificate of completion, and

official license to operate within Bunaken and other NP waters may improve the quality of guidance substantially:

- develop training course and education materials;
- develop Diving Code of Behavior;
- certify guides to work in Bunaken NP;
- provide Guides with more power (e.g. capacity to ban divers in relation to bad diving behavior).

7. Regulate numbers of divers per dive guide, based on maximum ratio of four divers to one guide.

   Most Guides appear in favor of these measures, but some are concerned for their jobs if they should offend difficult clients.

Diver and diving related impacts and site condition:

8. Improve diver education programs, including dive briefings and environmental awareness for divers and snorkelers, with dedicated audio-visual presentations (see above).

9. Restrict snorkel boats and snorkelers to waters > 3 m depth (except in emergency situations), where standing by snorkelers cannot occur, and promote the message 'swim don't stand'.

10. Develop improved regulation of diver activities (e.g. restrict total numbers of dive centers and/or divers per Operator, based loosely on the present *status quo*, through permit / license system through Bunaken NP & Local / Provincial Tourism Departments).

11. Implement Operator use-roster at busy sites (e.g. random allocation of days per month to different operators at busiest sites).

12. Improve surveillance and enforcement with ‘In water’ patrols to assess diver behavior, with options for warnings / bans for divers, Guides and / or Operators who consistently breach Diving Code of Behavior. To work, this would require independent impartial surveillance and enforcement.

Boats:

13. Develop improved regulation of boating activities (e.g. restrict numbers of boats and numbers of divers per boat, based loosely on the present *status quo*, through permit / license system through Bunaken NP & Local / Provincial Tourism Departments. License boat skippers to operate within Park waters.

14. Limit boat sizes within Park waters based on tonnage / capacity / length, to minimize potential for impacts re dragging of moorings and the exceeding of CC limits.

15. Develop regulations to effectively manage the trend for foreign (primarily Thailand-based) dive live-aboard boat operators to set up seasonal operations in North Sulawesi during the "low season" in their respective areas of regular operation. These operators should be subject to strict licensing requirements that ensure employment of local guides and ship crew and compliance with all local regulations that North Sulawesi-based tourism operators must abide by.

16. Improve surveillance and enforcement with increased surface patrols for boating breaches of regulations.

Moorings:

17. Review and where necessary upgrade or remove moorings.

18. Remove all very shallow moorings and other moorings that allow boats to strike the reef crest under some current directions.

19. Restrict boats to one per mooring.

20. Provide better education for boat skippers in regard to correct mooring and driving safety procedures.

21. Provide more stringent surveillance and policing of mooring / anchoring offences.

Homestays:

22. All island-based accommodation providers should develop appropriate sewage disposal systems, to minimize potential for seepage / leaching of nutrient-rich wastes into coastal waters.

23. All accommodation providers within Bunaken NP should be licensed by the Bunaken NP Authority and / or local and provincial governments, with the licenses subject to review, restriction and ultimate revocation if significant breaches of Park and / or government regulations occur.

24. A maximum number of bed / guest numbers should be established for all accommodation providers within Bunaken NP, and regulated by the appropriate Park and / or local and provincial government authorities. These may be set initially at present levels, with opportunities for review.

25. Any further construction of accommodation should be subject to strict environmental codes, particularly in relation to:
    - vegetation clearance and soil erosion;
    - mangrove / seagrass disturbance - clearance. These are important natural filters and wildlife areas, including nursery grounds for commercially important species. No disturbance should occur unless specifically permitted and supervised by relevant authorities (e.g. Bunaken NP Authority, local and provincial governments);
    - sewage treatment - as noted above, all island resorts should upgrade to environmentally friendly systems approved by the Bunaken NP Authority. Systems should be set back as far as practicable from the coast;
    - disturbance and changes to shoreline, coastal vegetation and shallow reef communities in relation to construction.

26. Organic wastes should be composted or used as animal feed (as already occurs). Inorganic and other wastes should be transported to Manado for suitable disposal. However, at present, a major part of the inorganic solid wastes present on the Bunaken NP islands arrive as floating debris from Manado, such that there is a far greater waste disposal issue for the city itself.

27. Access to accommodation should not further compromise coastal ecosystems, such that existing boat channels should continue to be used as the main access points. These channels should not be significantly dredged below their present depths and **no further channels should be constructed**; both the Pangalisang and Liang Beach areas of Bunaken Island and Siladen Island already have a number of channels that provide access to these areas. Park authorities may want to consider installation of

prominent channel markers for those channels which already exist. In the case of potential homestay expansion to other islands, careful construction of a limited number of piling-style jetties is ecologically highly preferable over further channel construction, which can negatively impact corals and seagrass beds by altering hydrology and especially reef flat water levels at low tide.

Domestic Tourism Arrivals:

28. Although largely outside of the scope of this study, the recent tremendous increase in domestic tourist arrivals to Bunaken National Park (up nearly 78% from 2002, and accounting for ~75% of overall arrivals) should be carefully considered by park and tourism authorities. As these beach-going day visitors increasingly turn to snorkeling as a recreational activity, the potential for further reef degradation will increase markedly. Authorities may want to consider an increase in domestic user fees in order to both limit expansion of this market and provide the additional financial resources that will be necessary to effectively manage impacts from domestic day-trippers.

Non-tourism Impacts:

29. Improve surveillance and enforcement of destructive fishing - particularly in more isolated / remote areas. Consideration may be given to licensing tourist operators as honorary rangers, following suitable training, and with limited powers to police activities within the Park.

30. Maintain vigilance / monitoring and continue community-based (NSWA) control programs of crown-of-thorns seastar outbreaks as required.

31. Work with relevant local and provincial government authorities to develop better management of solids and other wastes in and around Manado, including effective implementation of integrated coastal and river catchment management.

Licensing and Legislation:

32. Develop comprehensive legislation that clearly and transparently establishes licensing procedures for dive centers, homestays, marine tourism boats, skippers, and dive guides. While a number of licensing systems already exist (e.g., the SIOPSUS license for marine tourism boats), many tourism operators expressed significant confusion over these systems, and feel that they are rarely applied evenly to all operators with respect to requirements and associated fees.

33. Specific licensing and legislation recommendations are detailed in the above list and include:
    - number of dive centers and/or boats licensed to operate in specific areas (eg., Bunaken National Park, Lembeh Strait, etc),
    - dive guide and skipper certification,
    - ratio of dive guides/divers (1:4 minimum),
    - number of divers per operator and/or per boat,
    - boat size/tonnage,
    - number of boats per mooring,
    - minimum requirements for homestay septic tank systems (for both present and planned homestays),
    - strict environmental building codes for any new homestays,
    - total number of beds in homestays within Bunaken National Park, and
    - requirements for foreign live-aboard vessel operation in North Sulawesi.

Ringkasan Eksekutif

Laporan ini membahas penilaian mengenai tingkat penggunaan dan dampak wisata bahari di masa kini dengan fokus pada rekreasi selam (recreational Scuba Diving) di Taman Nasional Bunaken, Sulawesi Utara dan terumbu karang di sekitarnya, termasuk Selat Lembeh, Bangka, dan kepulauan Gangga. Laporan ini juga memberi beberapa rekomendasi kebijakan yang bertujuan untuk meminimalkan dampak dan dengan sendirinya menjaga kelestarian ekologi dan sosial ekonomi wisata bahari di Sulawesi Utara.

***Kawasan Selam**:*
Saat ini, Sulawesi Utara memiliki kira-kira 120 kawasan selam yang tersebar di lima lokasi utama, yaitu Kepulauan Taman Nasional Bunaken, Selat Lembeh, tanah daratan Sulawesi Utara ke Utara dan Selatan Manado, Kepulauan Gangga-Bangka-Talise, dan bagian Selatan daratan Taman Nasional Bunaken, ditambah dengan lebih banyak lagi kawasan yang ditemukan secara reguler. Selat Lembeh dan Kepulauan Taman Nasional Bunaken menjadi kawasan selam yang paling banyak dikunjungi (masing 34% dan 27%), diiikuti kemudian dengan daratan Manado (termasuk Tanjung Pisok di dalam Taman Nasional Bunaken mencapai 19%) dan Kepulauan Gangga-Bangka-Talise (17%).

***Jumlah Penyelam**:*
Saat ini, data biaya masuk ke Taman Nasional Bunaken menunjukkan setidaknya 9000 penyelam berkunjung ke kawasan terumbu karang di Sulawesi Utara setiap tahunnya. Jumlah ini dilayani oleh 40 operator selam yang menyediakan layanan panduan selam dengan rasio satu pemandu untuk empat penyelam untuk total penyelam yang mencapai 11.250 orang setiap tahunnya. Rata-rata, setiap penyelam melakukan 15 kali penyelaman (berkisar dari 4 sampai lebih dari 30 penyelaman) selama berada di kawasan selam atau total antara 110.000 dan 225.000 penyelaman setiap tahunnya.

Kegiatan Penyelaman:
Jika kegiatan selam yang dilakukan saat ini menyebar secara merata di 120 kawasan, maka jumlah penyelam yang menggunakan kawasan tersebut akan kurang dari 2000 untuk setiap kawasan per tahunnya. Hal ini sesuai dengan batas kapasitas dukung yang

merekomendasikan antara 4000-6000 penyelam setiap tahunnya untuk kawasan terumbu karang lainnya.

Namun, pada saat ini (dan kemungkinan juga di masa mendatang), kegiatan di 120 kawasan tersebut tidak tersebar secara merata. Dengan alasan aksesibilitas, logistik-ekonomi, keselamatan, dan "kelayakan selam" (arus yang dapat dikendalikan, kecocokan untuk tempat pelatihan, daya tarik wisata/harapan, dll), maka pada 30% kawasan selam dilakukan lebih banyak kegiatan selam. Kepulauan Taman Nasional Bunaken merupakan kawasan selam yang jumlah kunjungannya paling tidak seimbang di antara kawasan-kawasan selam lainnya. Kawasan Bunaken merupakan kawasan yang paling sering dikunjungi atau sama dengan 40% dari seluruh jumlah kunjungan ke kawasan selam. Bagi kebanyakan kawasan selam ini, kegiatan selam yang dilakukan para operator selam terjadi setiap harinya dengan tiga sampai enam perahu yang beroperasi dalam waktu bersamaan pada saat-saat sibuk.

Kawasan-kawasan selam yang paling sering dikunjungi menampung lebih dari 6000 penyelam setiap tahunnya. Hal ini melebihi rekomendasi kapasitas daya dukung dari tingkat batas kerusakan terumbu karang minimal. Sedangkan untuk hampir semua kawasan selam lainnya, jumlah penyelaman dilakukan jauh di bawah batas ini.

Jumlah maksimum penyelam yang dapat ditampung di kurang lebih 40 resor selam, tempat pemondokan, dan delapan perahu selam di Sulawesi Utara, hanya kira-kira 1000 orang di mana 380 diantaranya bisa menginap di pemondokan bergaya cottage di kepulauan yang terdapat di dalam kawasan Taman Nasional Bunaken.

Saat ini jumlah batas maksimum penyelam jarang atau bahkan tidak pernah tercapai, karena masing-masing resor selam memiliki siklus titik puncak yang berbeda. Dengan semakin berkembangnya wisata selam, batas maksimum tersebut dapat lebih sering tercapai. Jika jumlah maksimum penyelam tadi dapat dipertahankan selama setahun penuh, dan seandainya setiap penyelam tinggal selama dua minggu, maka jumlah total penyelam dapat mencapai 25.000 setiap tahunnya. ***Berdasarkan pengalaman internasional dan kecenderungan menyelam saat ini, jumlah batas yang besar untuk kapasitas dukung wisata bahari secara keseluruhan di Sulawesi Utara sudah terjangkau.***

Interaksi Penyelam:

Sebanyak 2364 interaksi antara penyelam dan dasar laut telah tercatat selama 38 jam survai terhadap 176 penyelam dengan lebih dari 60 interaksi untuk setiap penyelam setiap jamnya. Sebagian besar interaksi dilakukan oleh penyelam yang melakukan rekreasi selam sehingga lebih dari setengah jumlah penyelam yang sedang diteliti merupakan penyelam rekreasi. Angka tertinggi interaksi penyelam adalah menyentuh (tidak termasuk berdiri di atas) karang (27 sentuhan setiap penyelam setiap jamnya). Hal ini diikuti dengan berkurangnya frekuensi:

- Penyelam yang berdiam diri (22 interaksi per penyelam hr^{-1});
- Berpegangan, sebagian besar dilakukan pada akhir penyelaman saat terjadi arus kuat, dan oleh fotografer (13 interaksi per penyelam hr^{-1});
- Gangguan endapan (10 interaksi hr^{-1});
- Gangguan yang disengaja (misalnya terhadap fauna yang tidak jelas, ikan anemone, kura-kura, dsb., 8 interaksi hr^{-1}); dan
- Gelembung yang mengenai gorgon dan fauna dinding karang lainnya (6 interaksi hr^{-1}).

Kerusakan organisme benthic jauh berkurang (dua kerusakan per penyelam hr^{-1}), dan hanya tercatat dua kerusakan yang disengaja. ***Namun demikian, gangguan dan perusakan dengan sekitar 10 interaksi gabungan per penyelam perjam menjadi bentuk interaksi yang negatif, khususnya bila mempertimbangkan kegiatan selam secara keseluruhan di Sulawesi Utara (11.000 penyelam setiap tahunnya melakukan kegiatan selam sebanyak 100.000 kali***).

Ada banyak jumlah dan jenis interaksi antar para penyelam dan kelompok selam yang berbeda, dan antar operator selam sendiri. Bahkan, pada satu operator selam, walau memiliki kualitas pengarahan dan prosedur petunjuk selam yang sama tinggi, para kelompok selam tersebut tetap memiliki sikap yang berbeda.

Perbedaan juga terdapat pada “kualitas” pemandu selam saat memberi pengarahan selam, pengawasan bawah laut / petunjuk menyelam, dan tingkat gangguan. Bahkan beberapa pemandu selam justru menjadi pelanggar yang paling parah dalam hal gangguan yaitu dengan mengambil dan merusak organisme laut seperti kuda laut pygmy dan “makhluk” lainnya untuk tamu mereka. Tindakan ini memperoleh dukungan para operator selam karena mereka beranggapan bahwa tamu telah membayar mahal untuk melihat dan

memotret hewan-hewan langka tersebut sehingga operator dan pemandu merasa wajib untuk memenuhi tuntutan para tamu tersebut.

Kualitas Pengarahan Selam:

Suatu penilaian telah dilakukan terhadap cara enam operator selam (semua anggota Asosiasi Olah raga Air Sulawesi Utara/NSWA) memberi pengarahan selam pada saat tamu datang di kawasan selam dan / atau sebelum menyelam. Ternyata hasil yang diperoleh menunjukkan adanya perbedaan kualitas pengarahan selam yang diberikan pemandu kepada para tamu saat kedatangan dan yang diberikan oleh pemandu saat sebelum menyelam. ***Walau pengarahan yang diberikan saat kedatangan maupun sebelum penyelaman berkisar dari yang hanya sepintas sampai yang sangat mendetail, namun masih terdapat ruang untuk penyempurnaan seperti yang akan dirinci kemudian***.

Kapal untuk para penyelam*:*

Tercatat tiga insiden perahu menabrak karang dan melempar sauh di karang yang dangkal. Walau hanya terjadi beberapa menit kerusakan yang terjadi sangat besar bila dibandingkan dengan yang dapat dilakukan ratusan penyelam dalam beberapa jam. ***Pengendalian atas pembuangan sauh dan penggunaan tambat yang lebih tepat akan sangat mengurangi kerusakan fisik di kawasan selam.***

Ada banyak ragam kualitas pengendalian perahu dan kontrol terhadap kapal untuk penyelam berkaitan dengan hal-hal keselamatan yang berhubungan dengan tugas penanganan para penyelam, khususnya pada saat awal dan akhir menyelam. Beberapa pengendali perahu menunjukkan tingkat ketrampilan dan kepedulian yang tinggi, meskipun banyak yang menempatkan tamu mereka dan tamu operator lainnya dalam bahaya, khususnya ketika beberapa operator melakukan selam lepas secara bersamaan (misalnya di Lekuan II, III, Muka Kampung, Pangalingan). ***Banyak kapal untuk penyelam yang bergerak terlalu cepat di dekat para penyelam yang sedang berada di permukaan air. Hal ini sangat membahayakan karena dapat menyebabkan luka bahkan kematian.***

Kondisi terumbu karang dan dampak penyelaman:

Wawancara dengan operator selam dan pemandu selam dari 9 operator selam (semua anggota NSWA) menyatakan bahwa kerusakan besar akibat penyelam terjadi di kawasan selam yang banyak dikunjungi seperti kerusakan permukaan karang akibat jangkar,

tertabrak perahu dan penyelam yang berdiri di atas terumbu karang. Kerusakan juga terjadi pada dinding karang yang dipenuhi fauna, terutama gorgonian fan corals, mulai dari kerusakan yang disengaja maupun tidak, dan kemungkinan akibat dampak gelembung oksigen penyelam secara berkala. Keanekaragaman jumlah, dan ukuran ikan juga mulai berkurang pada akhir 1980-an sampai awal 1990-an yang mungkin diakibatkan oleh tekanan yang besar dalam menangkap ikan dan praktik penangkapan ikan yang merusak dengan menggunakan bahan peledak, jarring, dan racun. Hal ini kemudian diikuti dengan pemulihan yang berarti, dan mungkin semakin stabilnya jumlah spesies ikan karang dibanding hiu karang sejak pertengahan 1990-an yang kemungkinan besar disebabkan oleh adanya system pengelolaan yang cenderung membaik. Ada persepsi yang konsisten antar para operator selam yang sudah lama dan pemandu selam yang menyebutkan bahwa kawasan selam yang paling banyak dikunjungi telah menurun dalam hal lapisan karang dan ikan serta kehidupan invertebratanya yang kemungkinan besar diakibatkan oleh pemanfaatan yang berlebihan oleh para penyelam.

Data kuantitatif dari empat kawasan yang paling sering diselami di Taman Nasional Bunaken mendukung cerita anekdot mengenai kerusakan dengan ***rata-rata tingkat puing-puing batu karang mati yang tinggi dan sangat tingginya jumlah batu karang yang rusak dan pecah (1000 batu karang yang rusak dan pecah untuk setiap kawasan). Hal ini memang konsisten dengan dampak tingkat tinggi yang berhubungan dengan kegiatan selam***.

Keanekaragaman Spesies dan Jumlah Karang yang Rusak:

Keanekaragaman spesies pecahan tersebut (mewakili sekitar 200 spesies batu karang secara keseluruhan) dan kepadatan 'coraliths' (koloni batu karang yang hidup bebas dengan jaringan hidup di semua sisinya akibat sering berputar balik) adalah yang paling diketahui penulis. Spesies yang menunjukkan dampak paling besar (menghasilkan paling banyak pecahan dan batu karang rusak yang menempel) menunjukkan ragam pilihan jenis batu karang yang biasanya bercabang rapuh dan berbentuk daun yang sedang tumbuh. Spesies daun seperti *Mycedium mancaoi* dan *Montipora stellata* dan cabang *Acropora brueggmanni* adalah yang paling rentan dengan tingkat kerusakan yang tinggi, sementara daya cakupnya rendah (< 1% untuk setiap spesies). Batang poritids *Porites nigrescens* dan *P. cylindrica* juga sangat rentan dengan daya cakup yang masih lebih tinggi (2 - 3%). Spesies lainnya yang rentan adalah batang *Montipora cactus*, *Montipora vietnamensis*, dan ahermatypic dendrophyllid *Tubastraea coccinea*. *T. coccinae* tampak jelas di dinding karang dan menjalar, dan dampak yang tinggi terhadap spesies ini adalah

abrasi yang terus menerus oleh para penyelam dan gelembung yang mengenai dinding karang. Sebaliknya, spesies lainnya memiliki daya cakup yang tinggi dan tingkat kerusakan yang rendah, termasuk koloni *Porites* spp dalam jumlah besar dan bunga karang.

Akomodasi pemondokan di dalam Taman Nasional Bunaken:
Duapuluh penyedia jasa pemondokan di kepulauan kawasan Taman Nasional Bunaken diwawancarai sehubungan dengan pengelolaan lingkungan. 18 dari 20 pemondokan memiliki sistem pembuangan air dan hanya satu yang memiliki sistem yang modern dan ramah lingkungan. ***Banyak unit pembuangan yang dekat dengan pantai dengan bahaya yang menyertainya seperti perembesan/pelepasan air (eutrophication)***. Sistem pembuangan terdekat di empat pemondokan berjark hanya 10 meter dari pantai, empat lagi berjarak 20 meter dari pantai, 8 lainnya berjarak 50 meter, dan 2 sisanya berjarak 100 meter dari pantai.

Hampir semua pemondokan (14) telah melakukan usaha yang cukup berarti dalam kaitannya untuk mengurangi dampak fisik terhadap terumbu karang yang ada di sekelilingnya, mengangkut tamu, mengangkut dan menurunkan barang-barang persediaan dan mengakses kawasan selam melalui saluran di terumbu karang sehingga mengurangi kerusakan terumbu dan batu karang menjadi lebih parah lagi. Tujuhbelas pemondokan menyebutkan bahwa mereka memberikan instruksi kepada para wisatawan mengenai cara menyelam yang benar dan berjalan di terumbu karang yang tepat dan akses ke terumbu karang melalui saluran yang telah ditentukan (16 pemondokan).

Dampak terhadap kelestarian wisata bahari:
Pengembangan wisata bahari dan penerapan batas pelestarian (melalui Kapasitas Dukung (CC) dan/atau Batas Toleransi Perubahan – LAC) sangat tergantung pada status/kondisi lingkungan laut. Dampak yang berpengaruh pada kualitas lingkungan laut juga akan berdampak pada wisata bahari dan kelestariannya. Dampak-dampak tersebut termasuk yang merupakan hasil langsung dari pariwisata itu sendiri, dan yang berdiri sendiri atau tidak berhubungan langsung dengan pariwisata namun memliliki efek yang mengganggu.

Dampak yang berhubungan dengan pariwisata **termasuk**:
- kerusakan pada penyelam;
- kerusakan pada sauh;

- kerusakan akibat tabrakan perahu dan gangguan pada baling-baling yang menyebabkan pendangkalan dasar laut, dan perahu cepat yang merusak batu karang dan para penyelam;
- polusi akibat limbah padat;
- polusi akibat pembuangan kotoran (eutrophication);
- polusi akibat endapan hasil pembangunan penginapan;
- Tekanan akibat penangkapan ikan yang terus meningkat untuk menyuplai para wisatawan.

Dampak yang tidak berhubungan dengan pariwisata yang dapat mempengaruhi kondisi lingkungan laut dan wisata baharipada akhirnya, adalah:

- Pengembangan kawasan pesisir yang tidak berhubungan dengan pariwisata;
- Sungai yang banjir/meluap;
- Ombak badai;
- Penangkapan ikan yang berlebihan dan destruktif, seperti menggunakan bahan peledak dan racun;
- Penangkapan ikan dengan menggunakan racun untuk memenuhi kebutuhan perdagangan akuarium hias;
- Polusi dari Manado;
- Penjarahan batu karang oleh bintang laut bermahkota atau moluska *Drupella*
- Pemutihan batu karang akibat fluktuasi suhu atau tekanan lainnya.

Beberapa dampak di atas tadi dapat menjadi tanggung jawab pengelola setempat sementara yang lainnya tidak. Walaupun demikian, semua dampak tadi berkenaan dengan batas CC dan LAC.

Dari sudut pandang ekologi, social ekonomi, dan estetis, CC wisata bahari, dalam hal ini jumlah total penyelam yang dapat ditampung sebuah kawasan, berkaitan langsung dengan tersedianya lokasi selam yang berkualitas tinggi; kawasan yang keanekaragaman spesiesnya tinggi dan jumlah batu karang, ikan, dan organisme lainnya yang banyak dengan sedikit dampak manusia. Dengan jumlah kawasan yang terbatas, kawasan yang rusak sampai yang sering dikunjungi maka perhatian akan semakin terfokus pada sisa kawasan yang masih berkualitas tinggi. Dalam hal ini, ***pentingnya menjaga kawasan dalam kondisi yang baik tidak dapat ditekankan secara berlebihan.***

Untuk menangani dampak ini, model yang fleksibel yang menggabungkan CC dan LAC sangat disarankan. ***Jumlah maksimum penyelam/pengunjung secara keseluruhan harus diatur*** dan dibenahi melalui monitoring dengan mengubah peraturan untuk mengatasi dampak-dampak yang berhubungan maupun tidak dengan penyelaman sehingga setiap kawasan dapat pulih dan terbebas dari gangguan.

Pada praktiknya, kawasan-kawasan yang telah sangat rusak biasanya tidak terlalu menarik bagi para penyelam sehingga membutuhkan fasilitasi dan bantuan yang reaktif dari pengelola seperti misalnya menutup kawasan untuk sementara waktu.

Penilaian awal terhadap sebuah kawasan dan monitoring secara terus menerus sangatlah penting untuk memahami kondisi kawasan sehingga tingkat CC dan LAC dapat diatur secara realistis dan prakarsa reaktif manajemen secara dapat dimulai.

Rekomendasi Pengelolaan Wisata Bahari

Langkah pencegahan untuk pembangunan dan pengembangan wisata bahari sangatlah dibutuhkan mengingat tingginya angka interaksi antar penyelam, tingkat kerusakan di kawasan yang paling sering dikunjungi, dan tingkat ketidakpastian dalam hubungannya dengan tekanan kegiatan selam saat ini. Batas Kapasitas Dukung kurang dari 6000 penyelam untuk satu kawasan per tahunnya yang diusulkan di sini adalah untuk perbandingan semata sebagai angka sementara sampai hasil monitoring kawasan tertentu dapat memberikan angka yang relevan untuk Sulawesi Utara. Pada akhirnya, akan menjadi penting untuk menetapkan tingkat kerusakan yang tidak dapat diterima (misalnya perbandingan koloni yang rusak atau angka rata-rata cabang yang rusak per koloni yang melebihi seperti yang terdapat pada kawasan yang dikendalikan, sebesar 10%). Angka ini dapat menggambarkan tingkat pemicu untuk dilakukannya penyelidikan, dibanding tingkat pemenuhan yang kaku. Keuntungan pendekatan ini adalah menghindari keharusan untuk menulis jumlah mutlak dan kriteria pemicu dapat diperbarui untuk mencerminkan faktor-faktor yang tidak berhubungan seperti variasi iklim yang mempengaruhi pengendalian.

Dari perspektif estetis (sosial / kenyamanan) mengendalikan jumlah penyelam guna menjaga nilai kenyamanan dapat didasarkan pada jumlah rata-rata penyelam yang beralih dari kesenangan untuk menyelam. Bagi banyak penyelam, hal ini terjadi jika penyelam dari satu atau lebih operator selam lainnya menyelam di kawasan yang sama secara

bersamaan. Anggota NSWA telah membuat peraturan sendiri di tiap kawasan secara sendiri-sendiri yang nantinya akan diatur secara lebih formal. Ini juga nantinya akan membantu jumlah maksimum penyelam pada kawasan-kawasan yang paling sibuk.

***Membuka Kawasan Selam - Penilaian dan Monitoring**:*

1. Saat akan membuka kawasan selam baru, harap diperhatikan hal-hal seperti penilaian awal, monitoring berkala, dan pembatasan penyelaman:
   a. Batas pemanfaatan penyelaman bagi individu harus berdasarkan penilaian awal terhadap kawasan dan evaluasi terhadap kepekaan khusus di kawasan tersebut yang berhubungan dengan kerusakan akibat penyelaman (misalnya jenis/bentuk batu karang , dlsb).
   b. Kegiatan selam saat ini bisa dibatasi melalui pemberian izin kepada para operator yang menggunakan taman nasional. Izin harus memuat daftar kawasan/terumbu karang yang dapat dikunjungi operator.
   c. Tindakan pengawasan dan pengaturan dapat ditingkatkan dalam kaitannya dengan melebihi batas CC secara sengaja oleh operator selam.
   d. Rencana pemintakatan taman nasional merupakan cara yang berguna untuk mengendalikan/mengatur pembukaan kawasan selam lainnya.

2. Protokol penilaian dan monitoring kawasan yang standar dan sederhana harus dikembangkan dan dilaksanakan berdasarkan Protokol Jaringan Monitoring Terumbu Karang Global dan metode bidang yang digunakan selama studi berlangsung. Variabel yang harus dimonitor adalah ternasuk tingkat kerusakan batu karang (misalnya jumlah pecahan, jumlah dan perbandingan koloni yang rusak).

3. Guna menjaga kawasan dalam kondisi yang baik, dibutuhkan kerjasama tingkat tinggi antar operator selam (seperti yang telah dilakukan NSWA) dalam kaitannya dengan menentukan LAC yang realistis.
   1. LAC dapat diukur dari segi kerusakan batu karang (misalnya jumlah pecahan, jumlah dan perbandingan koloniyang rusak) dan daya cakup batu karang yang utuh/rusak/mati, dan puing-puingnya, keanekaragaman dan jumlah ikan (dan petunjuk lainnya), dan dengan cara melakukan inventarisasi kawasan secara spesifik dan detail.

   2. Kriteria keputusan pengelolaan reaktif perlu dikembangkan sehubungan dengan penambahan batas LAC.

3. Berkenaan dengan LAC, kewaspadaan/monitoring dan pengelolaan reaktif sangat dibutuhkan. Deteksi statistik dan penugasan yang definitive untuk mengubah hal-hal yang disebabkan penyelam dapat menjadi sangat kompleks bila dikaitkan dengan perubahan variasi alam di dalam kawasan.

4. Penggunaan “kendali” atau referensi kawasan yang ditutup bagi penyelaman, namun memiliki struktur komunitas dan sifat-sifat lainnya yang sama akan berguna untuk memahami sumber dan dampak kerusakan yang berhubungan dengan penyelaman. Namun, di Sulawesi Utara ada kesulitan-kesulitan yang signifikan dengan pendekatan seperti ini (lihat metode).

5. Hal ini bisa memakan biaya, sehingga perlu melaksanakan pemantauan serta pengelolaan anggaran yang realistis

6. Beberapa aspek monitoring dan manajemen dapat dicapai oleh operator selam bekerjasama dengan staf manajemen taman. Hal ini menjadi penting bukan hanya untuk dampak yang berhubungan dengan selam, tapi juga untuk gangguan-gangguan lainnya yang dapat mempengaruhi kualitas kawasan selam (penjarahan batu karang akibat bintang laut bermahkota).

7. Kawasan yang sudah rusak parah (melebihi batas LAC) harus mendapat tindakan manajemen reaktif seperti penutupan kawasan untuk sementara waktu guna regenerasi dan meninjau kembali Batas CC.

Pengarahan dan Petunjuk Menyelam

4. Presentasi pengarahan menggunakan alat audio-visual standar sebaiknya ditingkatkan penggunaannya oleh para operator. Presentasi harus memberikan pengetahuan mengenai pengalaman unik menyelam di Sulawesi Utara (arus, dinding, batu karang yang rapuh, dslb) dan mendidik penyelam cara menyelam yang baik. Presentasi tidak perlu memakan waktu lama (5-10 menit) ataupun “berat” tapi sebaiknya bersifat informative, “ringan” dan mendalam sehingga tamu yang datang akan terpesona dan kagum sekaligus menghormati dan turut menjaga taman. Presentasi ini wajib untuk dihadiri, diikuti dengan sesi Tanya jawab sebelum Pernyataan Kepedulian Lingkungan ditandatangani. Dengan menggabungkan langkah-langkah sederhana ini, maka akan memperbaiki perilaku penyelam secara substansial.

5. Karena banyak tamu yang menginap di pemondokan sering menyelam dari pantai tanpa pengawasan pemandu, poster yang informative dan menarik perhatian sebaiknya ditempel. Poster sebaiknya memberikan petunjuk cara menyelam yang benar di terumbu karang. Fokuskan pada tema “Berenang, Jangan Berdiri!”. Poster ini harus mencantumkan peta yang menunjukkan saluran-saluran karang yang harus dilalui untuk menuju ke puncak terumbu karang selama air surut. Poster sebaiknya dibuat dalam Bahasa Indonesia dan Bahasa Inggris dan disebarkan secukupnya untuk dipasang di kamar-kamar pemondokan dan pusat-pusat penyelaman. Poster juga harus disebarkan dalam bentuk yang sudah dilaminating dan ditempel di kaca kapal dan perahu yang disewa oiperator untuk para penyelam.

6. Pemandu selam harus dilatih dan memiliki izin bekerja dalam kawasan perairan Taman Nasional Bunaken, khususnya dalam hal pengawasan dan gangguan bawah laut. Saat ini, beberapa pemandu selam merupakan penyelam yang sifatnya paling merusak di Sulawesi Utara, sementara yang lain patut dijadikan contoh. Pelatihan standar dengan sertifikat kelulusan dan izin resmi untuk bekerja di Bunaken dan perairan taman nasional lainnya dapat meningkatkan kualitas kepemanduan secara substansial:
   - Mengembangkan kursus pelatihan dan bahan-bahan pendidikan;
   - Mengembangkan Tata Perilaku Menyelam;
   - Memberikan sertifikat kepada para pemandu selam untuk bekerja di Taman Nasional Bunaken;
   - Menyediakan pemandu yang memiliki lebih banyak wewenang (misalnya; mempunyai wewenang untuk mencegah penyelam yang menyelam dengan perilaku buruk).

7. Mengatur jumlah penyelam untuk satu pemandu berdasarkan rasio maksimum 4 penyelam untuk 1 pemandu.

   Kebanyakan pemandu tampaknya setuju dengan perhitungan ini, namun sebagian khawatir dengan pekerjaan mereka jika harus menegur tamu yang susah diatur.

Penyelam dan Dampak yang berhubungan dengan selam dan kondisi kawasan*:*

8. Tingkatkan program pendidikan bagi para penyelam, termasuk pengarahan selam dan kepedulian lingkungan bagi para penyelam dengan menggunakan presentasi (lihat atas)

9. Batasi perahu dan penyelam pada air dengan kedalaman lebih dari 3 meter (kecuali dalam situasi darurat), di mana penyelam tidak mungkin berdiri, dan galakkan pesan "Berenang Jangan Berdiri!"

10. Membuat peraturan yang lebih baik untuk kegiatan penyelaman (misalnya batasi jumlah total pusat selam dan/atau penyelam untuk setiap operator yang melakukannya secara bebas berdasarkan status quo sekarang ini. Ini dapat dilakukan melalui sistem perizinan yang harus diberikan dinas pariwisata propinsi/setempat dan melalui taman nasional Bunaken).

11. Menetapkan jadual daftar nama operator di kawasan-kawasan yang padat (misalnya mengalokasikan hari secara acak dalam sebulan untuk operator yang berbeda di kawasan yang padat).

12. Meningkatkan pengawasan dan menggalakkan "patroli dalam air" untuk memantau perilaku penyelam dengan pilihan memberikan peringatan/larangan bagi penyelam, pemandu dan/atau operator yang secara konsisten melanggar Tata Perilaku Menyelam (Diving Code of Behavior). Supaya berhasil, hal ini membutuhkan pengawasan dan penegakan hukum yang tidak memihak.

Perahu:

13. Membuat peraturan mengenai kegiatan yang menggunakan perahu (misalnya membatasi jumlah perahu dan jumlah penyelam dalam satu perahu yang dilakukan secara bebas berdasarkan status quo sekarang ini, melalui sistem perizinan yang diperoleh dari dinas pariwisata propinsi/setempat dan melalui taman nasional Bunaken. Hanya pengemudi perahu yang memiliki izin bisa beroperasi di perairan taman nasional.

14. Batasi ukuran perahu yang beroperasi di perairan taman nasional berdasarkan berat, kapasitas, panjang guna mengurangi potensi dampak yang mungkin terjadi seperti tambat yang terseret dan melebihi batas CC.

15. Membuat peraturan yang secara efektif dapat mengatur kecenderungan operator perahu selam asing yang secara musiman beroperasi di Sulawesi Utara pada masa teduh (low season) di kawasan mereka biasa beroperasi. Operator asing ini diwajibkan memiliki izin dan mempekerjakan pemandu selam setempat dan awak kapal serta memenuhi peraturan setempat yang harus dipatuhi oleh operator wisata di Sulawesi Utara.

16. Meningkatkan pengawasan dan penegakan hukum dengan cara menggalakkan patroli di laut setempat untuk menindak perahu-perahu yang melanggar peraturan.

Penambatan

17. Mengkaji ulang dan jika perlu, memperbarui atau mengangkat tambat.

18. Memindahkan semua tambat yang sangat dangkal dan tambat-tambat lainnya yang memungkinkan perahu menabrak permukaan batu karang di bawah arus air.

19. Membatasi jumlah perahu pada setiap tambatan.

20. Memberikan pendidikan yang lebih baik bagi pengemudi perahu dalam hal memperbaiki tambatan dan prosedur keselamatan mengemudi.

21. Melakukan pengawasan dan patroli secara lebih ketat terhadap pelanggaran penambatan dan pelemparan sauh.

Penginapan:

22. Para penyedia akomodasi penginapan di pulau harus membangun sistem pembuangan yang baik untuk meminimalkan perembesan air ke perairan pesisir.

23. Semua penyedia jasa penginapan di Taman Nasional Bunaken harus memiliki izin yang dikeluarkan oleh pihak berwenang di Taman Nasioanl Bunaken dan/atau pemda setempat dengan ketentuan izin harus ditinjau kembali, dibatasi, atau pada akhirnya dicabut, jika pelanggaran terhadap taman dan/atau peraturan pemerintah terjadi.

24. Jumlah maksimum tempat tidur yang tersedia atau tamu yang menginap harus ditentukan oleh semua penyedia jasa penginapan di Taman Nasional Bunaken dan

diatur oleh pihak berwenang taman dan/atau pemda setempat. Ini bisa disiapkan pada tahap sekarang dengan kemungkinan untuk ditinjau kembali.

25. Setiap pembangunan penginapan harus mematuhi peraturan-peraturan yang berkenaan dengan lingkungan hidup, terutama yang berhubungan dengan:
    - Pemangkasan tumbuhan dan erosi tanah;
    - Gangguan dan pemangkasan rumput laut dan bakau. Keduanya merupakan filter alam dan kawasan cagar alam, termasuk lahan bibit untuk spesies penting yang diperdagangkan. Tidak boleh ada gangguan apapun kecuali jika memang diizinkan atau diawasi oleh pihak berwenang yang relevan (Manajemen Taman Nasional Bunaken, pemprov, dan pemda);
    - Sistem pembuangan - seperti ditulis di atas, semua pulau harus memperbarui sistem pembuangannya sehingga menjadi ramah lingkungan dengan izin dari pihak berwenang Taman Nasional Bunaken. Sistem tersebut harus diletakkan jauh dari kawasan pesisir;
    - Gangguan dan perubahan garis pesisir, tumbuhan dan karang yang dangkal yang berhubungan dengan pembangunan.

26. Limbah organik harus dijadikan pupuk kompos atau dijadikan makanan hewan (seperti yang sudah berjalan). Limbah anorganik dan jenis lainnya harus diangkut ke Manado untuk dibuang. Akan tetapi, saat ini, sebagian besar limbah padat anorganik yang ada di kepulauan Taman Nasional Bunaken mengapung dalam bentuk serpihan dari Manado sehingga menjadi masalah pembuangan limbah yang besar bagi kota itu sendiri.

27. Akses ke akomodasi penginapan tidak boleh dikompromikan dengan ekosistem pesisir sehingga jalur perahu yang sudah ada harus terus digunakan sebagai titik akses utama. Saluran ini tidak boleh dikeruk lagi di bawah kedalamannya yang sekarang ini ***dan tidak boleh ada saluran baru lagi yang dibangun***. Pantai Pangalisang dan Liang di Pulau Bunaken dan Pulau Siladen sudah memiliki sejumlah saluran yang menjadi akses ke kawasan ini. Pejabat taman bisa mempertimbangkan pemasangan tanda saluran yang jelas untuk saluran-saluran yang telah lama ada. Jika terjadi pengembangan jumlah penginapan ke pulau-pulau lain, lebih baik membangun dermaga bertingkat dalam jumlah terbatas dibanding membuka saluran baru yang dapat berdampak negatif bagi batu karang, rumput laut karena mengubah hidrologi dan terutama air datar karang menjadi surut.

Kedatangan Wisata Domestik:

28. Meski sangat tidak berhubungan dengan studi ini, meningkatnya jumlah kedatangan wisatawan domestik ke Taman Nasional Bunaken (hampir 78% dari tahun 2002, dan total kedatangan yang mencapai 75%) harus ditanggapi dengan hati-hati oleh pejabat taman dan pariwisata. Mengingat pengunjung semakin banyak yang beralih ke menyelam sebagai kegiatan rekreasi, potensi degradasi batu karang akan semakin jelas. Para pejabat dapat mempertimbangkan untuk menaikkan biaya pemakaian domestik guna membatasi perkembangan pasar dan memberikan sumber keuangan tambahan yang akan diperlukan untuk mengelola secara efektif dampak yang diakibatkan oleh pengunjung domestik.

Dampak Yang Tidak berhubungan dengan Pariwisata:

29. Meningkatkan pengawasan dan penegakan hukum atas tindakan penangkapan ikan secara destruktif di kawasan terpencil dan terisolasi. Pertimbangan dapat diberikan untuk para operator wisata sebagai pengawas kehormatan, diikuti dengan pelatihan yang sesuai sampai kegiatan kepolisian di kawasan taman.

30. Berjaga-jaga, tetap waspada/ monitoring dan meneruskan program pengendalian berbasiskan masyarakat (NSWA) atas berkembangnya bintang laut bermahkota sesuai kebutuhan.

31. Bekerjasama dengan pejabat pemprov dan pemda yang relevan untuk mengembangkan pengelolaan sistem pembuangan limbah padat dan lainnya di dalam dan di sekitar Manado, termasuk pelaksanaan pengelolaan pesisir terpadu dan resapan air yang efektif.

Perizinan dan Perundang-undangan*:*

32. Membuat peraturan yang komprehensif yang secara jelas dan transparan mengatur prosedur pemberian izin bagi pusat-pusat selam, penginapan, pengelola perahu wisata, pengemudi perahu, dan pemandu selam. Meskipun sudah banyak sistem perizinan yang ada (misalnya izin SIOPSUS untuk perahu wisata), banyak operator wisata yang merasa bingung dengan sistem-sistem tersebut dan merasa tidak pernah diterapkan secara merata untuk semua operator jika dikaitkan dengan persyaratan dan biaya yang harus dikeluarkan.

33. Rekomendasi perizinan dan peraturan dirinci di atas dan mencakup:
    - Jumlah pusat selam dan/atau perahu yang memiliki izin untuk beroperasi di daerah tertentu (misalnya TN Bunaken, Selat Lembeh, dll);
    - Pemberian sertifikat kepada pemandu dan pengemudi perahu;
    - Rasio pemandu selam/penyelam (maksimum 1:4);
    - Jumlah penyelam untuk setiap operator atau setiap perahu;
    - Ukuran/berat perahu;
    - Jumlah perahu untuk setiap tambatan;
    - Persyaratan minimum untuk sistem pembuangan limbah di penginapan (untuk penginapan yang sudah ada ataupun yang akan dibangun);
    - Peraturan lingkungan yang ketat untuk setiap pembangunan penginapan yang baru;
    - Jumlah total tempat tidur di penginapan yang ada di TN Bunaken;
    - Persyaratan bagi kapal asing yang beroperasi di Sulawesi Utara

1. Introduction

1.1 Background and Study Rationale

Tourism can provide many benefits for the ecologically sustainable development of marine natural resources such as coral reefs, mangroves and seagrass beds, including a sustainable funding source for management. Tourism is generally regarded as a relatively benign form of use in comparison with most other forms of exploitation of marine natural resources (e.g. fisheries), and, when well managed, can provide both tangible and intangible benefits. Tangible benefits include sustainable revenue from user / visitor fees. This has proven successful in several tropical Marine Protected Areas (MPAs), including Australia's Great Barrier Reef and Indonesia's Bunaken National Park (the focus of the present study), where visitor fees generate significant funding for management, and in this latter case, sustainable development assistance for local villages. Tourism can also create substantial foreign revenue for the host nation, at local, provincial and national levels. When well managed, less tangible benefits of tourism include maintenance of biodiversity, ecological structure and function of the tourism area, with significant potential to contribute to fisheries replenishment from tourism 'no take' (replenishment) zones.

However, there are limits to both the ecological and socio-economic sustainability of tourism. As with other forms of use, mass tourism can have significant negative impacts when uncontrolled. Coastal tourism developments, extensive boat and anchor damage and mass diving have adversely affected the natural attributes of tourism attraction on coral reefs in some parts of the world, notably in areas of the Red Sea. This in turn impacts on both the traditional and developing livelihoods of locals and threatens the very tourism market that drove the initial expansion.

Coral reefs, as with other natural ecosystems, have intrinsic (albeit dynamic) levels of sustainable use, for fisheries, tourism or other activities, below which the ecosystem can cope and remain resistant and / or resilient to the use, but above which detrimental changes can occur. This 'Carrying Capacity' concept, introduced to coral reefs in the mid-1980s (Salm 1986a, b), is now well known from the substantial and increasing number of publications on the subject (see e.g. Hawkins and Roberts 1997 and de Meyer and Glass 2002 for reviews).

Previous studies of visitor Carrying Capacity and diver impact on coral reefs have focused on SCUBA divers in the Egyptian Red Sea, the Caribbean Sea and the Great Barrier Reef (e.g. Hawkins and Roberts 1992, 1997, Dixon et al. 1993, Davis and Tisdell 1995, 1996, Harriott et al. 1997, Hawkins et al. 1999, Jameson et al. 1999, Rouphael and Inglis 1997, 2001, 2002). These studies have found that carrying capacity for marine tourism will depend not just on the number of divers, but also on the types of divers, their training - education and guidance, the types of coral growth-forms (e.g. fragile / stout) - community structure, and the types and amount of infrastructure support (Fig. 1). These studies concluded that reefs could cope with more environmentally-educated / aware than 'naïve' divers (Fig. 1a), and that in some cases, the infrastructure associated with marine tourism could cause more damage than the diving itself (Fig. 1b).

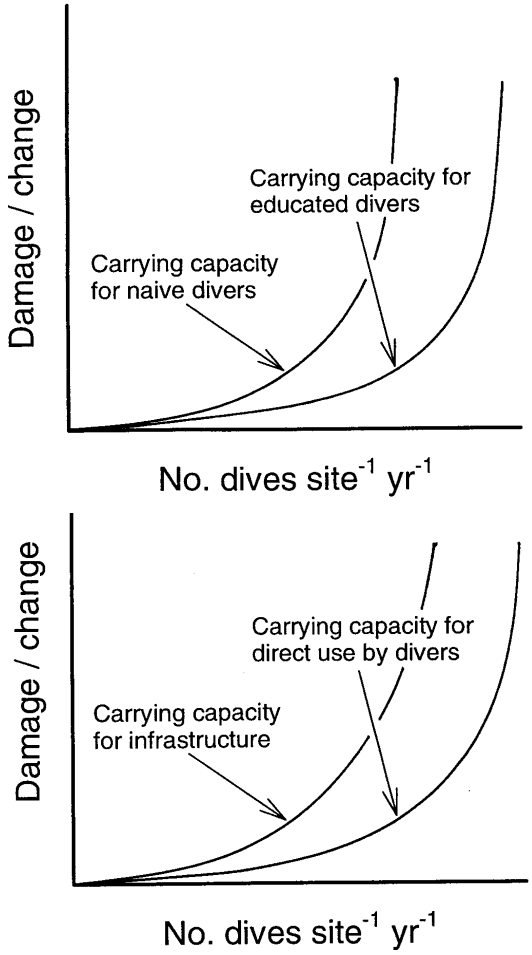

Figure 1: Different hypothesized levels of impact and carrying capacity on reefs for educated and naïve divers (top); and for infrastructure and direct use by divers (from Hawkins and Roberts 1997).

Hawkins and Roberts (1997) recommended that:

"Managers should fix the level of use of coral reefs based on the lowest level of tourist use which causes unacceptable damage".

Diver damage thresholds

In a review of several major studies of diver impact and CC in the Egyptian Red Sea and in Saba and Bonaire in the Caribbean, Hawkins and Roberts (1997) concluded that increases in diver use result in an exponentially increasing level of damage (Fig. 2). These authors found an apparent threshold of 5,000 - 6,000 dives per site per year below which there was little damage but above which damage accumulated more rapidly, and concluded that:

"… for the amount of broken coral on a reef, there does seem to be a biologically meaningful level of carrying capacity which can be measured objectively".

Hawkins and Roberts (1997) recommended that the figure of 5,000 - 6,000 dives per site per year could be used to estimate the overall capacity of a protected area to support recreational diving, depending on the number of dive sites available.

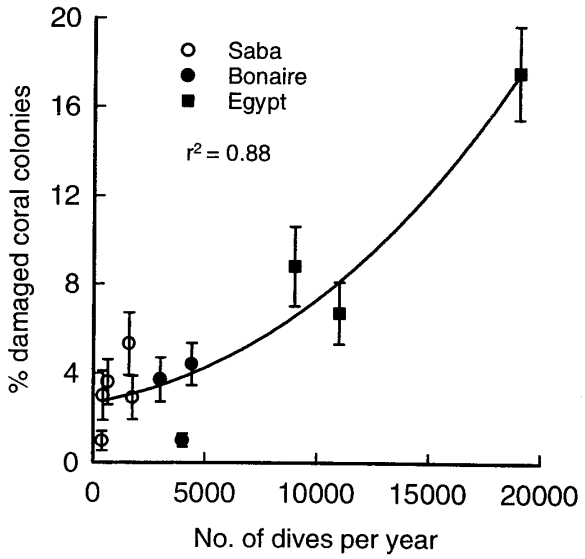

Figure 2: Effects of scuba diving on coral damage levels in three different reef areas (from Hawkins and Roberts 1997).

Similarly, Dixon et al. (1993) suggested a threshold of 4,000 - 6,000 dives per site per year above which diving caused a detrimental shift in the structure of the coral community in Bonaire (Caribbean Sea). Assuming 300 days per year of diving at a particular site, the recommended figures from both Dixon et al. (1993) and Hawkins and Roberts (1997) equate to between 13 and 20 divers per dive site per day.

However, there are many caveats, both implicit and explicit, in such broad recommendations. For example, complex interactions among the:

- type of diving (drift, swim, photography etc.);
- nature of the site (slope angle, current flow, coral community type and other innate characteristics) which vary within and among sites;
- experience / behavior of the divers;
- natural levels of coral breakage;
- concentrated (dive trails) versus dispersed diving activity;
- access to a dive site – reef walking, snorkeling or from a boat;
- whether the dive boat is using a mooring or is anchoring; and
- size of the dive site

all of which can affect Carrying Capacity (CC), and are important considerations in assigning numbers of divers per site. Thus, setting numerical limits on the number of divers allowed on a site (or indeed in a larger dive area) is unlikely to be effective on its own, if introduced as the sole management strategy.

Furthermore, extensive studies of the ecological and social consequences of different levels and patterns of use have been unable to demonstrate a predictable relation between use level and impacts (Prosser 1986, Oliver 1995, Rouphael and Inglis 2002). Some recent studies of diver impacts on reefs have disputed the cumulative diver damage model (e.g. see Rouphael and Inglis 2002). These studies suggested that most site damage occurs with the opening of new dive sites, rather than with increasing use, and proposed that it is not the total number of divers that are the key factor.

Thus, caution is required in employing the CC approach, as different sites are likely to have different capacities, as outlined above, and a fine scale 'site by site' approach is likely to prove most appropriate, particularly in complex reef areas with a range of habitats and dive conditions. In this regard, another concept, the 'Limits of Acceptable Change' (LAC, Stankey et al. 1985, Oliver 1995), has been developed. This is another

interesting concept in theory - where a management agency determines what levels of diver-, visitor- or infrastructure-caused change or damage is acceptable (e.g. decline in coral cover of 5 %). Compliance monitoring and reactive management then aim to maintain a particular tourism site within those levels.

The LAC approach is designed to address some of the perceived problems with the CC approach (Rouphael and Inglis 2002, A. Rouphael, pers. comm.):

- The CC approach suggest that damage to reefs accumulates more rapidly once a certain number of divers / visitors or level of infrastructure is exceeded (see slope of graph in Fig. 2 above), and that damage remains low below these 'CC' levels. However, damage may accumulate rapidly once sites are first opened to divers, rather than cumulatively with increasing use.

- Difficulties can arise in deriving accurate numerical values for visitor numbers, because of differences in reef attributes and diver behavior. Reefs and sites within reefs differ in their resistance and / or resilience to physical impact - typically because the percent cover of fragile coral growth forms differs markedly even at relatively small spatial scales.

- Even when applying the CC approach, monitoring of the sites is necessary to ensure the level of diving is not impacting the corals. If damage does accumulate rapidly once sites are opened, then management agencies need to establish effective monitoring and reactive management programs prior to the opening of new dive sites.

The LAC approach, in turn, requires:

a) Definition of what is acceptable (e.g. damage must not exceed the natural range of coral damage or, damage shall not exceed 10% of natural damage levels. Practitioners of CC must also define this, having set CC estimates based on some acceptable / unacceptable ecological condition (e.g. see quote above from Hawkins and Roberts 1997);

b) Clear identification and specification of monitoring methods, and

c) Clear statement of decision criteria and management actions if / when the LAC criteria are exceeded (Oliver 1995 provides a workable example).

Proponents of this approach claim it works even when the management agency is unsure of what factors / impacts are causing damage at the site - it simply means that the management agency must identify the source(s) of impact and stop or control the source of impact. Clearly divers are not the only source of physical damage at sites in many reef areas. Therefore, setting numerical limits on the number of divers per site may be unlikely to stop damage.

However, the LAC approach can also prove difficult to implement in practice. In order to set LAC, it is necessary to define the 'normal' condition of the system, and how this changes through time in relation to various disturbances, both 'natural' (eg. coral bleaching, storms etc.) and human-induced. This has been attempted through the establishment and monitoring of 'control' or scientific reference sites with similar community structure and environmental conditions to the dive sites of interest.

It is also necessary to define the entire scope of the system being managed, and to determine whether it should be managed from an 'ecocentric' or 'anthropocentric' perspective (Oliver 1995). As Oliver (1995) notes:

"Having determined (or guessed) what the normal 'acceptable' state is and how it might be defined in quantitative terms, it is still necessary to determine just what level of change is unacceptable. Here again, our ignorance of how complex ecosystems function, and the lack of good long-term quantitative data on the response of such systems to different levels of disturbance makes it very difficult to come up with any scientifically based limit of acceptable change".

Furthermore, natural impacts may cause changes in condition well beyond those deemed as 'acceptable', irrespective of human impacts, or indeed the best reactive efforts of the management agency.

The LAC concept has not gained widespread acceptance in natural resources management to date, primarily because of the difficulties outlined above, notably problems in defining and measuring unacceptable changes in complex and dynamic ecosystems (Oliver 1995). Selection of a measurable variable or set of variables that is

the best indicator of ecosystem 'health' or integrity is not a trivial matter. In most cases there are only a few variables that can be accurately *and* economically measured. Often the relations among these variables and ecosystem 'health' are speculative. In Australia's Great Barrier Reef Marine Park for example, abundances of fish, corals and macro-algae are the principal variables for assessment and monitoring, but their usefulness as indicators of ecosystem integrity has not, at least to some observers, been adequately demonstrated (Oliver 1995). To most observers however, these variables do represent useful, tractable indicators of reef condition, and now are widely used globally (e.g. Wilkinson 1998, 2000, 2002).

In any case, monitoring remains a highly useful tool in understanding site condition, and initiating reactive management responses, and the LAC concept has some applicability (Oliver 1995, Rouphael and Inglis 2002), providing it differentiates the *manageable* impacts, such as diving, from the *unmanageable* impacts.

In this regard, a flexible approach founded in the Carrying Capacity concept (i.e. setting overall limits to use of a dive area and specific dive sites) that also incorporates the LAC concept *as far as is practicable*, is likely to prove most effective. This is particularly so in tropical developing nations where capacity for regular monitoring and reactive management may not be sufficient to fully satisfy the requirements of LAC. In this approach it is most important that CC limits are set at optimum levels, because if CC is too low the diving tourism industry may be restricted unnecessarily, thereby limiting a legitimate industry.

With a flexible model incorporating both CC and LAC, overall maximums for diver / visitor numbers and infrastructure can be regulated and fine-tuned, as far as practicable, through monitoring of LAC, with amendments to regulation to allow individual sites to recover from disturbances (both diving and non-diving related). In practice, sites that have been badly damaged usually become less attractive to divers, facilitating / assisting reactive management measures such as temporary site closure.

Coral community structure and susceptibility to damage

Different reef habitats may support different coral species, forming different coral assemblages and community types, in relation to ambient environmental factors and gradients. These factors include light penetration - illumination, wave energy, sub-aerial exposure, sediment levels, slope angle and current flow, among others (Sheppard 1982,

Done 1982). Habitats exposed to strong wave energy generally support stout corals of low encrusting or submassive - massive form, with more fragile coral morphologies either absent or restricted to sheltered micro-habitats in the lee of other corals. Sheltered habitats, such as reef lagoons, usually support a broader range of growth forms, including the more fragile foliose and delicate branching forms. Steep walls, often with significant current flow, support another suite of characteristic species, including the spectacular sea fans and black corals. Around Bunaken NP, and North Sulawesi more generally, a wide range of habitat types and coral communities occur (Turak and DeVantier 2003), distributed widely in relation to depth - illumination, slope angle and exposure. Communities of Lembeh Strait and the Bangka - Gangga Islands differ from those of Bunaken NP, in relation to their differing environmental conditions (E. Turak and L. DeVantier, unpubl. data).

Corals of fragile - delicate branching / foliose growth forms are more easily broken than their more robust columnar - massive counterparts, and are thus more susceptible to diver damage (Hawkins and Roberts 1997, Rouphael and Inglis 1997, 2002). Physical damage will also make some colonies more susceptible to mortality due to algae overgrowth or disease. Conversely however, some fragile, easily-broken species may recover more rapidly from breakage / fragmentation, and indeed the broken fragments themselves may survive and form new colonies, expanding the area of the original coral colony. By contrast, massive corals are more robust and less easily broken than their more fragile branching and foliose counterparts, but may take much longer periods to recover from damage, and may also suffer increased susceptibility to disease and / or overgrowth.

This capacity for recovery is in turn influenced by the condition and health of the individual corals themselves in terms of other stressors (e.g. bleaching, sedimentation, predation) and the ecological history and trajectory of the community (past disturbances, present status and future impacts).

Thus, the particular susceptibility, resistance and resilience of individual corals, and of the coral communities they form, are neither simple nor straightforward, but rather require careful, specific research and monitoring. These aspects, although crucial to understanding CC and LAC, have been little studied, and only cursorily addressed in most calculations of CC conducted to date. This is attributable, at least in part, to the nature of most studies, which have been short 'snap-shot' surveys rather than long-term assessments, also true of the present study which had a total of three weeks of field time

(see Materials and Methods). Fortunately in the present case, prior surveys by the present authors (Turak and DeVantier 2003) provided significant detail on coral community structure in Bunaken NP, useful to the present analysis.

1.2 Dive history and visitor trends in Bunaken National Park and adjacent waters

Recreational SCUBA diving has been occurring in North Sulawesi waters for more than two decades, but remained relatively low key, with just several dive operations, until the 1990s, when dive tourism began to increase rapidly. In 1996-97 for example, tourism arrivals reached some 25,000 visitors per year and diver damage to the reefs was strongly evident (NRM III supporting documents).

Subsequently, an unrelated series of international events with regional - global ramifications for international tourism occurred. These included the Asian financial crisis, Indonesian political instability, the September 11th World Trade Center catastrophe in New York, the Bali nightclub bombing in 2002 and the Severe Acute Respiratory Syndrome (SARS) disease outbreak of early 2003. The dramatic reduction in global tourism that resulted has given Bunaken NP's reefs a five year respite from rapidly escalating tourism pressures.

In the latter part of 2003 however, both the Bunaken National Park Advisory Board (*Dewan Pengelolaan Taman Nasional* DPTNB) and the North Sulawesi Watersports Association (NSWA) have become increasingly concerned at the rapid increase in dive operators and visiting dive tourists to Bunaken NP. Diving in Bunaken NP is world renowned, featuring regularly in international SCUBA magazines, and attracted visitors from more than 45 countries in 2002 (Mark Erdmann, NRM III, pers. comm.). In late 2003, Bunaken NP won the global 'Tourism for Tomorrow' award from British Airways (Box 1), further enhancing its appeal to international visitors, with potential for a several-fold increase in visitation levels.

Box 1. Excerpt from Press Release - British Airways *Tourism for Tomorrow* awards (courtesy M. Erdmann, NRM III).

"Bunaken National Marine Park in North Sulawesi, Indonesia, beat more than 70 other entrants in the worldwide competition, which raises awareness of the world's leading role models for responsible tourism.

The judges assess how projects benefit the local community, protect the natural and cultural heritage, control energy and water use, educate local people and visitors and contribute towards a better life for future generations.

Bunaken's management has brought an end to damaging environmental practices in the park such as coral mining, mangrove cutting, and blast and cyanide fishing. At the same time, it has helped improve livelihood opportunities for 30,000 local residents and made education a priority, through scholarship programs and links with local schools and universities.

The marine park's beaches have been cleaned and a joint patrol of villagers, rangers and police officers established to safeguard its valuable natural resources. In the last two years live coral cover has increased in the park by more than 11 per cent

Almost a third of the park's entrance fees are used to fund conservation and development projects which are proposed and implemented by the community. The local community has a strong input into the park's management initiative, as five of its fifteen board members are local residents.

Speaking about the global winner Professor David Bellamy, chairman of the judging panel said, "Bunaken is what natural parks and nature based tourism are all about. It is a biodiverse area of great beauty and importance to its nation and the world.

"The park is sustainably managed by the local community, safeguarding their own heritage, a rich living resource which they can hand on to their children. This Global winner is a perfect mix of national pride and tourism that doesn't cost the earth more than it can afford."

The 2003 Bunaken NP entrance fee data shows clearly that this increase has already begun. In total, the park recorded 39,183 visitors in 2003 – with arrivals up more than 52% from a total of 25,697 visitors in 2002 (Fig. 3). While the majority of these arrivals (~75%) are beach-going domestic day-trippers, a distinct increase in international divers/snorkelers was seen in late 2003 as compared to the preceding two years. Previously, visitation was concentrated in the tourism 'high season' of May - September, however this appears to be changing, with some operators reporting busiest periods in February - March. Future trends are likely to continue this seasonal expansion, with the 'high season' ultimately filling most of the year.

At least ten new dive tourism operations have opened in the first six months of 2003, with more than 40 dive operations now working in the area (Annex 1). Some of the most recently established operations appear relatively amateur and aimed at the backpacker tourist market, causing concern amongst DPTNB and NSWA that standards of dive safety and dive briefings to minimize diver impacts will be significantly lowered. There is a strong concern that the environmental carrying capacity of the reefs and islands in the Park, and in North Sulawesi more generally, will soon be exceeded.

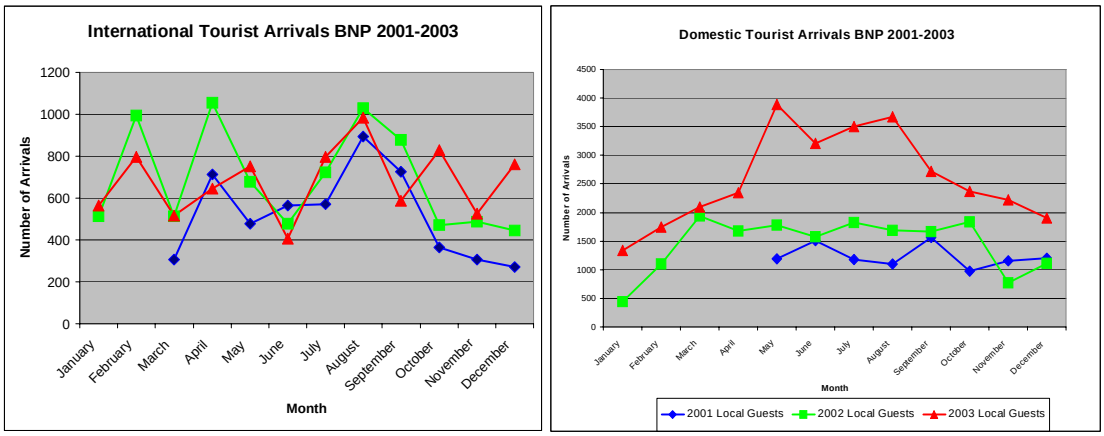

Figure 3: Trends in visitation to Bunaken National Park from 2001 - 2003. (Figures courtesy of Mark Erdmann, NRM III).

1.3 Towards Management of Marine Tourism in Bunaken NP and adjacent waters

To deal with this growing concern, a multi-pronged approach is being implemented by the management authority and tourism industry:

- Most, if not all, NSWA members conduct diver briefings to encourage appropriate diver behavior; coupled with
- Development of a NSWA standard 'Environmental Awareness Statement' form that all divers read and sign, indicating their understanding of appropriate dive behavior (Annex II);
- The DPTNB and NSWA are beginning a dialog with local government tourism departments to educate them on the dangers of mass tourism; and
- The importance of maintaining high standards of safety and environmental responsibility amongst operators applying for dive center licenses; as well as

- Limiting the number of licenses issued if diver carrying capacity is in danger of being exceeded.

At the same time, the dive operators themselves are actively trying to develop as many new diving sites, both within and outside of Bunaken NP, as possible – in order to decrease pressure on the heavily dived sites on the Park's reefs. The two primary areas being focused on for further development are the Lembeh Strait and the Bangka/Talise/Gangga Archipelago off Likupang. Additionally, the southern section of Bunaken NP, on the Sulawesi 'mainland' to the south of Manado, is beginning to attract more dive interest.

To succeed fully, this cooperative educational approach will require a solid grounding in a quantitative assessment of the diver and snorkeler carrying capacity of Bunaken NP's reefs – as well as those of Lembeh Strait and the Bangka/Talise/Gangga Archipelago. In this regard, the entire tourism sector in North Sulawesi (both private sector and government tourism departments) has shown a strong interest in commissioning an independent assessment of this carrying capacity, the primary driver for the present study.

Moreover, the provincial tourism department has shown a strong interest in directly utilizing such results to enact a new licensing system, designed to limit the number of visitors through limiting the number of dive operator licenses (along with limits on boat capacity, dive guide to diver ratios, and other appropriate regulations).

1.4 Purpose and Objectives of this Study

The main purpose of the present study was to conduct a diver carrying capacity study of Bunaken's, Lembeh's and Bangka's reefs and, based on the findings, provide well-supported policy recommendations for ensuring that marine tourism in North Sulawesi remains within environmentally sustainable levels. Towards this goal, policy recommendations for both CC and LAC concepts are developed.

The main objectives, achieved in collaboration with NRM III staff, DPTNB, NSWA, the provincial and city tourism departments and other relevant tourism stakeholders, were to:

- Plan and implement a quantitative assessment of diver carrying capacity of the reefs of Bunaken National Park, Lembeh Strait and the Likupang area. The recommended

CC limits of 4,000 - 6,000 divers per site per year derived for other reef areas are used herein for purposes of comparison. Inputs to this assessment included a combination of reef surveys for current diver-related damage to the reefs, direct observation of diving and snorkeling groups underwater, and dive center surveys on quality of pre-dive briefings. The findings will provide quantitative 'base-lines' on levels of diver interaction and reef damage from which future changes can be assessed.

- Plan and implement a rapid environmental impact assessment of cottage and homestay developments on the islands within Bunaken National Park and, if time permits, Lembeh Island and the islands off Likupang, to aid development of a set of policy recommendations on licensing for further cottage developments in the Park. Main inputs to this study were from a questionnaire survey of the homestays conducted by NRM III staff.

2. Materials and Methods

The study was carried out during November 2003, within the diving tourism “high season”, when a quantitative assessment of dive use and impacts on North Sulawesi’s reefs was conducted, focusing, in order of priority, on Bunaken NP, Lembeh Strait, and the Bangka/Talise/Gangga Archipelago off Likupang.

2.1 Study Area

Located near the centre of the 'coral triangle' of highest coral reef biodiversity (Veron 2000), the reefs of North Sulawesi are of crucial conservation importance, and management measures are now being implemented. Predominant among these measures is Bunaken National Park, established in 1991, and considered one of the most strategically important Marine Protected Areas in the world. The Park covers approx. 90,000 ha of coral reefs, mangrove forests and seagrass beds surrounding five islands and coastal sections of the northern area of Sulawesi, and supports a local population of some 30,000 villagers. As with most coastal areas of the region, the integrity of the natural ecosystem of the Park is threatened by human activities that are both marine and land-based, such as resource over-exploitation, destructive fishing practices and unsustainable tourism (see eg. Erdmann and Merrill 2003, Erdmann and Toengkagie 2003, Erdmann et al. 2003a,b).

The Park management authority, in collaboration with USAID’s Natural Resources Management Program (NRM III), has recently undertaken various activities to address these impacts. These include a major revision of the original zoning scheme (Usher and Merrill 2000, Erdmann and Merrill 2003), strengthening of surveillance and enforcement, and increasing community involvement in management. Revised zonation plans for most islands in the Park (Bunaken, Manado Tua, Mantehage and Siladen Islands), have been completed and planning is currently underway for the remaining sections.

The present study forms part of this broad management focus, aimed at developing ecological and socio-economic sustainability of coral reefs and associated ecosystems in Bunaken NP and North Sulawesi (Fig. 4) more generally. This approach is in accord with the recent recommendation that, because of its outstanding biodiversity and universal

value, the area be considered for listing on the World Heritage Register (Hillary et al. 2003).

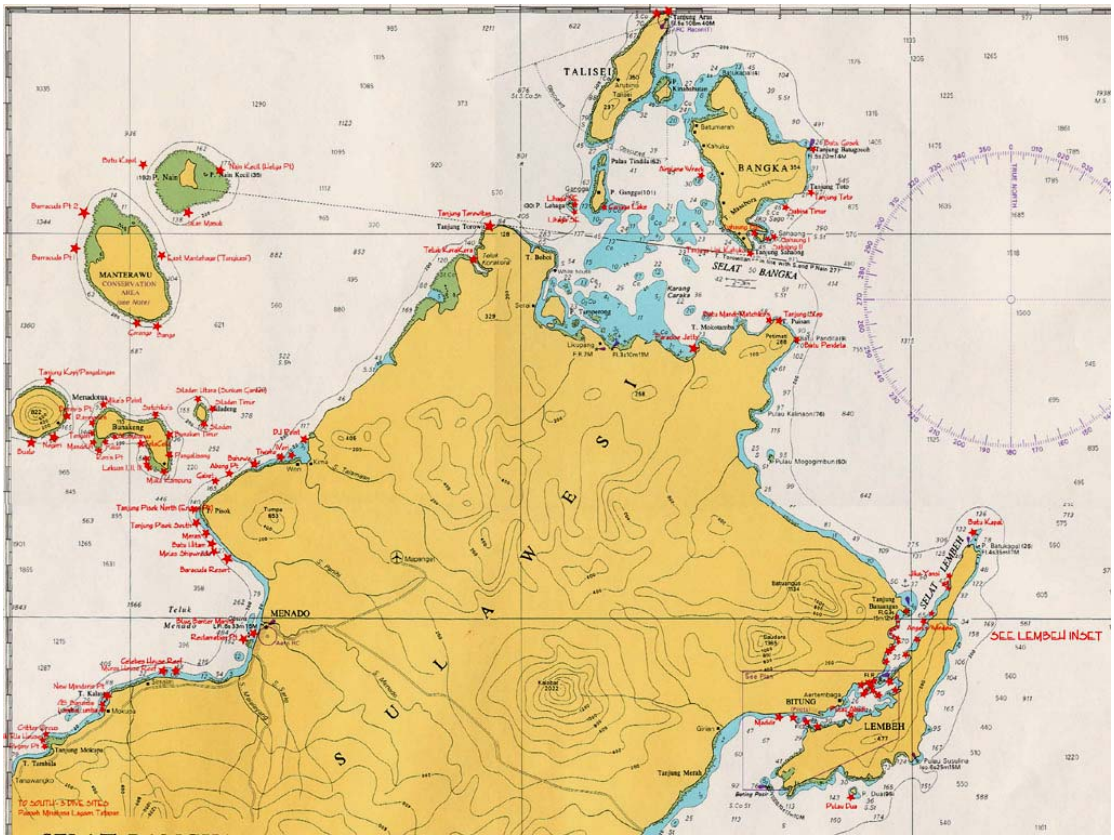

Figure 4. Study area of North Sulawesi, including Bunaken National Park, the Bangka - Gangga Islands and Likupang area, and Lembeh Strait. The area supports some 120 recognized SCUBA dive sites, as designated by the red stars (Figure courtesy M. Erdmann, NRM III).

Status of diving in North Sulawesi

Long-term dive operators and dive guides were interviewed in relation to their knowledge of diving in the Bunaken NP and North Sulawesi.

2.2 Dive sites, Use and Changes through Time

2.2.1 Dive Sites: Dive sites were identified during discussions among NSWA members, in five broad locations:

- Bunaken NP islands,
- Lembeh Strait,

- Manado mainland, including Tanjung Pisok (in Bunaken NP),
- Gangga - Bangka - Talise islands, and
- Southern mainland section of Bunaken NP, south of Manado.

2.2.2. Dive use: Several approaches were used to gauge dive use:

a) The relative level of use, ranked as three broad categories of occasional, moderate or heavy was classified for each dive site in each of the five broad locations identified above.

b) The approximate numbers of divers that use Bunaken NP and North Sulawesi annually were estimated from the Park entrance data.

c) The approximate numbers of divers using some of the main dive sites during busy, average and quiet days were estimated by dive operators and dive guides, to provide 'ball park' figures on daily use.

The approximate number of divers using each site on a daily basis was also estimated from quantitative data provided by 12 NSWA dive companies for the three months of August - October 2003. Importantly, these 12 operators account for over 80 % of the total dive numbers in Bunaken NP (M. Erdmann. NRM III, pers. comm.), providing a reasonably accurate picture of current dive usage. Nevertheless, given that there are some 40 dive companies in all, some of which are not members of NSWA, it was not possible to determine exact figures for dive usage. Rather, a range of diver numbers, representing the consensus view of the present authors and NSWA members in relation to diver numbers, was determined.

2.2.3 Changes: Interviews were conducted with long-term operators and guides in relation to changes, positive or negative, in diversity, abundances and sizes of fish and mobile invertebrates and corals and other attached organisms.

2.3 Quality of Dive Briefings

The 'quality' of dive briefings provided by dive operators, and guidance by dive guides was also assessed using standard survey forms (Annex III). Logistic constraints limited the number of such assessments to four dive operations, all NSWA members.

Field Surveys - Diver Impacts

2.4 Diver Observations

Surveys of diver use and impact were conducted at 17 sites in Bunaken NP, Lembeh Strait, Bangka and Gangga Islands from 31st October to 16th November 2003 (Fig. 5). At each site, the numbers of divers and their interactions with the reefs were recorded. The numbers and types of diver interactions, for recreational divers, photographers and dive guides independently, were classified in the following categories during timed 'diver observation' swims:

- touching the reef;
- holding the reef;
- accidental breakage;
- deliberate breakage;
- standing (snorkelers);
- harassment - e.g. waking / chasing turtles, prodding pygmy seahorses etc.;
- sediment disturbance by divers' fins, hands etc., which can smother / bury sessile organisms;
- bubbles - running up reef walls and contacting attached species such as gorgonians;
- number of camera flashes.

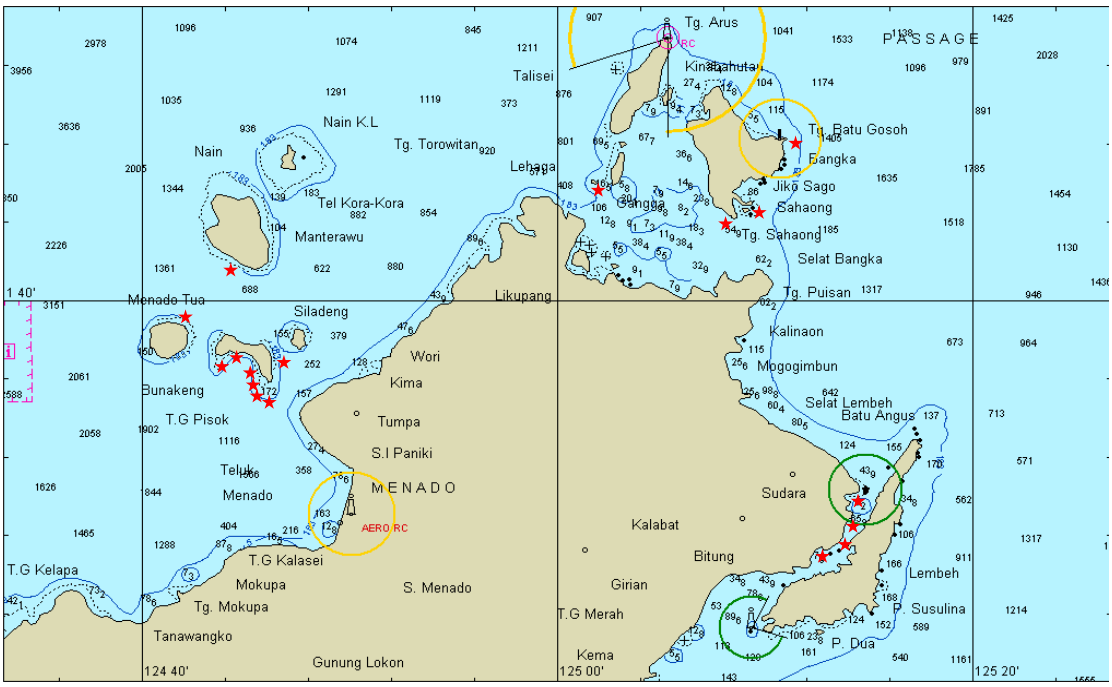

Figure 5. Sites of assessment of diver interactions (red stars), North Sulawesi 2003.

2.5 Dive Site Condition

Quantifying Diver Impacts

Sampling design: 'Before After Control Impact' (BACI) or 'Impact Gradient' sampling designs were considered for quantifying levels of diver-related damage to the reefs (see e.g. Rouphael and Inglis 2002). However, following extensive discussions with long-term dive operators, and detailed prior ecological survey of the reefs of Bunaken NP (Turak and DeVantier 2003), it became clear that these approaches would not be appropriate, for several reasons.

- The lack of 'control' sites or a clear gradient in use / impact. Many non-dived sites were subject to other forms of use and impact, notably destructive fishing, confounding a gradient approach and any conclusions regarding diver impacts. In some areas, destructive fishing has caused extensive damage (e.g. blast fishing at N.W. Mantehage Is., Turak and DeVantier 2003).

- The most heavily dived sites appear unique within Bunaken NP (and possibly North Sulawesi more generally), in several attributes, including aspect - exposure, limiting the possibility of finding suitable 'controls', irrespective of levels of impact from non-diving sources.

- The strong and often unpredictable current flow in many sites. Conducting quantitative reef surveys, with the requirement of working within a restricted (< one ha) area at the one site for extended periods, is not possible in many sites within Bunaken NP, where strong current flow make drift diving the only option.

Because of these difficulties, and significant logistic constraints in relation to the time available for the study, the quantitative survey of coral breakage was focused on four heavily dived sites in Bunaken NP (Fig. 6):

- Fukui,
- Alung Banua (the forereef at Tawara Lagoon),
- Lekuan III, and
- Bunaken Timor.

These sites were chosen following discussions with long-term dive operators who indicated that the sites were all heavily used for diving *and* had not been significantly affected by other forms of physical impact (e.g. destructive fishing) for the past several years. Thus most recent impacts could confidently be attributed to diving and related activities (anchoring, boat strike to shallow reefs), and levels of dive use could be estimated.

2.5.1. Coral Cover

Cover of living and dead corals and coral rubble at each site were assessed quantitatively in sets of four replicate 25 m point intercept line transects at two depths (9 - 14 m and 1 - 5 m). The method was modified from the Reefcheck point-intercept protocol, with the length of the replicate transects increased from 20 m to 25 m, and the distance between point intercepts reduced from 50 cm to 25 cm for increased precision. These modifications increased the sampling intensity from 40 points per 20 m transect (Reefcheck) to 100 points per 25 m transect (this study). The sessile benthos located beneath each of the 100 points on the replicate transects was recorded, although herein with improved taxonomic resolution, using the taxonomic references listed above, such

that hard corals were usually recorded to species level, soft corals to genus, and other sessile benthos to higher taxonomic level.

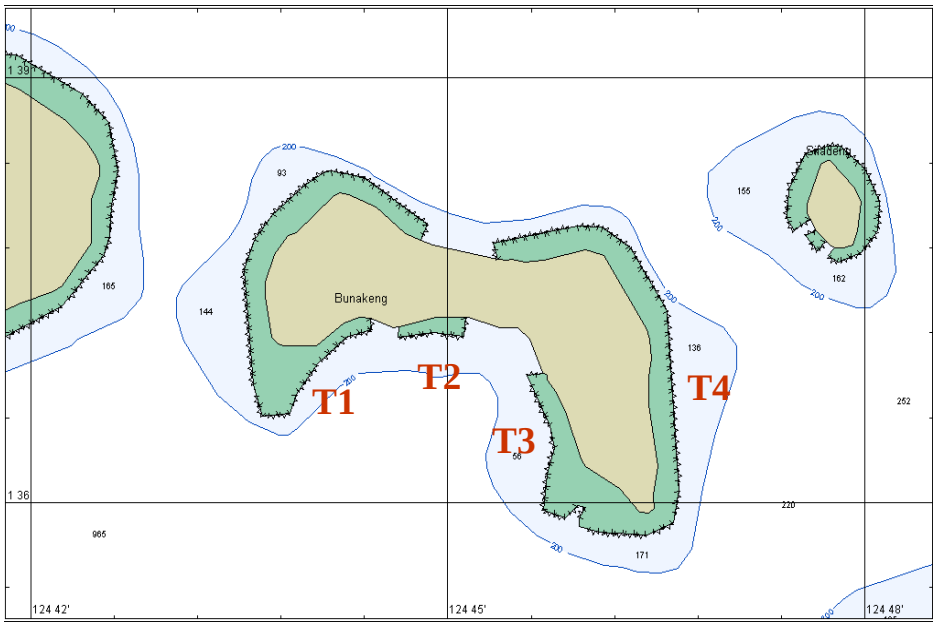

Figure 6. Sites of quantitative assessment of coral cover and breakage, Bunaken Island, Bunaken NP, 2003, where T1 - Fukui, T2 - Alung Banua (also known as Tawara Lagoon), T3 - Lekuan III and T4 - Bunaken Timor.

2.5.2 Coral Breakage

The numbers of recently broken corals were recorded in sets of four 'replicate' 100 m^2 belt transects (25 m length x 4 m width - 2 m each side of the 25 m central line transect) at two depths (9 - 14 m and 1 - 5 m) at each site. The belt transects were searched systematically for broken living corals and living coral fragments (live coral pieces completely detached from their parent coral colony). Broken corals were identified to species level *in situ* wherever possible (Veron and Pichon 1976, 1980, 1982, Veron, Pichon and Wijsman-Best 1977, Veron and Wallace 1984, Veron 1986, 1993, 1995, 2000, Best et al. 1989, Hoeksema 1989, Wallace and Wolstenholme 1998, Wallace 1999, Veron and Stafford-Smith 2002), otherwise genus and growth form (e.g. *Porites* sp. of massive growth-form). Soft corals and gorgonians, zoanthids, corallimorpharians and anemones were identified *in situ* to genus, family or broader taxonomic group (Allen and Steene 1995, Colin and Arneson 1995, Goslinger et al. 1996, Fabricius and Alderslade 2000).

The level of breakage for each coral was estimated to the nearest 10 % of total coral colony volume and scored as 0.1 - 0.9. For free-living coral fragments that had become completely detached from their parent colony, level of breakage was scored as 1. Counts were focused on living broken corals and living coral fragments to census recent breakage (months rather than years old), most likely attributable to diver and / or diving related impacts (e.g. anchoring, boat strike on shallow reef crests), rather than older breakage that may have been caused by destructive fishing. Nonetheless, a small proportion of the broken corals at each site may have been caused by other impacts (e.g., the recent increase in illegal fishing activity in tourism zones "after hours" that has resulted from a decline in patrol effectiveness since August 2003 – M. Erdmann and C. Muller, pers. comm.).

2.6 Rapid Ecological Assessment of Homestay Accommodation

Questionnaire surveys of visitation rates and waste management of 'homestay' cottages within BNP were conducted by staff of Bunaken NP and NRM III (R. Paat pers. comm.), using a standard survey form (Annex III).

2.7 Analysis

All data were input to EXCEL for storage and preliminary analysis, including descriptive summary statistics.

Results of the dive use and diver interaction surveys were summarized (descriptive statistics) and displayed graphically.

Results of the coral breakage transect surveys were summarized (descriptive statistics), displayed graphically and analyzed using Principal Components Analysis (PCA), to examine differences among sites and depths in relation to cover of living and dead corals and rubble, and numbers of fragments and broken parent corals.

Two indices of damage to corals in the belt transects were calculated:

- Total Damage - the sum of all damage scores (0.1 - 1) for every coral in each transect, depth and site; and
- Count of Damage - the count of all damage scores, irrespective of value, for every coral in each transect, depth and site.

Coral community structure at the four dive sites was examined using cluster analysis of the species - cover data from each of the eight transects at the four sites. The cover data were fourth-root transformed prior to analysis. Initial clustering used the Euclidean Distance metric (amalgamation schedule) and complete linkage (fusion strategy) to generate cluster site groups of similar community composition and abundance. These initial clusters were refined using K-means clustering, to maximize homogeneity within the initial groups derived from the hierarchical clustering. The data were plotted using Principal Components Analysis (PCA), and the groups defined by the K-means clustering were outlined as 'convex hulls' to illustrate the site boundaries of the different communities (also see DeVantier et al. 1998).

The species that best characterized each community group (key indicator taxa) were determined, based on relative abundance and fidelity to the community types (after Dufrene and Legendre 1997, DeVantier et al. 2000).

Damage levels to individual species and relations between species - abundance (cover) and levels of breakage were illustrated graphically.

Homestay surveys

Results of the homestay surveys were summarized in terms of numbers of guests, types of waste disposal - sewage treatment and waste management.

3. Results

3.1 Dive Locations

In total, some 120 individual dive sites were identified in North Sulawesi, in five main locations - Bunaken NP islands, Lembeh Strait, the North Sulawesi mainland to the north and south of Manado, the Gangga - Bangka - Talise islands and the southern mainland section of Bunaken NP (Fig. 4, Annex IV), with more being 'discovered' regularly.

At present, Lembeh Strait and the islands of Bunaken NP host most dive sites (34 % and 27 % respectively, Fig. 7), followed by the Manado mainland (including Tanjung Pisok within Bunaken NP, 19 %) and Gangga - Bangka - Talise Islands area (17 %). At present, the southern mainland section of Bunaken NP hosts relatively few dive sites, although this is an area identified for future expansion.

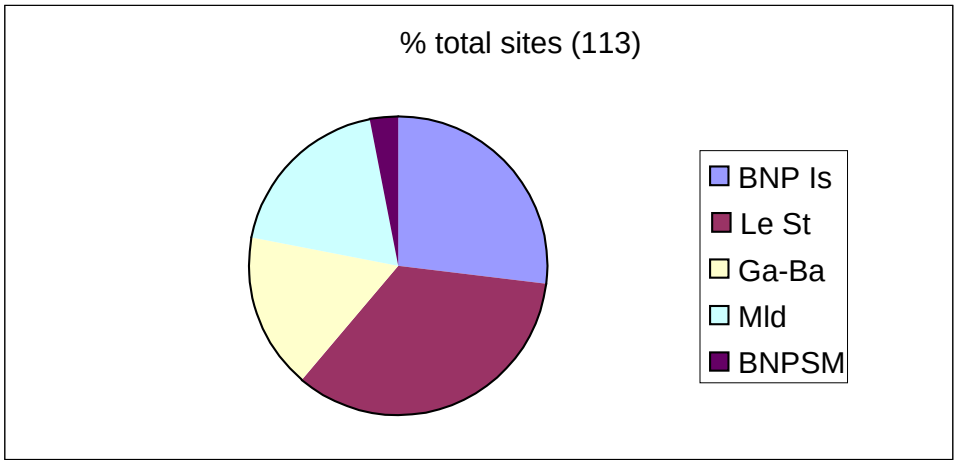

Figure 7: The proportion of dive sites of North Sulawesi in each of five locations - Bunaken NP islands (BNP Is), Lembeh Strait (Le St), Gangga - Bangka - Talise Islands (Ga-Ba), Manado mainland, including Tanjung Pisok in Bunaken NP (Mld) and Bunaken NP Southern mainland section (BNPSM).

3.2 Dive Usage

3.2.1 Entrance Fee Data

The Bunaken NP entrance fee data of 2001 - 2003 indicates that approx. 8,000 divers per year are presently using the Park (about one-third of all visitors). Additionally, some divers visit North Sulawesi that do not enter Bunaken NP, and thus do not pay an entrance fee, although this probably does not amount to more than 1,000 divers (M. Erdmann, NRM III, pers. comm.). Thus a conservative figure of 9,000 recreational divers per year visiting North Sulawesi may be assumed.

At any given time, dive guides are diving with visiting guests in an average ratio of 1:4 (ranging from 1:1 to 1:7). Thus, for 9,000 recreational divers, there will be a total of ca. 2,250 accompanying guide dives, for a total of 11,250 'divers' on North Sulawesi's reefs each year.

Most visiting divers in North Sulawesi conduct between 10 and 30 dives during their holidays. The overall range is from approx. 4 dives for the expatriate workers on weekend trips from the SE Asian region (e.g. Singapore, Kuala Lumpur and Jakarta) to more than 30 dives for the longer-stay visitors on three to four week dive trips. Many of the latter divers visit Bunaken NP, Lembeh Strait and also the Sangihe - Talaud islands to the north.

Assuming each diver does conduct, on average, 10 - 30 dives each, then 11,250 divers perform between 110,000 and 337,500 dives per year at present on North Sulawesi's reefs (Table 1). If the present diving effort were spread evenly over the 120 sites, present usage would equate to less than 2,000 divers per site per year, well within the recommended carrying capacity limits of 4,000 - 6,000 dives per site per year for other reef areas (Hawkins and Roberts 1997 and see Introduction above). However, dive effort is not spread evenly (see later).

Table 1: Annual dive usage in North Sulawesi at present (11,250 divers) and with projected future minor increase (15,000 divers), modest increase (doubling to 23,000 divers) and major, though not unrealistic, increases (50,000 - 300,000 divers). Number of sites is set constant at present level of 120. Levels approaching or above recommended

carrying capacity limits of < 6,000 divers per site per year for other reef areas are highlighted.

No. divers per year	10 dives per diver		20 dives per diver		30 dives per diver	
	Total	Per site	Total	Per site	Total	Per site
11,250	112,500	938	225,000	1,875	337,500	2,813
15,000	150,000	1,250	300,000	2,500	450,000	3,750
23,000	230,000	1,917	460,000	3,833	690,000	**5,750**
30,000	300,000	2,500	600,000	5,000	900,000	**7,500**
50,000	**500,000**	**4,167**	**100,000**	**8,333**	**1,500,000**	**12,500**
100,000	**1,000,000**	**8,333**	**2,000,000**	**16,667**	**3,000,000**	**25,000**
200,000	**2,000,000**	**16,667**	**4,000,000**	**33,333**	**6,000,000**	**50,000**
300,000	**3,000,000**	**25,000**	**6,000,000**	**50,000**	**9,000,000**	**75,000**

If diver visitation rates continue to increase through time as expected *and* diving is spread evenly among sites, it will require an approx. doubling - quadrupling in visitor numbers, to 23 - 50,000 divers per year, to reach the recommended carrying capacity limits for the other reef locations (Hawkins and Roberts 1997) for North Sulawesi as a whole (ca. 120 dive sites, Table 2).

This prediction makes three important assumptions:

- Dive frequency remains similar to the present (10 - 30 dives per visitor per year) - a realistic assumption;
- there will be no future expansion in the number of dive sites - unrealistic, as new sites continue to be 'discovered' on a regular basis and future expansion is assured, dependent on future zoning options; and
- dive usage is spread evenly among sites - also unrealistic (see later).

3.2.2 Accommodation Limits

At present the approximate maximum number of divers that can be accommodated in North Sulawesi at any one time is ca. 1,000, in the ca. 40 recognized dive resorts and homestays and eight live-aboard dive boats (Annex I). This maximum number of divers is at present rarely if ever achieved, as different resorts experience different peaks in their accommodation cycle.

However, with increasing dive tourism, the maximum will begin to be attained on a more frequent basis. Visitor arrivals data for 2003 demonstrate that for foreign visitors, which provide most of the SCUBA dive tourists in Bunaken NP and North Sulawesi, monthly variation is relatively stable, ranging between ca. 500 and 1000 visitors per month, in comparison with Indonesian nationals (Fig. 8).

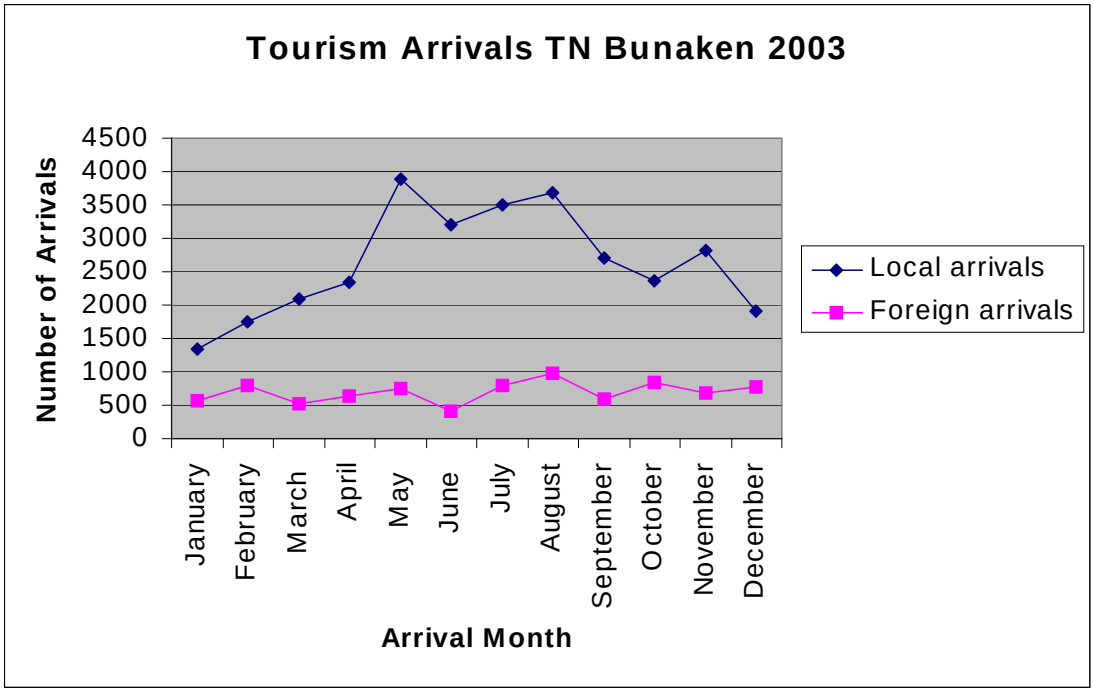

Figure 8: Monthly visitation rates, Bunaken NP, 2003. Figure courtesy M. Erdmann, NRM III.

Maximum bed numbers can provide a useful upper estimate of dive use, particularly during the peak dive season of July - November. Assuming the 1,000 divers stay, on average, for two weeks each, if the maximum diver numbers were maintained for the full year, total divers will reach ca. 25,000. Again assuming a similar range of dive activity per diver (10 - 30 dives), 25,000 divers per year approaches the hypothesized CC limits for North Sulawesi (Table 2). This trend may well be enhanced by continued expansion in accommodation. Thus it is conceivable that broad limits to dive usage and overall carrying capacity for North Sulawesi are already within reach, given the present levels of accommodation that are already available.

3.2.3 Variability - Selectivity in Site Use

Importantly however, present (and presumably future) dive effort is not spread evenly among the ca. 120 dive sites. Rather, it is concentrated on relatively few favored sites

(Fig. 9). For reasons of accessibility, logistics - economics, safety and 'divability' (manageable currents, suitable for training, tourist appeal / expectations etc.), approx. 30 % of sites receive far more dive effort than the 'average' determined from the Bunaken NP entrance fee data, as calculated above (Annex IV).

3.2.4 Dive site use levels

Of the recognized dive sites in North Sulawesi for which use rankings were available (113 sites), more than two-thirds (69 % of total) are dived only on an occasional (44 sites, 39 % of sites) or moderate (34 sites, 30 %) basis, equating with weekly rather than daily use. By contrast, some 35 sites (approx. 31 % of the total) are already subject to heavy use. For many of these sites, diving by multiple operators occurs on a daily basis, with from three to a maximum of six boats operating at the same time in the busiest circumstances (see Annex IV for full site list).

Within the five broad dive locations, Bunaken NP islands host a disproportionate amount of the most dived sites (Figs. 9 - 11), accounting for some 40 % of all heavily dived sites, yet hosting just 27 % of all dive sites in North Sulawesi (Fig. 7). Sites in Lembeh Strait and the Gangga - Bangka - Talise islands host similar proportions of heavily use sites (> 20 % each), with the Manado mainland experiences less heavy use and southern mainland section of Bunaken NP, no heavy use at present.

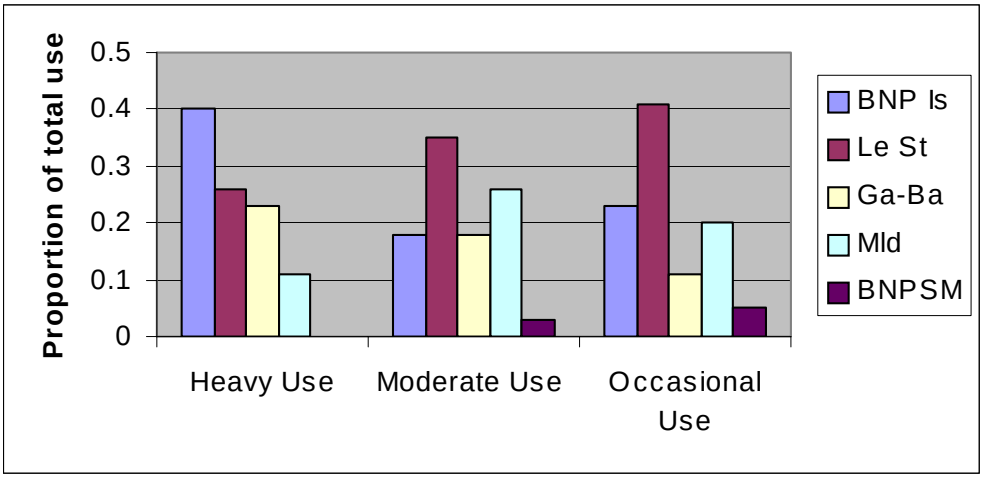

Figure 9. Site use levels for each of five dive locations, North Sulawesi, 2003. Bunaken NP islands (BNP Is), Lembeh Strait (Le St), Gangga - Bangka - Talise Islands (Ga-Ba), Manado mainland, including Tanjung Pisok in Bunaken NP (Mld) and Bunaken NP Southern mainland section (BNPSM).

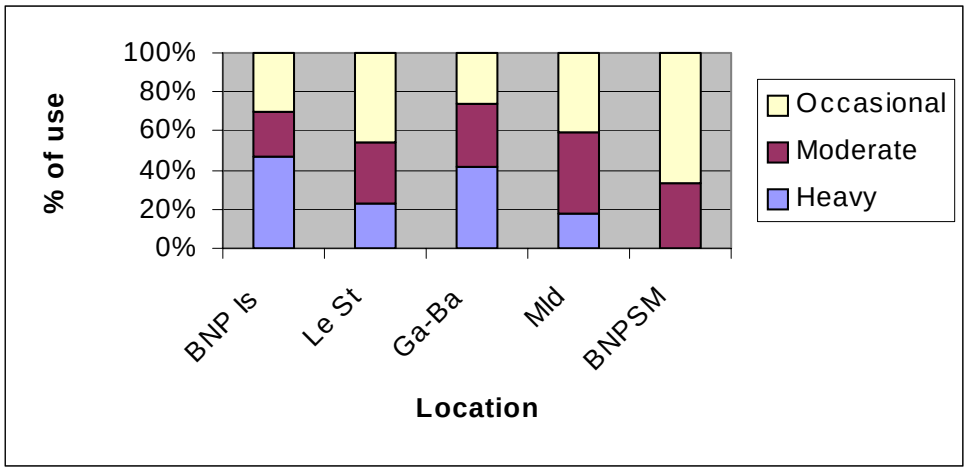

Figure 10. Relative percentages of different levels of use for each of five dive locations, North Sulawesi, 2003. Bunaken NP islands (BNP Is), Lembeh Strait (Le St), Gangga - Bangka - Talise Islands (Ga-Ba), Manado mainland, including Tanjung Pisok in Bunaken NP (Mld) and Bunaken NP Southern mainland section (BNPSM).

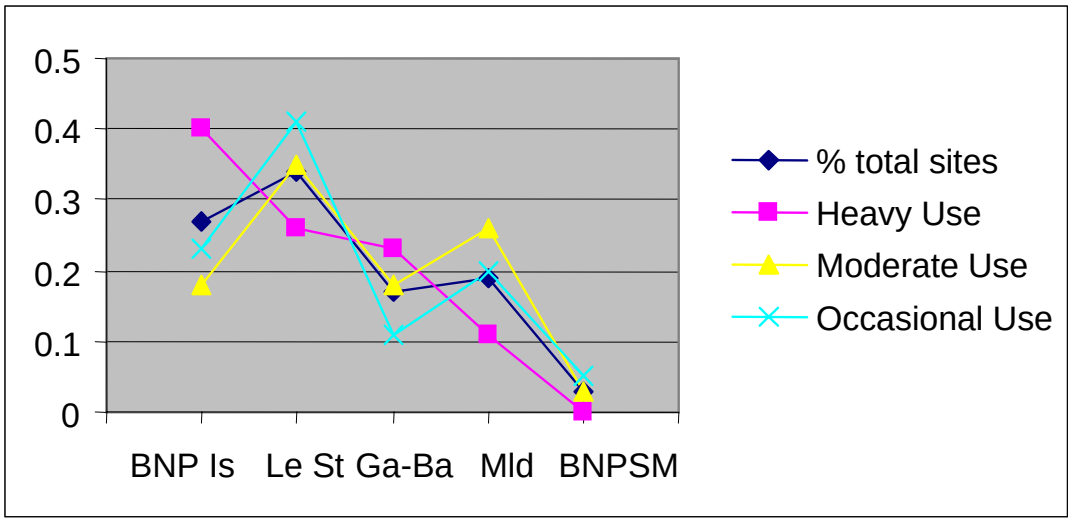

Figure 11. Relations among proportions of total dive sites and present levels of use (Heavy, Moderate or Occasional) for five dive locations, North Sulawesi, 2003.

3.2.5 Dive operator estimates of use

A questionnaire survey of dive operators and dive guides provided 'ball park' estimates of the maximum numbers of divers using the most heavily dived sites on busy, average and quiet days (Table 2). If average levels of use for these sites are as listed, and a yearly

average number of diving days at each site of 300 days is assumed, then some sites are already above the 'threshold' level for minimal damage of 4,000 - 6,000 divers per site per year (Dixon et al. 1993, Hawkins and Roberts 1997).

Table 2. Estimates of daily dive use at some of the most heavily dived sites in North Sulawesi, as provided by experienced dive operators and guides. The average number of divers per site per year was determined from the average daily use rate, assuming 300 days of diving per year. Sites exceeding recommended carrying capacity limits of 4,000 - 6,000 dives per year are highlighted.

Dive Site	Divers - Busy day	Divers - Ave. day	Divers - Quiet day	Ave. divers per site per yr
Bunaken NP				
Lekuan I	> 100	30 - 50	10 - 30	**9 - 15,000**
Lekuan II	> 100	30 - 50	10 - 30	**9 - 15,000**
Lekuan III	> 100	30 - 50	10 - 30	**9 - 15,000**
Fukui	> 50	20 - 30	5 - 10	**6 - 9,000**
Tanjung Kopi (Panggulingan) Manado Tua	> 50	20 - 30	5 - 10	**6 - 9,000**
Alung Banua (Tawara Lagoon)	> 30	10 - 20	5 - 10	3 - 6,000
Sachiko	20 - 30	5 - 10	2 - 5	1.5 - 3,000
Mandolin	20 - 30	5 - 10	2 - 5	1.5 - 3,000
Bunaken Timor	20 - 30	5 - 10	2 - 5	1.5 - 3,000
Lembeh Strait				
Nudi Retreat	> 50	20 - 30	5 - 10	**6 - 9,000**
Nudi Falls	> 50	20 - 30	5 - 10	**6 - 9,000**
Hair Ball	> 50	20 - 30	5 - 10	**6 - 9,000**

3.2.6 Dive operator statistics

Monthly dive site use data were provided by 12 NSWA operators for the three months of August - October 2003. Based on their accommodation limits, the operators are considered as a representative cross-section of the industry, including large volume, moderate volume and smaller volume operators. The data demonstrate that there is considerable variability in site use, both seasonally (monthly) and among sites (Figs. 12a-c, 13a-c). Over all sites and operators, August was the busiest month, followed by October and September.

Given that there are some 40 dive companies in all, some of which are not members of NSWA, it was not possible to determine exact figures for dive usage. Nevertheless, the 12 NSWA operators that provided data are thought to account for over 80 % of the total

dive numbers in Bunaken NP, providing a reasonably accurate picture of current dive usage (Table 3). Based on these figures, it is highly likely that the busiest sites are already hosting more than 6,000 divers per year.

In terms of total use among the 12 operators, dives sites around the Bunaken NP islands have the highest levels of use (Fig. 12a-c), with some sites (e.g. Lekuan I, II) hosting more than 700 divers in August 2003. Highest numbers for dive sites on the mainland (exluding the Molas Wreck) and Bangka – Gangga Islands and in Lembeh Strait (excluding Police Pier) were less than half these levels. However, diver numbers for Lembeh Strait and Bangka - Gangga Islands are significant underestimates because some operators did not provide data for individual dive sites in these locations.

There was significant among-site variability in dive usage (Fig. 14a-c), with the busiest sites in all three dive locations (Bunaken NP islands, Manado mainland - Bangka-Gangga Islands and Lembeh Strait) all supporting, on average, more than 60 divers per operator per month (> 2 divers per operator per day). Disproportionately high average diver numbers for Celebes, Abang Point, Tanjung Sepia, and Wori (c.f. Figs. 12, 13 and Tables 3 and 4) relate to the high diver numbers of the few operators that use those sites.

The precise ordering of dive sites may vary if additional dive data were available from other operators. However, the important points are that there is a wide range in use levels, and some sites are already heavily used. The four sites chosen for the quantitative assessment of diver impacts - Lekuan III, Bunaken Timor, Alung Banua and Fukui - are at the upper end of the use scale (Fig. 14a); see Methods section.

These average diver use numbers may be extrapolated for additional operators, assuming that the twelve operators from whom the data were derived are representative of the range in size of operations and that site preferences are similar among most operators (Tables 3 and 4).

Most operators practice a form of self-regulation in relation to crowding of dive sites, wherever possible avoiding diving the same site at the same time as other operators. Nonetheless, during the survey period, three different operators were present at the same sites on several occasions, and up to six operators may dive the same site at the same time (NSWA members, pers. comm.). Thus the calculations are based on a range in numbers

of operators per day of five (conservative present use), 10 (average present use) and 20 (very heavy present use / future use).

With average daily use by ten of the 40 operators, many sites are exceeding 20 divers per day, 500 divers per month, and 6,000 divers during the year (Table 4), approaching or above recommended CC limits (Dixon et al. 1993, Hawkins and Roberts 1997 and see Introduction above). This is particularly so when placed in the context of recent visitation trends, which show relatively little monthly - seasonal fluctuation in international visitor numbers (Fig. 8).

However, this daily use rate (20 divers) is well below the 'ball park' estimates for busy (or even average) days provided by dive operators during interviews (ca. 30 - 100 divers, Table 2). Observations during the survey period also suggest that, at least during the peak season, daily diver numbers at these busiest sites are significantly higher. For example, more than 20 divers were observed diving at the same time at Alung Banua, Pangalingan and Lekuan I. Indeed several of the largest operators can carry in excess of 20 divers per day. Thus the average estimates of use derived above are considered as conservative.

Table 3: Calculations of present use of busiest sites based on total diver data from 12 NSWA operators for August - October 2003, and assuming a) that the monthly average remains constant throughout the year; and b) that these 12 operators represent 80 % of total use. Numbers for Lembeh Strait and Bangka - Gangga Islands are significant underestimates because some operators did not provide data for individual dive sites in these locations. Yearly average dive use levels above recommended CC limits of 6,000 divers per site per year are highlighted.

Dive Site	Aug	Sep	Oct	Monthly Ave.	Yearly Ave. (12 operators)	Yearly Ave. (assuming 80 %)
Bunaken NP islands						
Lekuan I	767	657	674	699	**8392**	**10490**
Lekuan II	767	424	647	613	**7352**	**9190**
Satchiko's	666	485	529	560	**6720**	**8400**
Lekuan III	659	598	551	603	**7232**	**9040**
Fukui	575	385	442	467	5608	**7010**
Alung Banoa	525	309	314	383	4592	5740
Tanjung Kopi	496	361	386	414	4972	**6215**
Bunaken Timur I	435	333	390	386	4632	5790
Muka Kampung/Tanjung Pasir	403	411	462	425	5104	**6380**
Mandolin	396	347	287	343	4120	5150
Siladen	363	240	214	272	3268	4085
Raymonds	319	199	268	262	3144	3930
Negeri	246	203	148	199	2388	2985
Bualo Muka Gereja	212	150	137	166	1996	2495
Pangalisang	210	166	120	165	1984	2480
Cela-Cela	173	127	154	151	1816	2270
Mike's Point	139	91	140	123	1480	1850
Bunaken Timur II	156	81	93	110	1320	1650
Mainland - Bangka - Gangga Islands						
Molas Wreck	480	283	311	358	4296	5370
Tanjung Pisok Selatan	319	212	241	257	3088	3860
Tanjung Pisok Utara/Engine Point	193	102	96	130	1564	1955
Pulisan Batu Mandi, Matchiko	185	150	159	165	1976	2470
Sahaung	181	247	209	212	2548	3185
Celebes	150	128	120	133	1592	1990
Lembeh Strait						
Police Pier	379	242	241	287	3448	4310
Nudi Falls	343	224	344	304	3644	4555
Nudi Retreat	270	196	169	212	2540	3175
Angel's Window	231	160	131	174	2088	2610
Jahir (Jiko Aras)	193	161	246	200	2400	3000
Retak Larry ("Larry Tackett")	183	171	209	188	2252	2815
Hairball	159	124	131	138	1656	2070

Figure 12. Total use of the different dive sites, based on data from 12 NSWA operators at a) Bunaken NP islands, b) Manado and Bunaken NP mainland and Bangka-Gangga Islands, and c) Lembeh Strait, North Sulawesi, August (blue bars), September (brown bars) and October (yellow bars) 2003. Note differences in scale on Y axes.

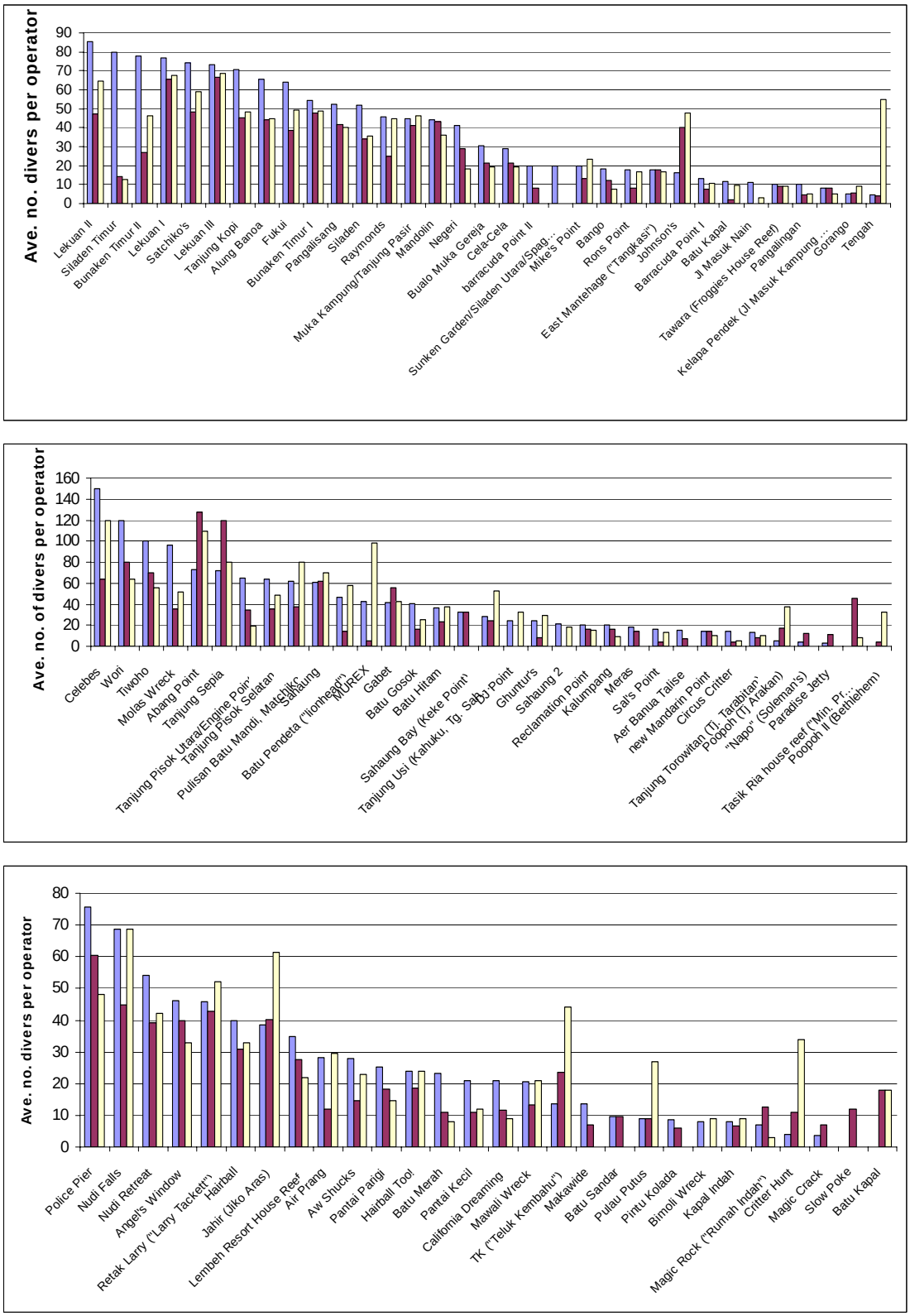

Figure 13 a-c. The average numbers of divers per dive operator at a) Bunaken NP islands, b) Manado and Bunaken NP mainland and Bangka-Gangga Islands, and c) Lembeh Strait, North Sulawesi, August (blue bars), September (brown bars) and October (yellow bars) 2003. Note differences in scale on Y axes. Average diver numbers were determined for only those operators that dive each site, not the total of 12 operators.

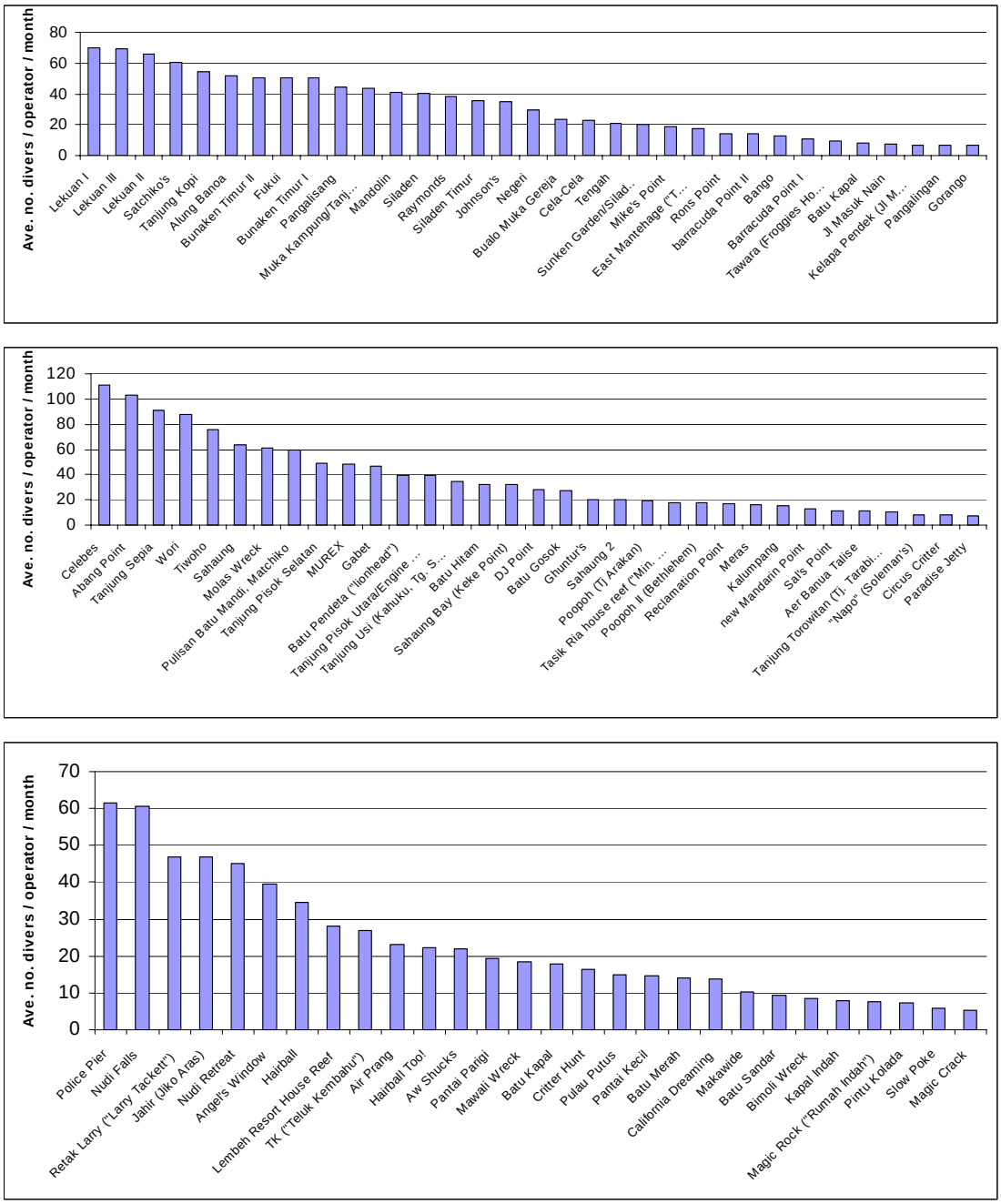

Figure 14a-c. The average numbers of divers per dive operator per month at a) Bunaken NP islands, b) Manado - Bunaken NP mainland and Bangka-Gangga Islands, and c) Lembeh Strait, illustrating major differences in levels of use among sites, North Sulawesi (August - October 2003). Note differences in scale on Y axes.

Table 4. Daily, monthly and yearly use levels for the 10 busiest dive sites at Bunaken NP islands, Manado and Bunaken NP mainland and Lembeh Strait, North Sulawesi, respectively, based on average diver data from twelve NSWA operators for the 3 'high-season' months of August - October 2003, extrapolated for the same level of average use by five, 10 and 20 operators per day. Note that average diver numbers were determined from those operators that dive each site, not the total of 12 operators (c.f. Figs. 12 and 13). Yearly average dive use levels above recommended CC limits of 6,000 divers per site per year are highlighted.

Dive site	Daily use		Monthly use		Yearly use	
Number of divers	Ave. per operator	5, 10, 20 operators	Ave. per operator	5, 10, 20 operators	Ave. per operator	5, 10, 20 operators
Bunaken NP islands						
Lekuan I	2.33	12, 24, 47	69.93	350, 699, 1399	839.20	4196, **8392, 16784**
Lekuan III	2.32	12, 24, 47	69.51	348, 695, 1390	834.17	4171, **8342, 16683**
Lekuan II	2.19	11, 22, 44	65.68	328, 657, 1314	788.13	3941, **7881, 15763**
Satchiko's	2.01	10, 20, 40	60.43	302, 604, 1209	725.11	3626, **7251, 1450**
Tanjung Kopi	1.82	9, 18, 36	54.74	274, 547, 1095	656.93	3285, **6569, 13139**
Alung Banoa	1.72	9, 17, 34	51.54	258, 515, 1031	618.50	3093, **6185, 12370**
Bunaken Timur II	1.68	8, 17, 34	50.50	253, 505, 1010	606.00	3030, **6060, 12120**
Fukui	1.68	8, 17, 34	50.50	253, 505, 1010	606.00	3030, **6060, 12120**
Bunaken Timur I	1.67	8, 17, 34	50.23	252, 502, 1005	602.79	3014, **6028, 12056**
Pangalisang	1.49	7, 15, 30	44.67	223, 447, 893	536.00	2680, 5360, **10720**
Mainland						
Celebes	3.71	19, 37, 74	111.33	557, 1113, 2226	1336.00	**6680, 13360, 26720**
Abang Point	3.44	17, 34, 69	103.33	517, 1033, 2067	1240.00	**6200, 12400, 24800**
Tanjung Sepia	3.02	15, 30, 60	90.67	453, 907, 1813	1088.00	5440, **10880, 21760**
Wori	2.93	15, 30, 59	88.00	440, 880, 1760	1056.00	5280, **10560, 21120**
Tiwoho	2.51	13, 25, 50	75.33	377, 753, 1507	904.00	4520, **9040, 18080**
Sahaung	2.13	11, 21, 43	63.92	320, 639, 1278	767.00	3835, **7670, 15340**
Molas Wreck	2.04	10, 20, 41	61.07	305, 611, 1221	732.83	3664, **7328, 14657**
Pulisan Batu Mandi, Matchiko	1.99	10, 20, 40	59.56	298, 596, 1191	714.67	3573, **7147, 14293**
Tanjung Pisok Selatan	1.64	8, 16, 31	49.11	246, 491, 982	589.33	2947, 5893, **11787**
MUREX	1.62	8, 16, 32	48.67	243, 487, 973	584.00	2920, 5840, **11680**
Lembeh St.						
Police Pier	2.05	10, 21, 41	61.50	308, 615, 1230	738.00	3690, **7380, 14760**
Nudi Falls	2.02	10, 20, 40	60.73	304, 607, 1215	728.80	3644, **7288, 14576**
Retak Larry	1.56	8, 16, 31	46.92	235, 469, 938	563.00	2815, 5630, **11260**
Jahir (Jiko Aras)	1.56	8, 16, 31	46.78	234, 468, 936	561.40	2807, 5614, **11228**
Nudi Retreat	1.51	8, 15, 30	45.15	226, 452, 903	541.80	2709, 5418, **10836**
Angel's Window	1.32	7, 13, 26	39.65	198, 397, 793	475.80	2379, 4578, **9156**
Hairball	1.15	6, 12, 23	34.50	173, 345, 690	414.00	2070, 4140, **8280**
Lembeh Resort House Reef	0.94	5, 9, 19	28.17	141, 282, 563	338.00	1690, 3380, **6760**
TK ("Teluk Kembahu")	0.90	5, 9, 18	27.06	135, 271, 541	324.67	1623, 3247, **6493**
Air Prang	0.78	4, 8, 16	23.28	116, 233, 466	279.33	1397, 2793, 5587

In summary, the various lines of evidence on levels of diver use in North Sulawesi suggest that for the busiest sites, use levels are already approaching or exceeding those recommended as upper CC limits for other reef areas. However, for most other sites, dive use is likely to be well below such CC limits at present. As noted above, the busy sites are preferred for a variety of reasons, and without intervention (and even with a degree of self-regulation by the dive operators themselves), increasing future dive tourism will place even greater levels of use on these busiest sites. It will also increase use levels in many of the remaining sites.

To gauge the effect of increasing dive use on the 'quality' of dive sites, long-term dive operators and guides were interviewed as to their perceptions of changes that have already occurred at these sites, to provide a recent historical context for future dive use trends. Many of the long-term dive operators in North Sulawesi are expatriates with substantial previous experience in other coral reef dive locations (e.g. Egyptian Red Sea). These operators are well aware of the negative impacts that can be caused by unregulated diving (e.g. Egyptian Red Sea, Jameson et al. 1999, and see Introduction), and have a wealth of personal knowledge of the history of diving in North Sulawesi.

3.3 Changes through time - anecdotal information

Interviews with dive operators and guides from nine operations (all NSWA members) revealed consistent responses to two key questions, as summarized below:

Question 1. What changes in corals and other reef-attached (sessile) species have you noticed while diving around Bunaken NP and adjacent waters over the past decade?

Response: Substantial diver-caused damage has occurred at heavily dived sites, notably to reef crest corals from anchoring, boat strike and snorkelers standing on the reefs. Damage has also occurred to the reef wall fauna, particularly gorgonian fan corals, from accidental and deliberate breakage, and possibly also from regular impacts of diver bubbles (Box 2, and see Annex V for site detail).

Box 2. Diver impacts to corals and other attached species, Bunaken NP, from Massimo Boyer, Celebes Divers (2003):

"During the last 2 months, diving in Bunaken, I noticed many damages involving what I was used to consider "obyek pariwisata" (tourism objects or features).

In details:

- **Sachiko point.** At 5 m depth there are 3 large rocks, each one of which had a large red sea fan (genus *Melithaea*). This was a very good spot for UW photographers, for the possibility to have large sea fans so close to the water surface. One of the gorgonians was recently on the cover of a scuba magazine in Italy. In July (2003) I noticed that 2 of the 3 fans are completely destroyed, detached from the rocks. One was still visible in August, dead and covered with algae, at the basis of the rock. *Melithaea* is a fragile gorgonian, its skeleton has flexible internodes and calcified nodes, it can be damaged by divers in a relatively easy way.

- **Lekuan 3.** Starting from the buoy and moving south, after about 50 m we can meet a vertical crack, going deeply into the reef. Near the entrance to this crack, on the right side (for who is entering) there used to be a large white gorgonian (genus *Annella*, the network like sea fans formerly called *Suberites*). Now the gorgonian is laying on the bottom, completely detached from its substrate.

- **Lekuan 3.** At the same site, about 10 m depth, on the opposite side of the crack, there used to be a small tabular *Acropora* (table like hard coral). Months ago it used to host a beautiful leaf scorpion fish, everybody knew that, and this was frequented by many divers and photographers. Now the *Acropora* is laying on the bottom, completely detached from its substrate.

- **Tanjung Kopi** (… "**Pangalingan**"). At about 20 m depth there used to be a large table like *Acropora*, that was usually home for young white tip reef sharks. Another "must stop" site (everytime the current allowed this). Now the *Acropora* is destroyed, broken into 2 pieces, with a large crack in the middle. This could be also an anchor damage, but who throws the anchor at 20 m?

- Another dive spot …. Around a small overhanging rock a pair of the new species of pygmy seahorses (the one that will likely be called *Hippocampus pontohi*) used to live in June (2003). I went often with photographers, and to take photos myself. Until one day I was no longer able to find the rock! Finally I saw it laying on the bottom, 10 m below, clearly identified by the fouling … the *Hippocampus* were gone.

- In many spots, I have noticed the large white, pink or brown network-like sea fans (genus *Annella*) broken in some parts. Some of the more beautiful sea fans of the park are unrecoverably gone. I suspect that this could be due to the habit of some dive guides (I witnessed this operation), to break small branches of the gorgonian just to show to the guests the beautiful egg cowrie that lives on it. This operation (apparently small) can weaken the structure of the sea fan, and make it less resistent to the currents, and cause large breakings.

- … **Fukui point**, the whole reef is falling down in many spots. Now, all those damages seem to me clearly caused by divers, maybe unintentionally, maybe by unexperienced divers with … bad buoyancy control brought on the wrong dive spot.

- … In 2 months we have lost many "obyek pariwisata". We can be temporarily happy because we have many divers, but soon, when we will have nothing to show them, the divers will stop coming. Let's try to think for a long term planning! This is what I call "Hurgadization" (and I am sure that everybody … in the diving business can understand)! Remember that a good briefing can prevent many damages to the reef, and avoid bringing unexperienced divers to spots where they can make only damages.

- I would like to underline the importance, for the calculation of a carrying capacity, not only of the hard corals but also of other dominating organisms, like gorgonians or black corals, that along vertical walls are even more exposed to damages by divers. Gorgonians, large sponges, heavily encrusted rocks, can be as fragile as hard corals, and even less resilient (more time needed for recovery after a damage).

… almost all the vertical or overhanging walls with intense diving activity (Likuan, Celah celah, Alung Banua) have many stems of dead black coral (gorgonian?) densely fouled. I did not observe any increase in the number of those stems in the last 7 years, but they clearly indicate a mortality event … or a chronic mortality of black corals. Could this be related with divers exhaust bubbles?

Question 2. What changes in fish and invertebrate life have you noticed while diving around Bunaken NP and adjacent waters over the past decade?

Response: An initial decline in fish diversity, abundances and sizes occurred during the late 1980s - early 1990s, attributable to increasing fishing pressure, particularly destructive fishing with explosives, nets and poisons. This has been followed by a marked recovery, and perhaps stabilization in abundances in many species of reef fishes, other than reef sharks, since the mid 1990s, attributable mostly to improved management (Box 3, and see Annex V for site details).

Box 3. Diver impacts to fish, Bunaken NP, from Massimo Boyer, Celebes Divers (2003):

"I did not observe in the 7 years of my work in Manado any apparently significant change in abundance of large fish, shark, turtles.

(However) in some cases fishes that were common in a given spot are now almost impossible to see … (e.g. *Sphyraena qenie* in Barracuda point, Montehage), but … it is likely that the school of barracuda actually moved rather than disappeared.

- A significant change in Fukui point: a large school of *Siganus guttatus* disappeared gradually and almost completely in the last 7 years. They are still there, but in a very small group. I think this can be effect of fishing (probably when it was perfectly legal).

- During the past years I performed some indicator fish visual census using obligate coral feeding butterflyfish (from Crosby and Reese method). At a first glance, comparing data from 1998 and 2001, it seems that in almost all the dive spots … the number of corallivorous butterflyfish is increasing, but a decrease is noticed in Lekuan and Panggalisang.

Impact from tourist boats-resorts? My data are not enough for drawing conclusions, maybe they can give a hint.

Looking at the single species, a general decrease is observed in *Chaetodon baronessa* and *C. trifascialis*, two obligate *Acropora* feeders normally living on the large tabular *Acropora* colonies. But this could be an effect of the mortality following the late 1998 bleaching episode. ...

In light of the above anecdotal information, there is a clear consistent perception among long-term dive operators and guides that some sites have declined in terms of their coral cover and fish and invertebrate life, mostly attributable to over-use by divers (also see Annex V).

3.4 Quality of Dive Briefings

Dive briefings, on arrival of guests at the resort and / or pre-dive by dive guides, were assessed for six operators, all NSWA members. Within this group, there were marked differences in the 'quality' of dive briefings delivered to guests on arrival and by dive guides before diving. Both arrival and pre-dive briefings ranged from the cursory to the detailed.

Arrival briefing: Cursory briefings involved little more than the handing out of a set of forms, including 'Death and injury liability waivers' and a standard 'Environmental Awareness Statement' prepared by the NSWA (Annex II). By contrast, detailed briefings involved presentations and group discussions, in one case lasting for more than one hour, among the newly arrived divers, the resort operator and one or more dive guides. These briefings covering a wide range of topics relating to diving, including diving awareness / etiquette in regard to minimizing dive impact.

Pre-dive briefing: Most pre-dive briefings focused entirely or almost-entirely on site characteristics and dive profiles, with little - no mention of diver etiquette / impact. However, two companies did provide more detailed instructions in relation to avoidance of the reef.

3.5 Diver - Reef Interactions

A total of 2,364 individual interactions of divers with the reef were recorded during the ca. 38 hours of surveys (Table 5) of 176 divers (136 recreational divers and photographers and 40 guides), with an overall average of more than 60 interactions per diver per hour (Figs. 15 - 18). When analyzed in relation to the three different types of divers (recreational, photographers and guides), most interactions were caused by recreational divers (Figs. 15 - 18), who also formed more than half of the divers in the study. Highest rates of diver interaction were for touches (excluding standing) of the reef, which averaged 27 touches per diver per hour (Fig. 15). The majority of the remainder of interactions were:

- Standing by snorkelers (22 interactions per diver hr^{-1});
- holding, mostly at the end of dives in strong current, and by photographers (13 interactions per diver hr^{-1});
- sediment disturbance (10 interactions hr^{-1});
- deliberate harassment (8 interactions hr^{-1}); and
- bubbles running up walls (6 interactions hr^{-1}) (Figs. 15 and 16).

Table 5. Total numbers of diver interactions recorded in 38 hours of surveys, North Sulawesi, 2003. The numbers of interactions are listed separately for recreational divers (R), photographers (P) and dive guides (G). Photographic flashes are listed separately and excluded from the summary total for physical interactions.

Interaction type	R	P	G	Total
Touch	495	373	153	1,020
Hold	273	133	38	444
Stand	132	0	18	150
Accidental breakage	49	14	3	66
Deliberate breakage	0	1	1	2
Harassment	68	90	126	284
Sediment disturbance	73	272	54	398
Bubbles	138	40	35	213
Total	**1089**	**883**	**393**	**2,364**
Photo flashes		313		313

Accidental breakages were less common (2 breakages per diver hr^{-1}), and there were just two deliberate breakages recorded during the survey. Nonetheless, harassment and breakages, with some 10 combined interactions per diver per hour, are major negative forms of interaction, particularly when considered in the context of overall dive use in North Sulawesi (11,000 divers per year performing in excess of 100,000 dives).

In relation to differences in interactions among the three types of divers (Figs. 16 - 18), recreational divers produce, on average, slightly more interactions per diver per hour than do photographers. Dive guides have substantially fewer overall interactions per diver per hour.

Most accidental breakages were caused by recreational divers, positively correlated with their abundance in the diver sample (> 50 %). By contrast, photographers caused a disproportionate amount of sediment disturbance, and were responsible for one of the two deliberate breakage incidents recorded. Dive guides, which formed a smaller proportion of the total diver sample (< 25 %), accounted for a disproportionate amount of harassment, and caused the other deliberate breakage.

In relation to differences in frequency of interactions among different dive sites, the busiest sites in Lembeh Strait are subject to far more interactions than sites in Bunaken NP (Fig. 19). This is primarily attributable to sediment disturbance and harassment by photographers, particularly macro-photographers focused on small, usually cryptic animals (e.g. pygmy sea-horses). Photographers in general, and macro-photographers in particular, form a larger proportion of divers in Lembeh Strait than elsewhere, as the area is renowned for its 'critter' diving and photo opportunities. In some cases, lines of photographers gather to photograph the same particular animal, waiting patiently for their turn, firing off multiple flashes in quick succession. The direct impact of the flashes on the species being photographed is unknown at present, although second-order effects of enhanced predation are well known (see questionnaire section Ic and Annex V).

Differences among / within operators

The present study focused on obtaining the broadest sample of divers and dive operations achievable during a three-week field survey period. Even so, four operators were resurveyed on two different occasions. These re-surveys revealed major differences in both numbers and types of interactions among different dive groups of the same operator. Indeed, one of the resurveyed operators had both the lowest and among the highest

numbers of interactions per diver per hour. This operator also had one of the best dive briefing protocols, with detailed briefings to divers on arrival and also pre-dive.

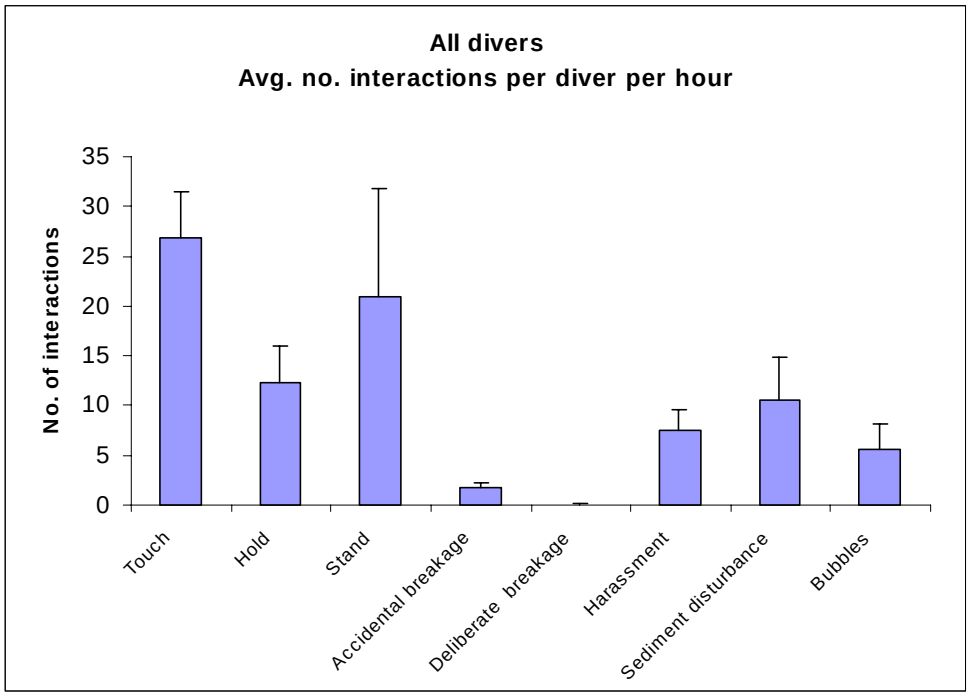

Figure 15. The average number of interactions per diver per hour (and s.e.), for all divers combined, North Sulawesi, 2003.

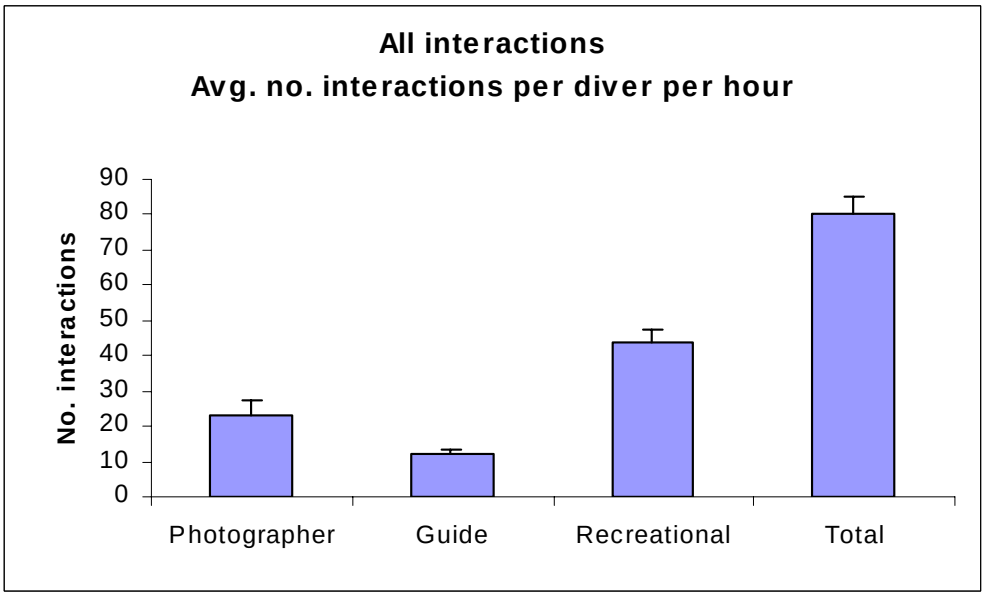

Figure 16. The average number of interactions per hour (plus s.e.) among three different types of divers, North Sulawesi, 2003.

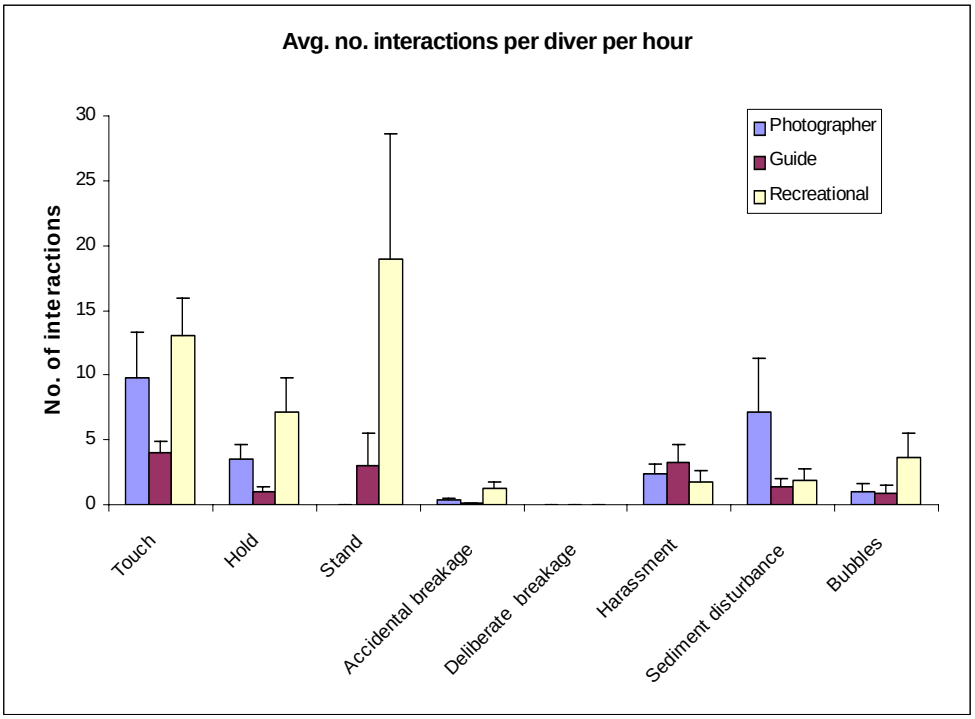

Figure 17. The average numbers of different types of interactions per diver per hour (plus s.e.) for each diver category, North Sulawesi, 2003.

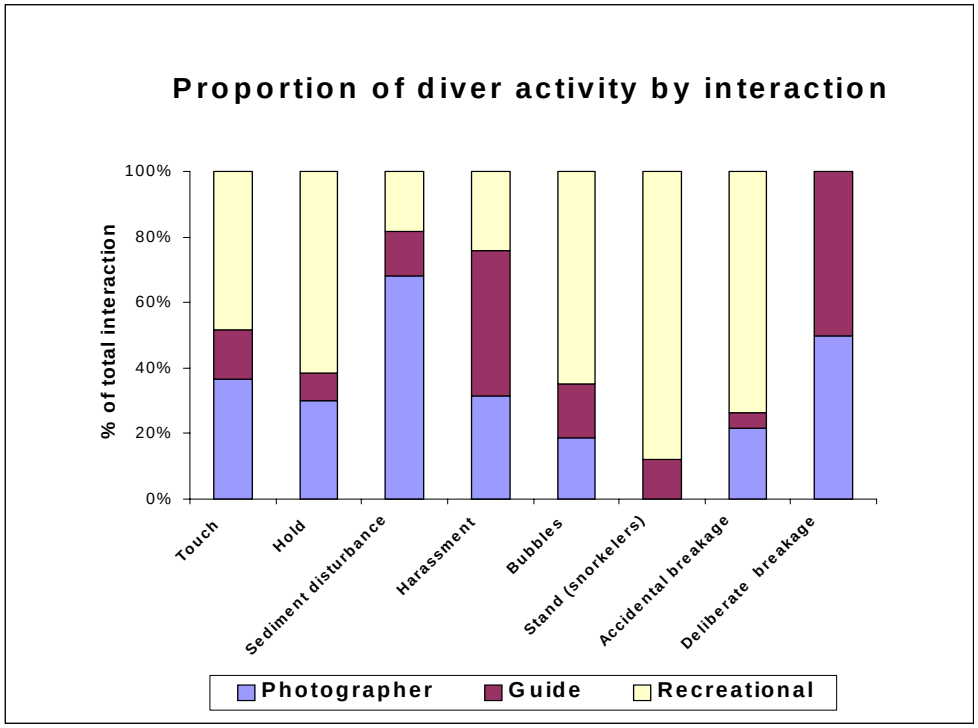

Figure 18. The relative contribution to each form of interaction made by different diver categories.

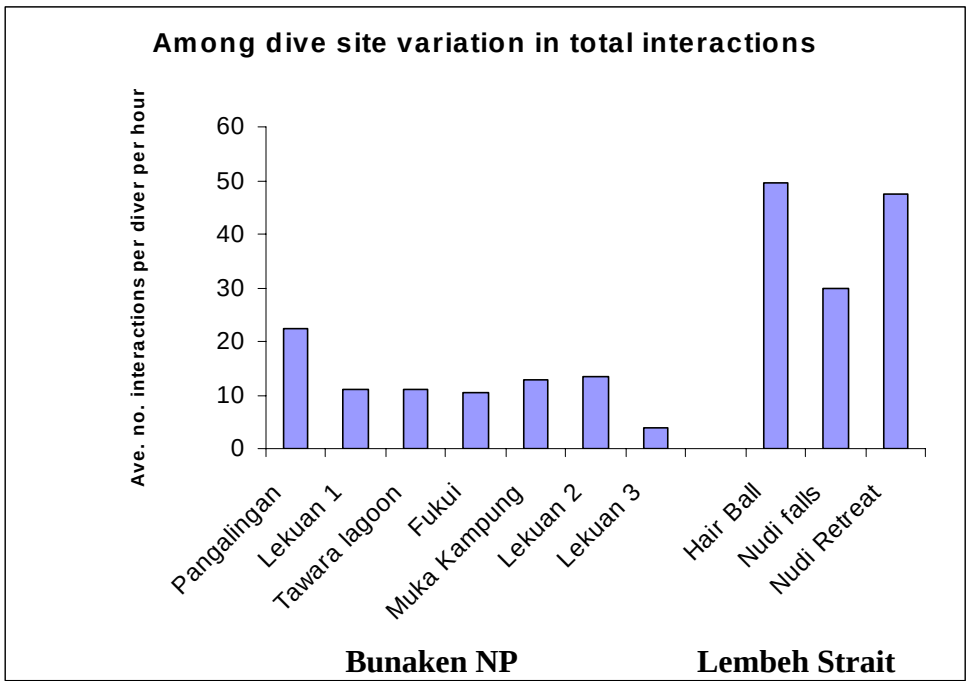

Figure 19. Comparison of total interaction frequencies per diver per hour among different dive sites. Sites were censused on one occasion only.

In summary, the diver interactions surveys revealed wide ranges in both the numbers and types of interactions among different divers and different dive groups, and among and within operators. Even for the same operator, with high quality briefings and dive guide procedures, different dive groups behaved very differently. There was also a wide range in 'quality' of dive guides, in relation to dive briefings, underwater supervision / dive guidance and levels of harassment. Some dive guides were among the worst offenders in terms of harassment, actively seeking out 'critters' for their clients. This practice is encouraged by some operations, as the dive clients have paid to see and photograph these particular animals (e.g. pygmy seahorses), and the operators and their guides feel obliged to deliver.

These findings suggest the need for improvement in dive briefings among some operators, and training for some guides. The findings also suggest that even with improved briefings among all operators and better-trained guides, some divers and dive groups will continue to interact inappropriately with the reef. This in turn suggests the need for the introduction of diver CC limits, in addition to the LAC approach.

3.6 Dive Site Condition - Quantifying Diver Impacts

The anecdotal information from long-term dive operators suggested that substantial changes have occurred in many dive sites over the past decade (Result section Ic and Annex V). The dive use surveys further indicate that use levels at some of the busiest sites are approaching or exceeding CC limits known to cause significant damage in other reef areas. The next section quantifies the condition of four of these heavily dived sites in relation to coral cover, community structure and levels of damage, providing detailed 'base-lines' for these four sites from which LAC levels and future changes may be assessed (Figs. 20 - 33).

Coral cover and community structure (25m point-intercept line transects)

Despite high levels of diver use, cover of living reef-building corals remained high at the four sites, ranging between 40 and 50% (Fig. 20), being highest at Lekuan III. Cover of recently dead corals ranged between five and 15%, being highest at Fukui and lowest at Bunaken Timor. Cover of coral rubble ranged between ca. 10 and 30%, being highest at Fukui.

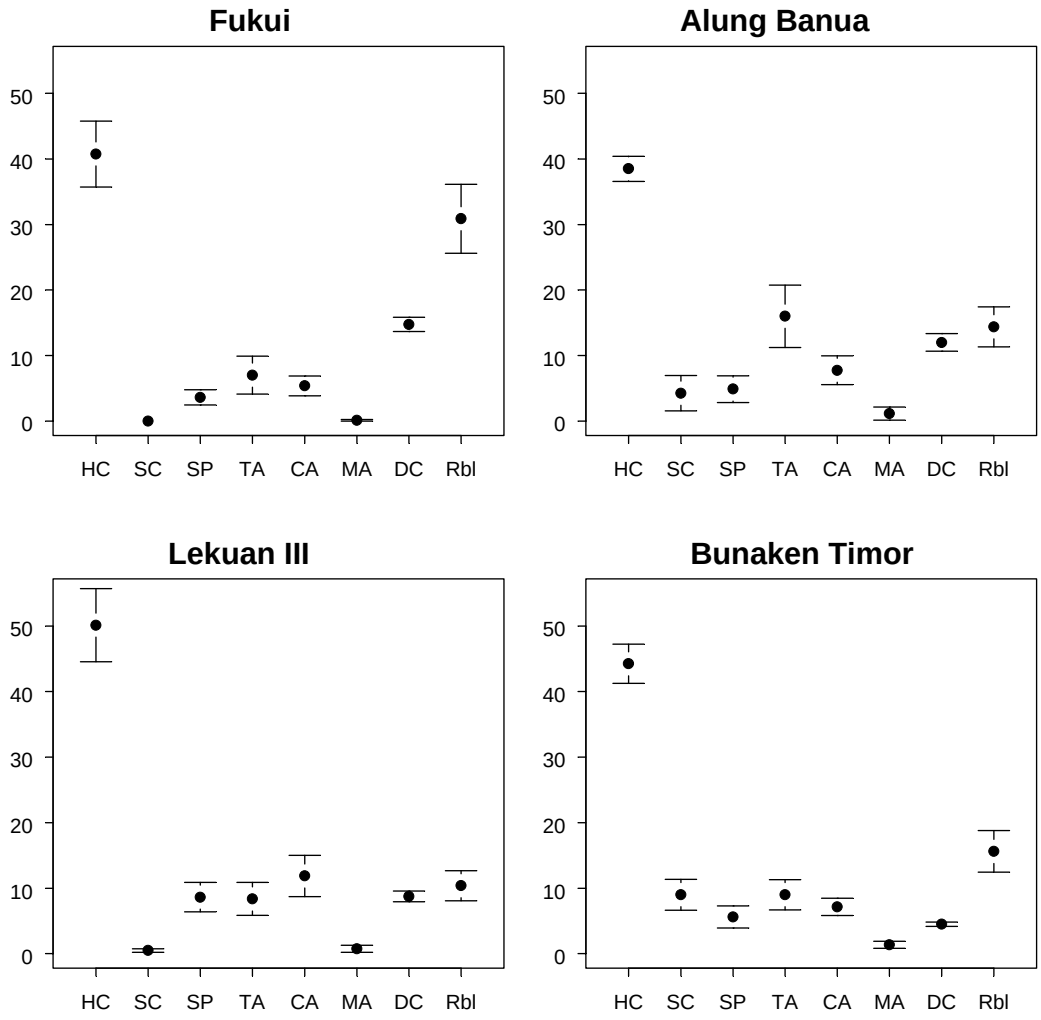

Figure 20. Average percent cover (Y axes, with s.e.) of sessile benthic attributes in four replicate 25 m line transects at two depths at four heavily-dived sites, Bunaken NP, North Sulawesi. HC - Hard Corals (including hydro-corals *Millepora* spp.), SC - Soft Corals and gorgonians, SP - Sponges, TA - turf algae, CA - Coralline Algae, MA - Macro-algae, DC - dead corals and RBL - Rubble.

Cover of dead coral and coral rubble (both > 5 %) at all four sites, are higher than the Coral Damage Index values (e.g. 3 % rubble) considered as identifying diver damage 'hot-spots' in the Red Sea (Jameson et al. 1999). However, some of the dead coral and rubble in the present study may have been produced by factors other than diving-related causes, notably previous destructive fishing at Fukui (NSWA operators and M. Erdmann, NRM III, pers. comm.). Nevertheless, rubble and broken corals continue to be produced

through diving-related activities in all four sites, including through boat strike, illegal anchoring, inappropriate placement of moorings and diver interactions (Plates 1 - 4 and see later).

Average cover of living hard corals was higher on the shallow slopes (48%, Fig. 21) than the deeper counterparts (39%). By contrast, cover of rubble was higher on the deeper slopes, in part attributable to down-slope transport (Fig. 21).

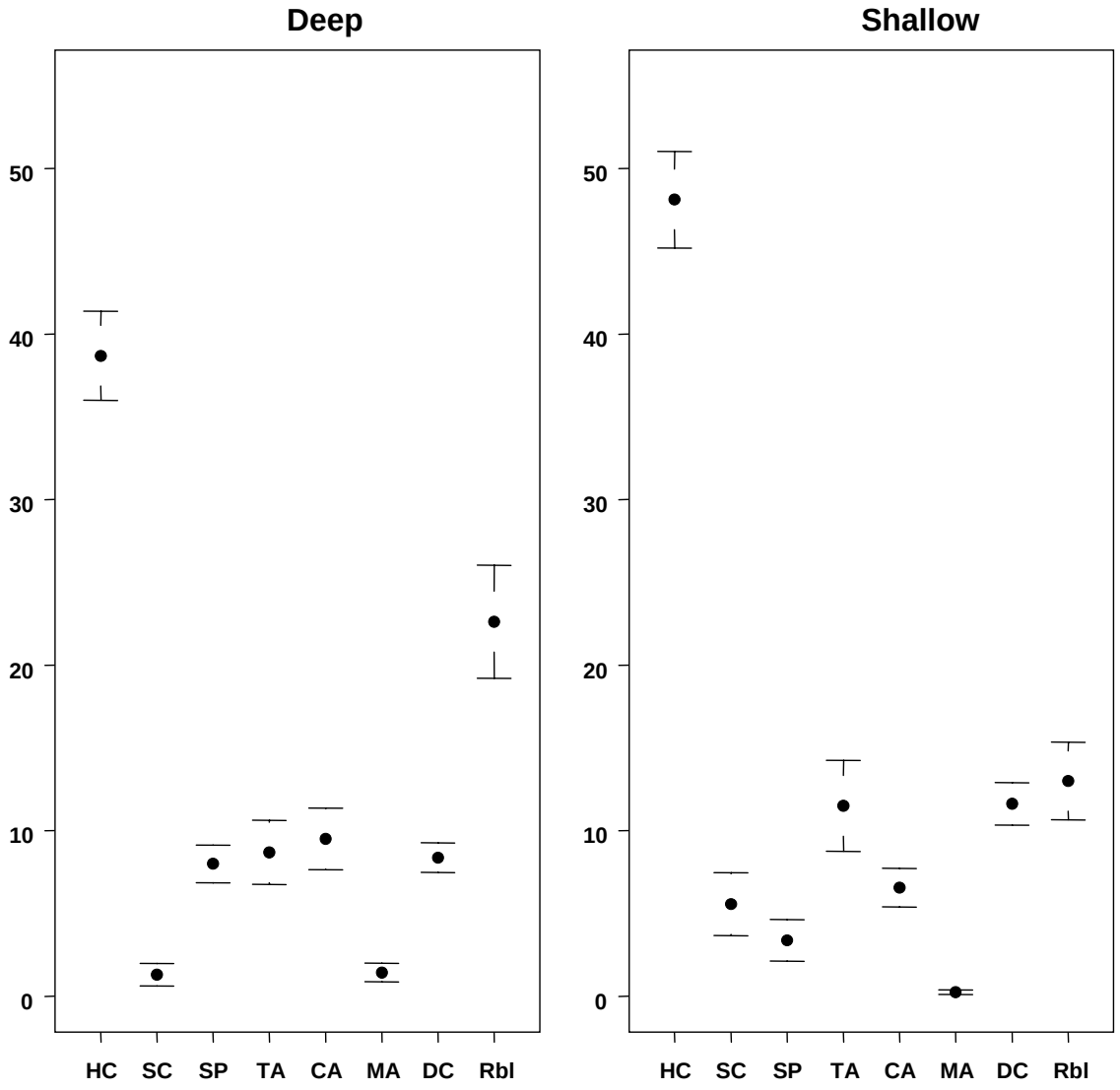

Figure 21: Depth-related differences in percent cover (Y axis, with s.e.) of sessile benthic attributes in four heavily dived sites, Bunaken NP, North Sulawesi, 2003. Codes for attributes are the same as for Fig. 20.

There were few major differences among the four sites in terms of these broad attributes of benthic cover (Fig. 22), other than the greater cover of coral rubble at Fukui.

Plate 1. Broken and pulverized coral *Porites* and *Acropora* spp. caused by boat strike, Alung Banua, Bunaken NP, North Sulawesi, 2003.

Plate 2: Broken coral, including *Montipora*, *Porites* and *Millipora* spp., caused by boat strike, Lekuan III, Bunaken NP, North Sulawesi, 2003.

Plate 3. Inappropriate placement of shallow mooring around massive coral *Porites* sp., Alung Banua, Bunaken NP, North Sulawesi, 2003. The mooring was subsequently removed by R. Paat.

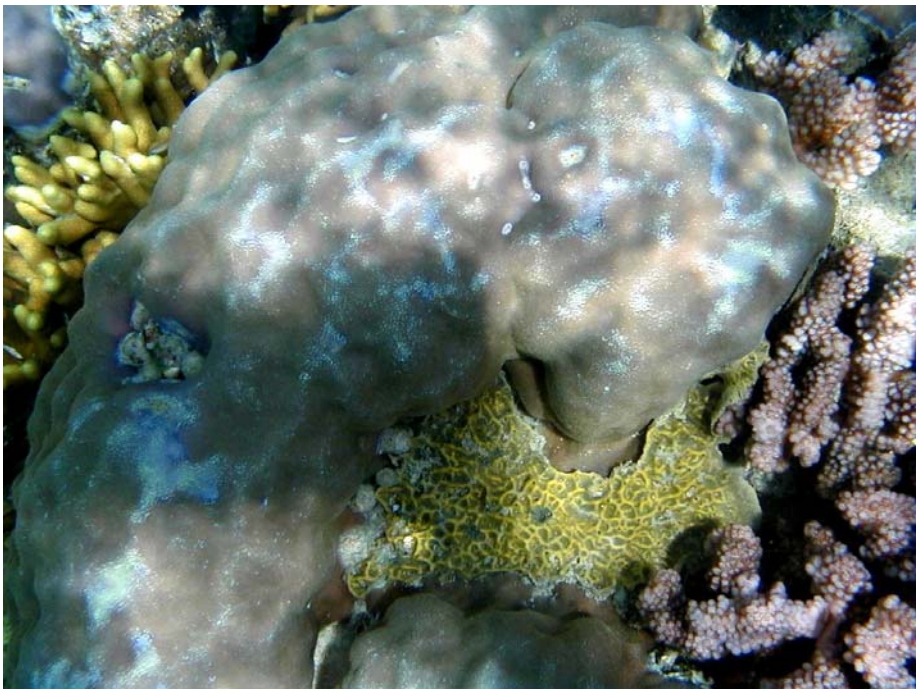

Plate 4. Abrasions to massive coral *Porites* sp. and broken branching coral *Porites cylindrica* (top left) and *Pocillopora verrucosa* (bottom right), Alung Banua, North Sulawesi, 2003.

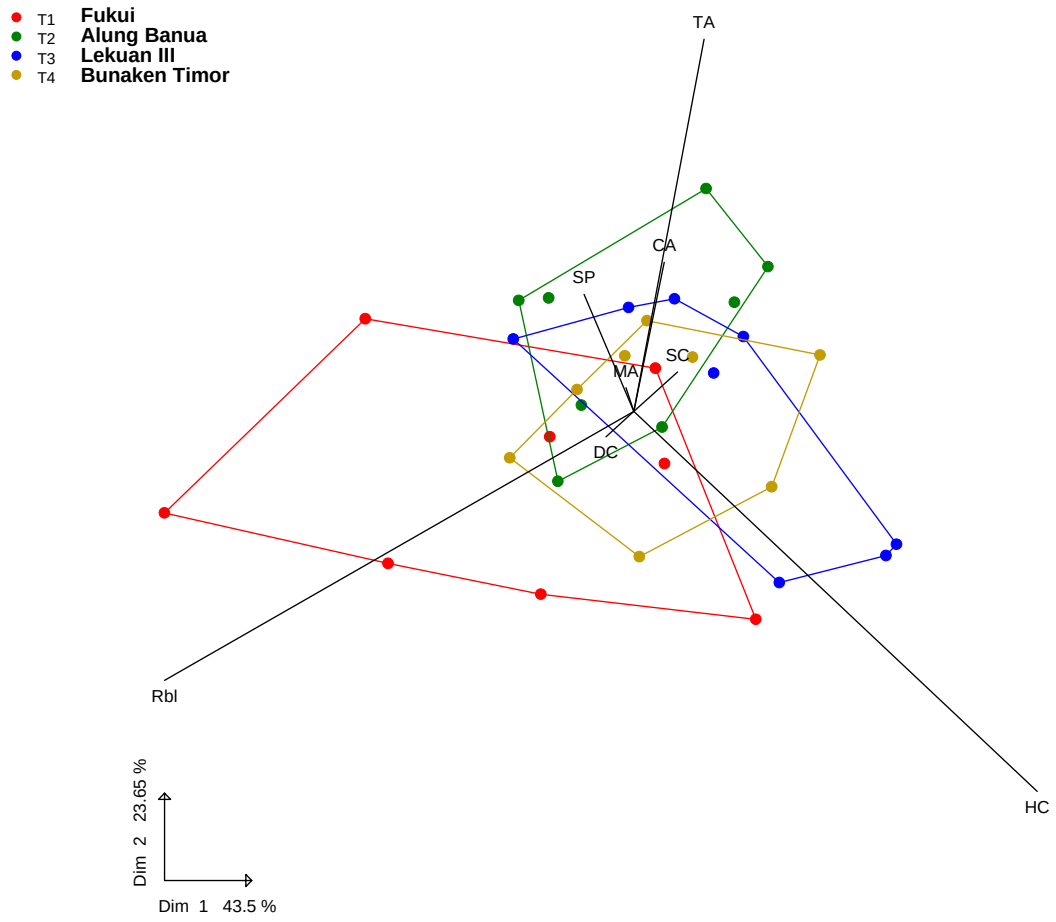

Figure 22. Principal Components Analysis biplot of the distribution of 8 transects (designated by coloured circles) in each of four sites (T1 - T4) in relation to their benthic cover attributes. Attribute codes are the same as for Fig. 20. PCA dimensions 1 and 2 account for 67% of the total variance.

There were however, larger differences in coral community structure among the four sites in relation to the different coral species present and their relative abundances (Fig. 23).

Corals in the four dive sites form four community types (KM1 - KM4, Fig. 24), characterized by key indicator species (Fig. 25), and broadly differentiated by depth:

- most shallow sites - KM1 and KM3;
- most deep sites - KM2 and KM4.

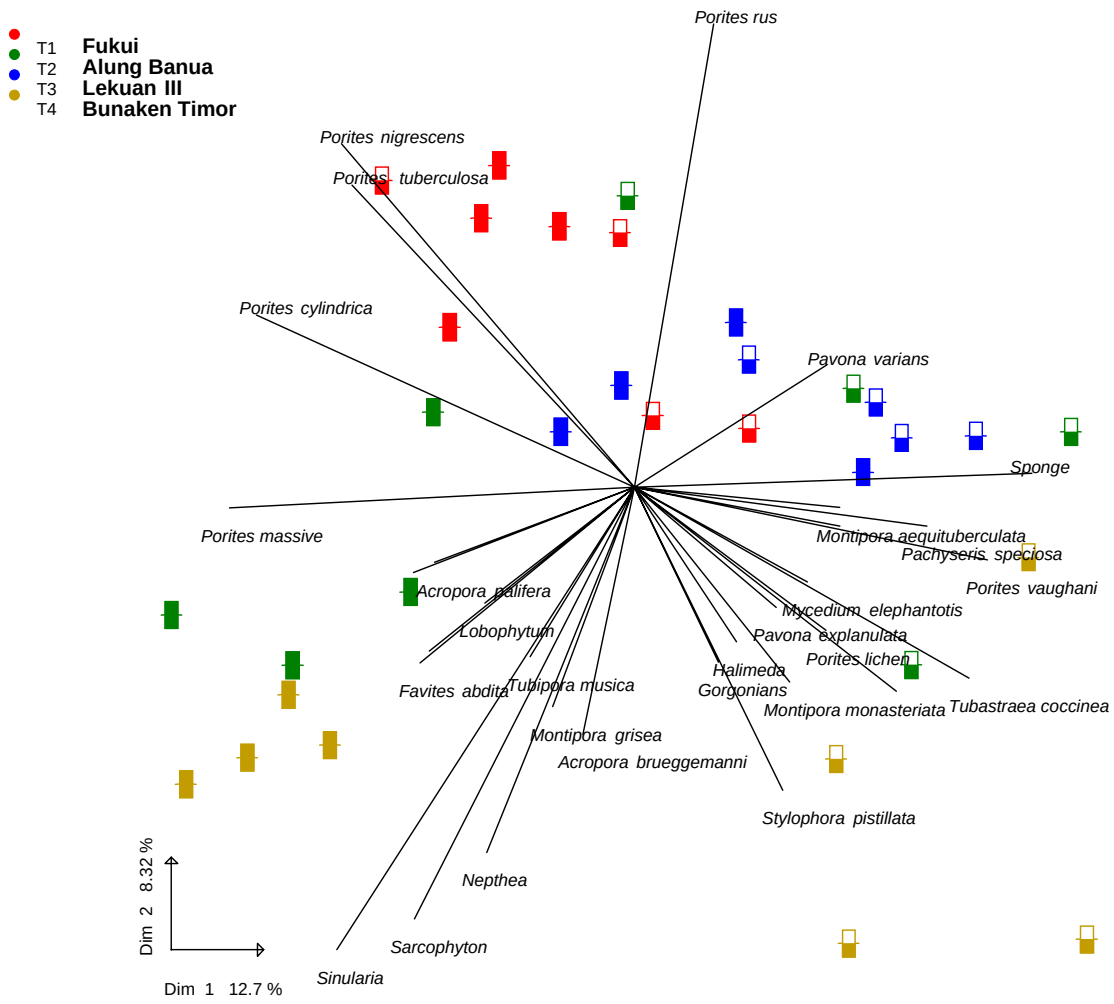

Figure 23. PCA biplot of the distribution of 8 transects (the 'thermometer' symbols) in each of 4 heavily dived sites (T1 - T4) in relation to coral community structure, Bunaken NP, North Sulawesi, 2003. The amount of fill in the thermometers represents either deep (half fill) or shallow (full fill) transects. Key coral species that help differentiate the transects are named. Vectors point in the direction of the highest percent cover values for each coral species. Dimensions 1 and 2 account for 21% of the total variance.

Some coral species showed little fidelity to a particular community type but occurred commonly in several. Notable among these ubiquitous species were the poritids *Porites cylindrica*, *Porites* of massive growth-form and *Porites rus* and the stout branching - columnar acroporid *Acropora palifera* (Fig. 25).

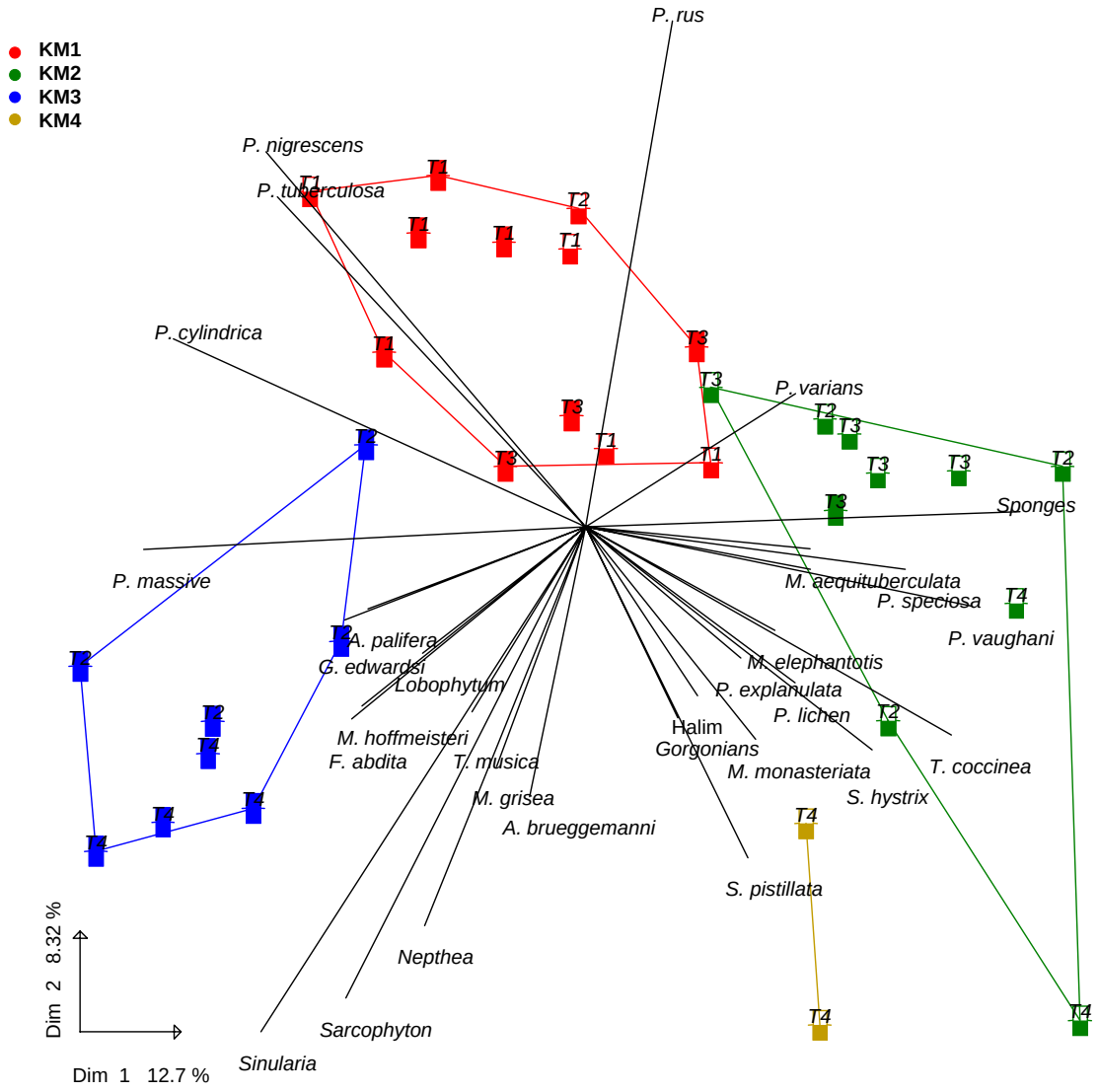

Figure 24. PCA biplot of the ecological distribution of transects (the 'thermometer' symbols) in each of 4 heavily dived sites (T1 - T4) in relation to coral community structure, Bunaken NP, North Sulawesi, 2003. Colours of the thermometers and the joining convex hulls denote each of four coral community types. The amount of fill in the thermometers represents either deep (half fill) or shallow (full fill) transects. Key coral species that differentiate the communities are named. Vectors point in the direction of the highest percent cover values for each species. Dimensions 1 and 2 account for 21% of the total variance.

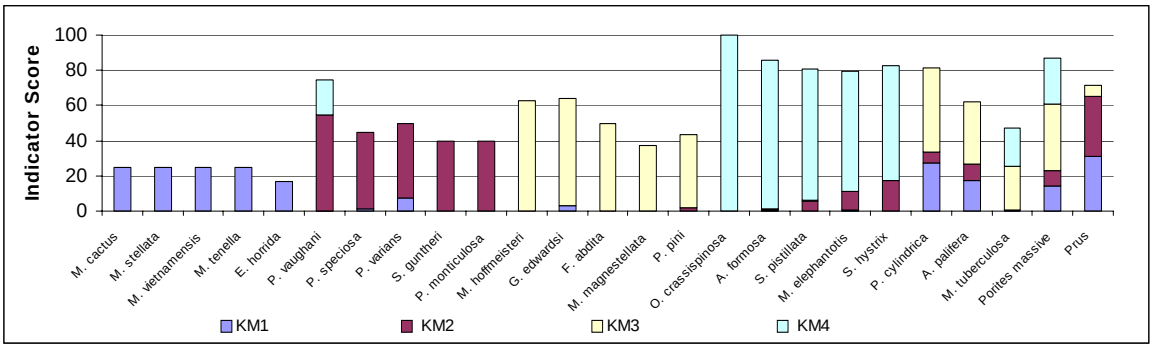

Figure 25. Key indicator coral species for communities KM1 - KM4, and ubiquitous species showing little fidelity to a particular community.

Coral breakage (100m^2 belt transects)

All sites had high numbers of broken corals and free-living fragments (Fig. 26), ranging from ca. 90 - 290 broken corals and fragments 100m^{-2} transect. Detached fragments were more common than broken attached corals at all sites other than Fukui deep slope. There, broken corals that remained attached to the substrate were very common (ca. 120 colonies 100m^{-2} transect), double or greater the number at all other sites, and probably attributable, at least in part, to poor buoyancy control among the trainee divers that frequent the site.

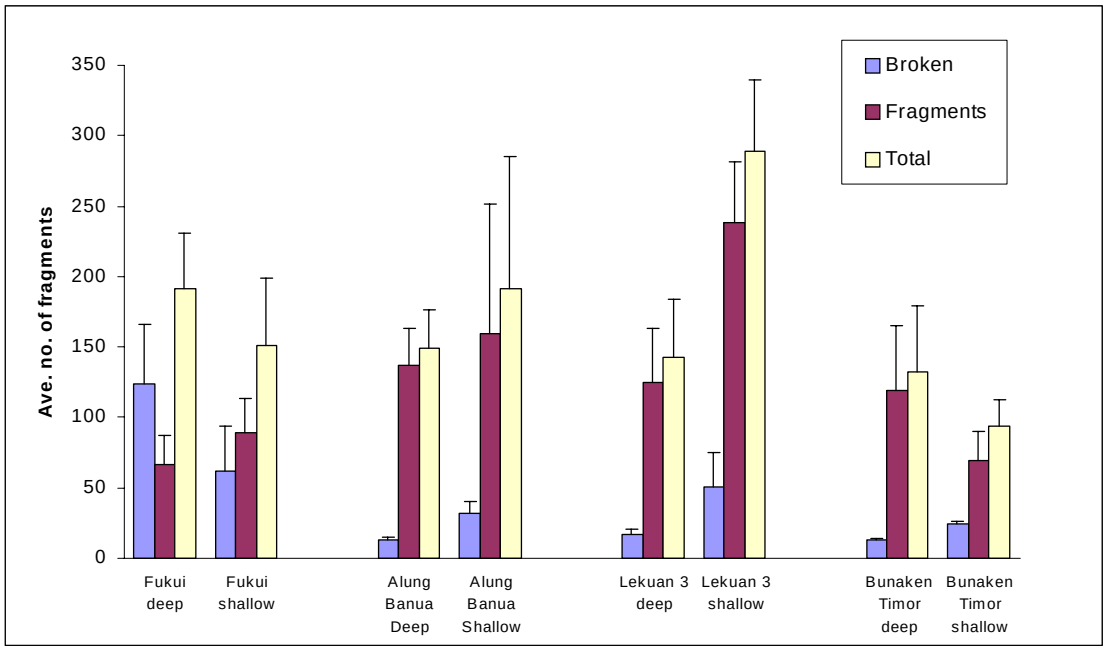

Figure 26. Average numbers (plus s.e.) of broken corals and detached fragments at two depths at four heavily-dived sites, Bunaken NP, North Sulawesi, 2003.

Of the broken, attached corals, most had relatively low levels of colony damage (i.e. damage of 0.1 or 10% or less of the colony broken, Fig. 27), rather than being heavily smashed. Whilst this may be taken as evidence that most of the damaged, attached corals will survive, such breakage may make the colonies more prone to infection by disease, and thus even low levels of breakage are a cause for concern.

Highest numbers of unattached living coral fragments occurred in the shallow site at Lekuan III (Fig. 26), with ca. 240 fragments $100m^{-2}$ transect and 300 broken corals and fragments per transect in total.

These numbers of fragments are among the highest observed by the present authors in ca. 40 years of coral surveys on Indo-Pacific reefs, being rivaled only by heavy cyclone impacts.

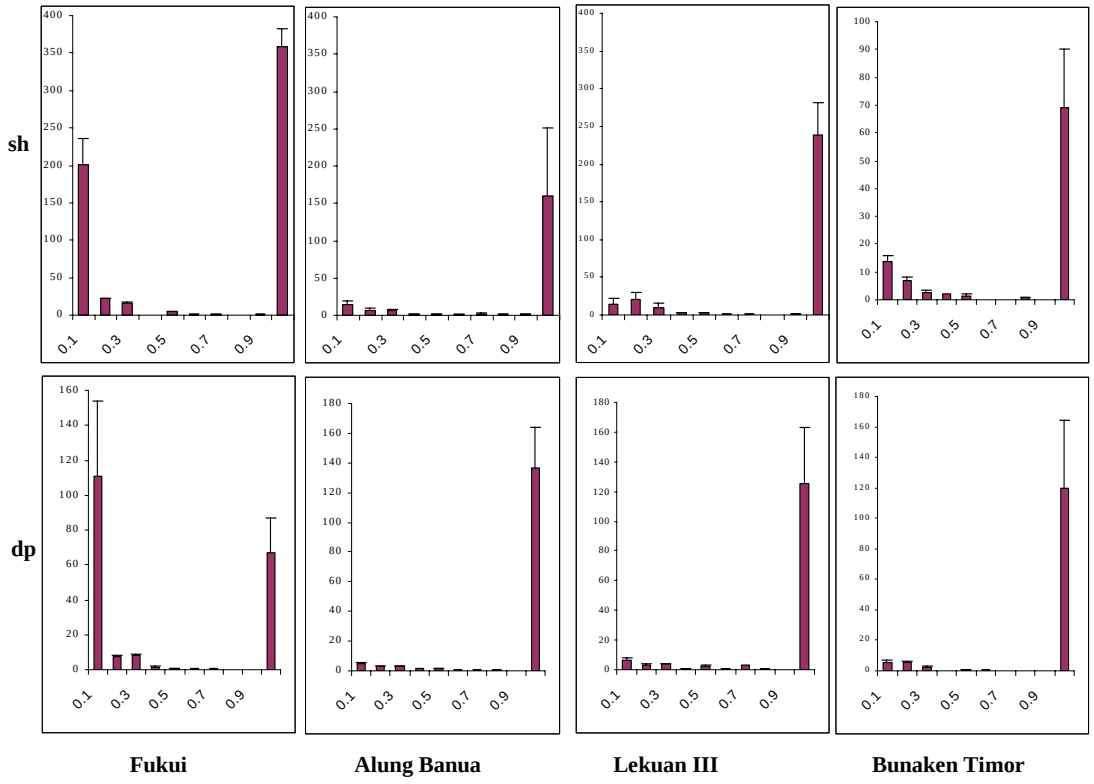

Figure 27. Average numbers (plus s.e.) of broken attached corals in each of nine classes of increasing colony damage (0.1 - 0.9) and detached fragments (1) in two depths (shallow - sh; deep - dp) at four heavily dived sites, Bunaken NP, North Sulawesi, 2003. Note that scales on Y axes among sites are different.

Among the four sites, the shallow slope at Lekuan III exhibited highest damage levels (Fig. 28), both in terms of overall total damage (sum of damage levels 0.1 - 1 in all damaged corals) and the number of damaged corals (count of damaged corals irrespective of damage level). The other sites were more similar to each other in terms of these indices. Overall similarities in scores for both indices at most depths and sites reflects the high proportion of detached fragments (score of 1), other than at the deeper slope of Fukui (Figs. 26 and 27), which was more dominated by broken, attached coral colonies (with damage scores of 0.1 - 0.9). Notably Lekuan III and Fukui are preferred training dive sites by most operators, and the impact of novice divers is likely to be significant, most notable in the present data set on the deeper slope at Fukui.

The level of damage to coral communities was not consistent among transects within sites. Rather there was a wide range in the levels of damage to corals in individual transects in each site, both in terms of total damage (Fig. 29) and numbers of damaged corals (Fig. 30). This level of variation also occurred among the four coral community types (KM1 - KM4, Figs. 30, 31), such that no particular community appeared substantially more or less impacted than the others.

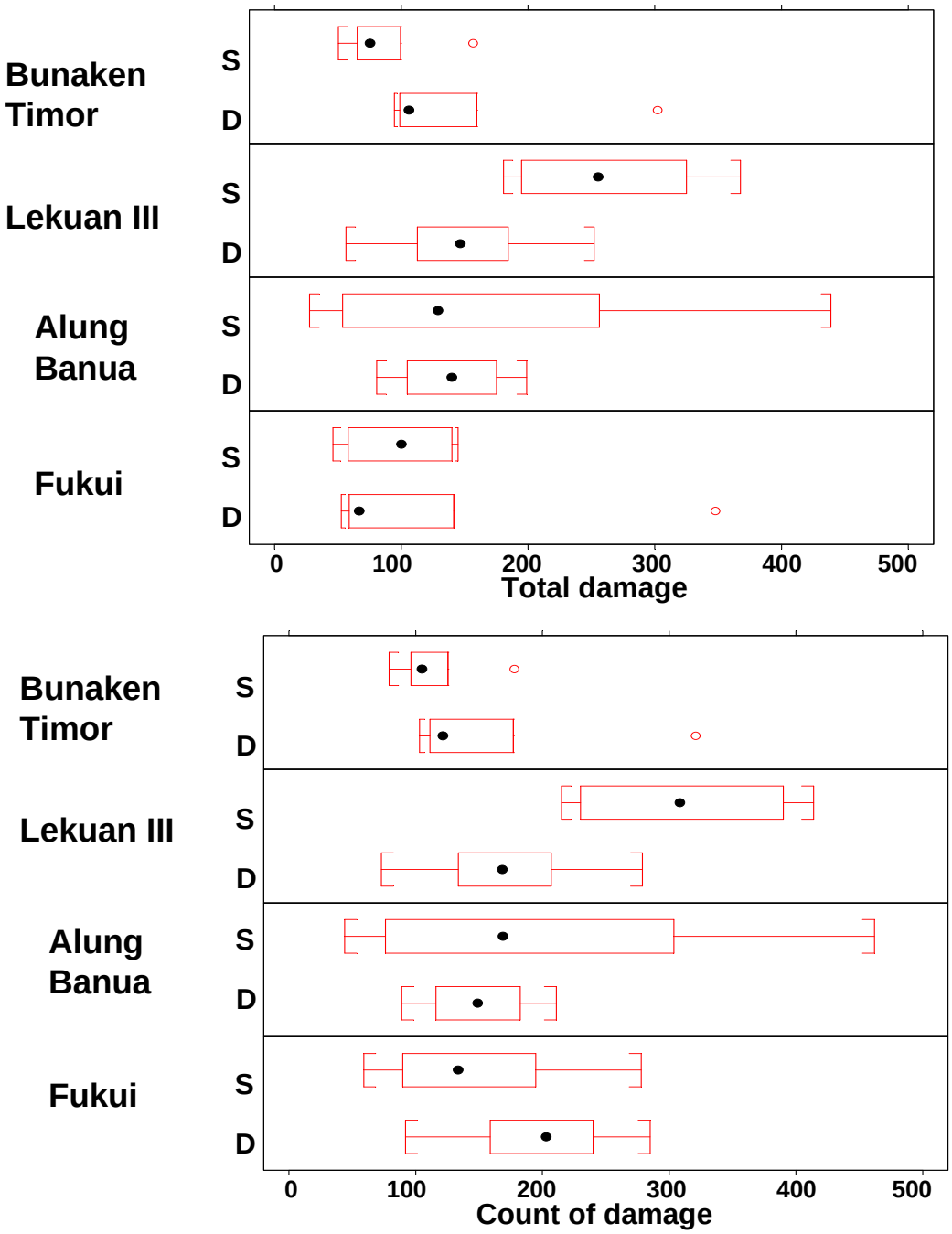

Figure 28. Box plots of median values (dots), upper and lower quartiles (boxes denote 50 % of the data ranges), the normal data ranges (bars) and any outliers (circles) for Total damage (sum of all damage records from 0.1 - 1 for all corals, top plot) and Counts of damage (numbers of damaged corals, irrespective of level of damage, lower plot) at two depths (S - shallow; D - deep) in four heavily dived sites, Bunaken NP, North Sulawesi, 2003.

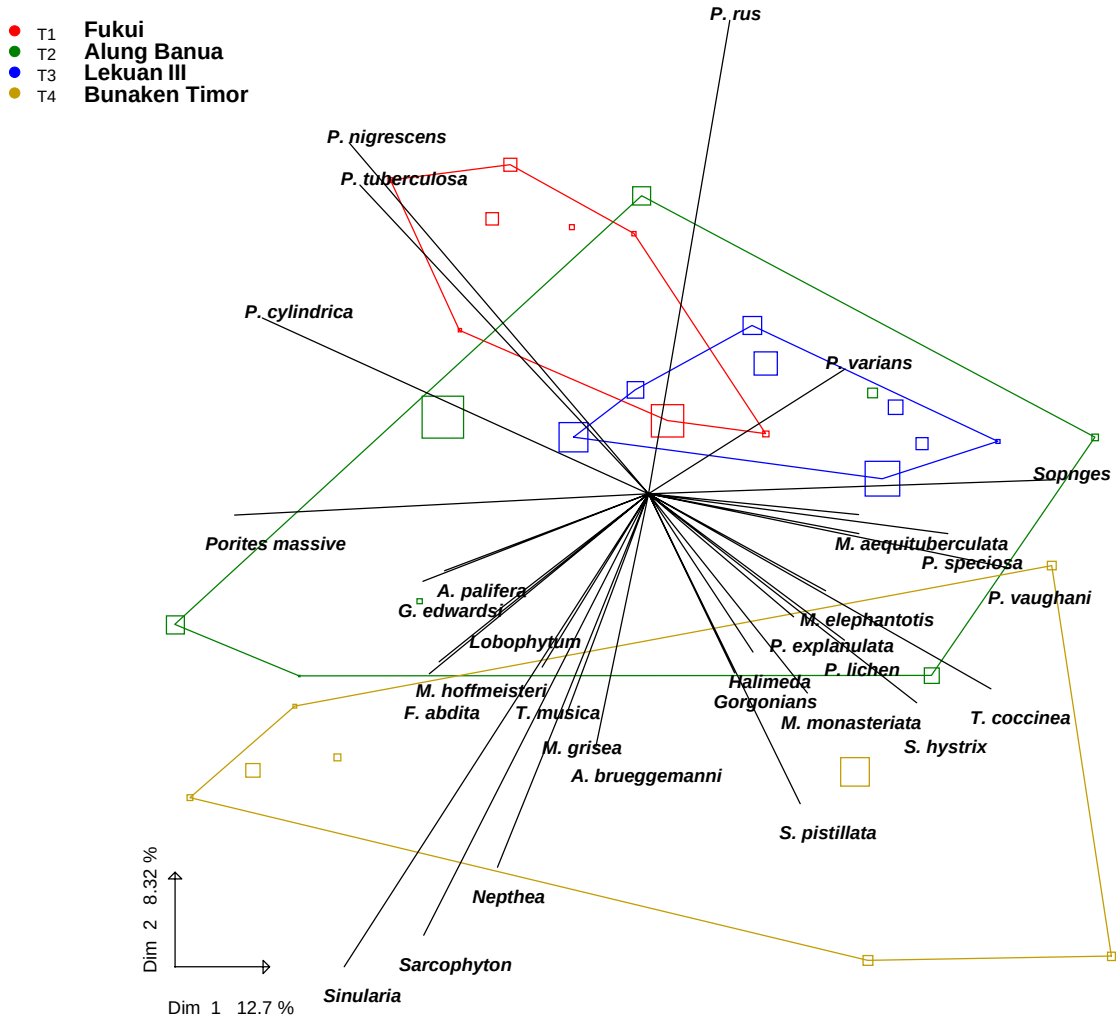

Figure 29. PCA biplot of the four heavily dived sites (denoted by differently colored convex hulls, with the corner squares representing transects) in relation to their coral community structure (also see Fig. 23). Levels of total damage (sum of all damage scores of 0.1 - 1) in each transect are scaled, with size of the transect squares representing amount of total damage in each transect.

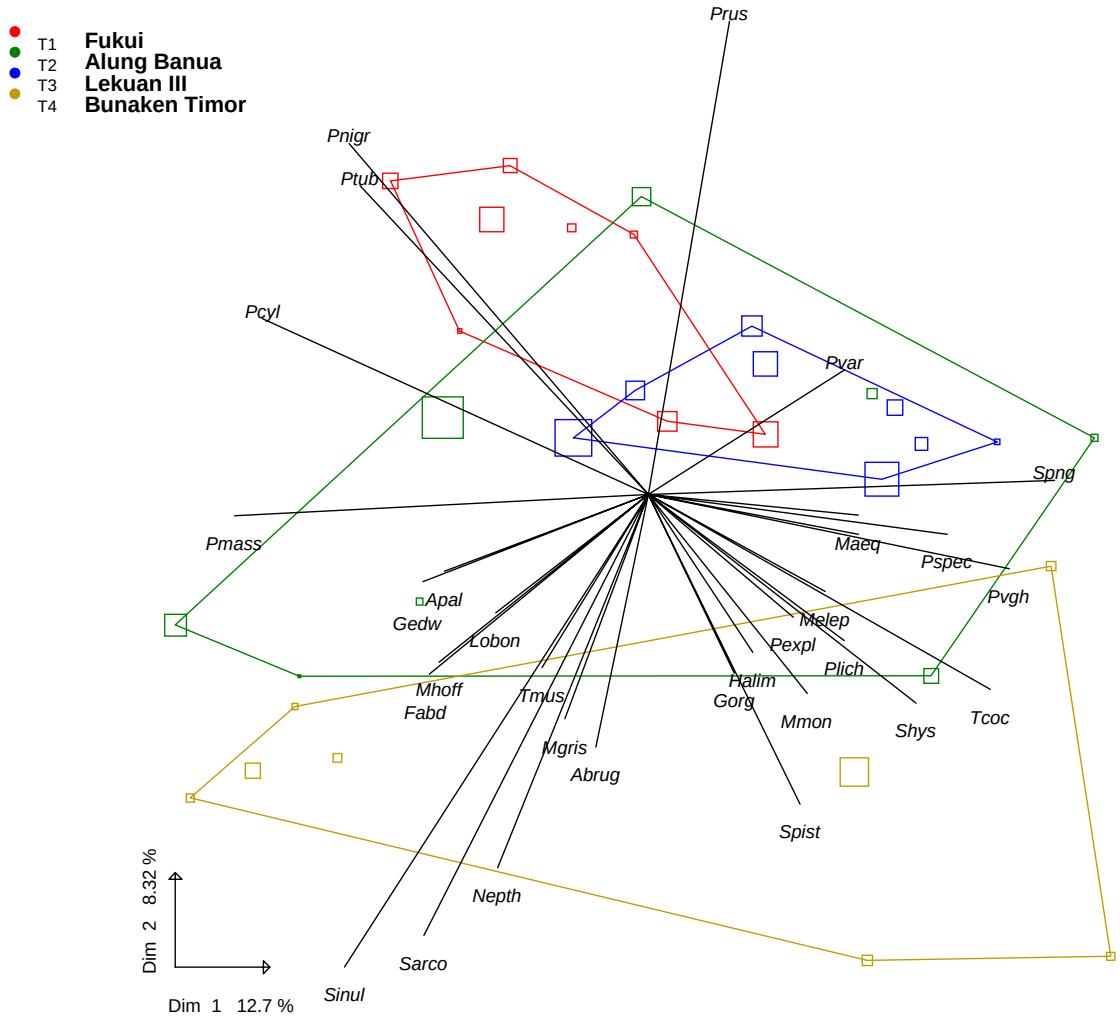

Figure 30. PCA biplot of the four heavily dived sites (denoted by differently colored convex hulls, with the squares representing transects) in relation to their coral community structure (also see Fig. 23). Counts of damage scores (irrespective of individual amounts of colony damage) in each transect are scaled, with size of squares representing total count of damage in each transect. Species names are abbreviations of those in Fig. 29.

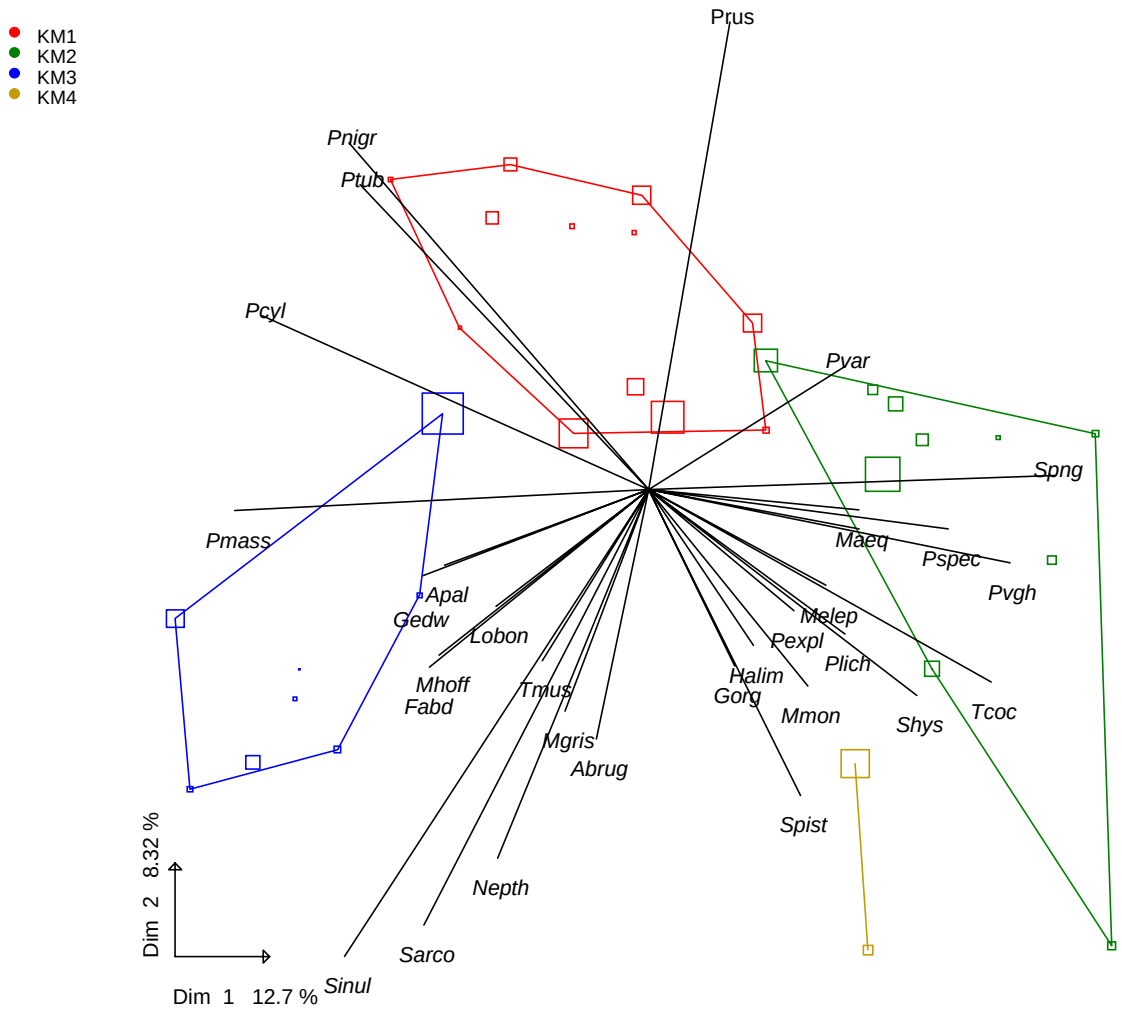

Figure 31. PCA biplot of the four coral communities (KM1 - KM4, denoted by differently colored convex hulls, with the corner squares representing transects) in relation to key species (also see Fig. 24). Levels of total damage (sum of all damage scores of 0.1 - 1) in each transect are scaled, with size of squares representing amount of total damage in each transect. Species names are abbreviations of those in Fig. 29.

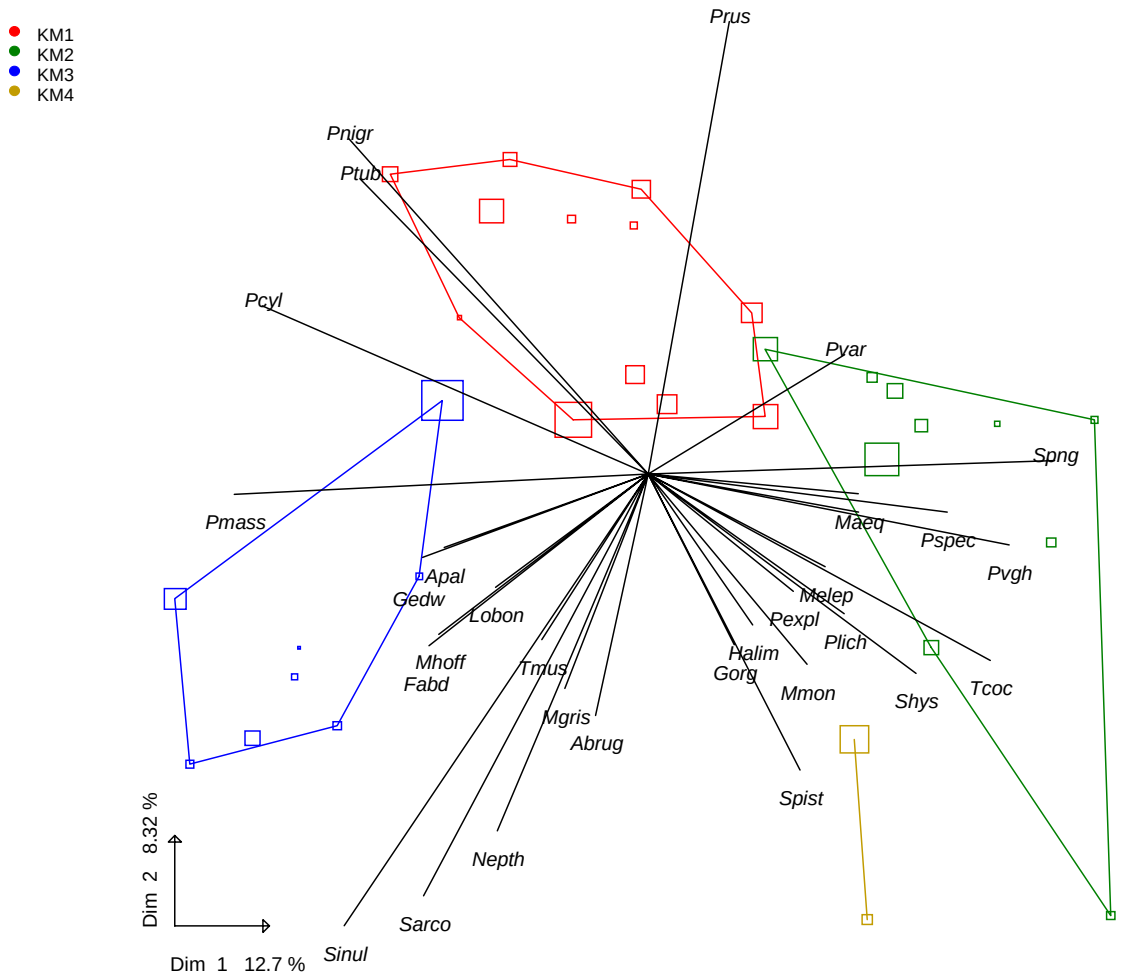

Figure 32: PCA biplot of the four coral communities (KM1 - KM4, denoted by differently colored convex hulls, with the squares representing transects) in relation to their coral community structure (also see Fig. 23). Counts of damage scores (irrespective of individual amounts of colony damage) in each transect are scaled, with size of squares representing total count of damage in each transect. Species names are abbreviations of those in Fig. 29.

Species diversity and abundance of damaged corals

The species diversity of fragments (representing some 200 coral species in total) and production of 'coraliths' (free-living colonies with living tissues on all sides because of regular over-turning) are the highest known to the present authors.

Species exhibiting most impact (producing most fragments and broken attached corals) included a wide range of coral genera and growth forms (Table 8). The branching poritids *Porites cylindrica* and *Porites nigrescens* experienced highest impact, followed by the foliose acroporid *Montipora aequituberculata*, pectinid *Mycedium mancaoi* and oculinid *Galaxea horrescens* (Table 6).

Table 6: The 20 coral species exhibiting highest levels of colony damage and fragmentation. Total damage is the sum of all damage scores (0.1 - 1) for each species from 8 belt transects in the four heavily dived sites, Bunaken NP, North Sulawesi, 2003. Typical growth-forms of each species and its natal family are also listed. DB - Delicate Branching; B - Branching; SB - Stout Branching; D - Digitate; F - Foliose, M - Massive; E - Encrusting.

Species	**Growth form**	**Family**	**Total damage**
Porites cylindrica	B	Poritidae	770.44
Porites nigrescens	B	Poritidae	747.67
Montipora aequituberculata	F	Acroporidae	406.7
Mycedium mancaoi	F	Pectinidae	236.39
Galaxea horrescens	DB	Oculinidae	207.2
Seriatopora hystrix	DB	Pocilloporidae	188.3
Acropora brueggemanni	SB	Acroporidae	166.1
Montipora cactus	B	Acroporidae	161
Montipora stellata	F - D	Acroporidae	149.7
Montipora foliosa	F	Acroporidae	101.22
Porites tuberculosa	SB	Poritidae	96.6
Tubastraea coccinae	B	Dendrophyllidae	93.2
Hydnophora rigida	DB	Merulinidae	90.7
Millepora tenella	B	Milleporidae	67.2
Millepora exesa	E	Milleporidae	59.6
Montipora vietnamensis	B - E	Acroporidae	58.7
Stylophora pistillata	B	Pocilloporidae	56.4
Porites massive	M	Poritidae	49.5
Montipora hirsuta	DB	Acroporidae	46.5
Porites rugosa	B	Poritidae	46.1

As may be expected, corals of branching and foliose growth-forms were most affected, with just one massive species group (*Porites*) in the 20 species with highest damage and fragmentation levels. Because the survey only recorded broken living corals and living coral fragments, it is reasonable to assume that most of the damage recorded was attributable to diving-related impacts. However, as noted above, a small proportion of total damage may be caused by other sources such as “after hours” illegal fishing in tourism zones (M. Erdmann and C. Muller, pers. comm.).

The duration of survival of free-living fragments is unknown, but may range from several weeks (where fragments are transported by waves / currents into unsuitable habitat) to years (particularly for species that most readily form coraliths). The high diversity and abundance of coraliths suggest that their survivorship may be higher in Bunaken NP than in many other reef areas, in response to the highly equitable environmental conditions for coral growth there. Furthermore, some fragments reattach to the reef substrate and continue to grow, forming new colonies and dispersing their natal clones across the reef. Many fragments however, do not survive, contributing to the accumulated coral rubble, notably very high in the present study sites (c.f. Jameson et al. 2001). A substantial proportion of fragments is transported down the reef slope beyond their preferred habitat and environmental conditions, contributing to the talus debris.

That certain species are more prone to breakage than others is illustrated by the relation between the percent cover and amount of damage for each species (Fig. 33). Foliose species such as *Mycedium mancaoi* and *Montipora stellata* and branching *Acropora brueggmanni* were most susceptible in these sites, exhibiting very high levels of damage with relatively low overall percent cover (< 1% for each species).

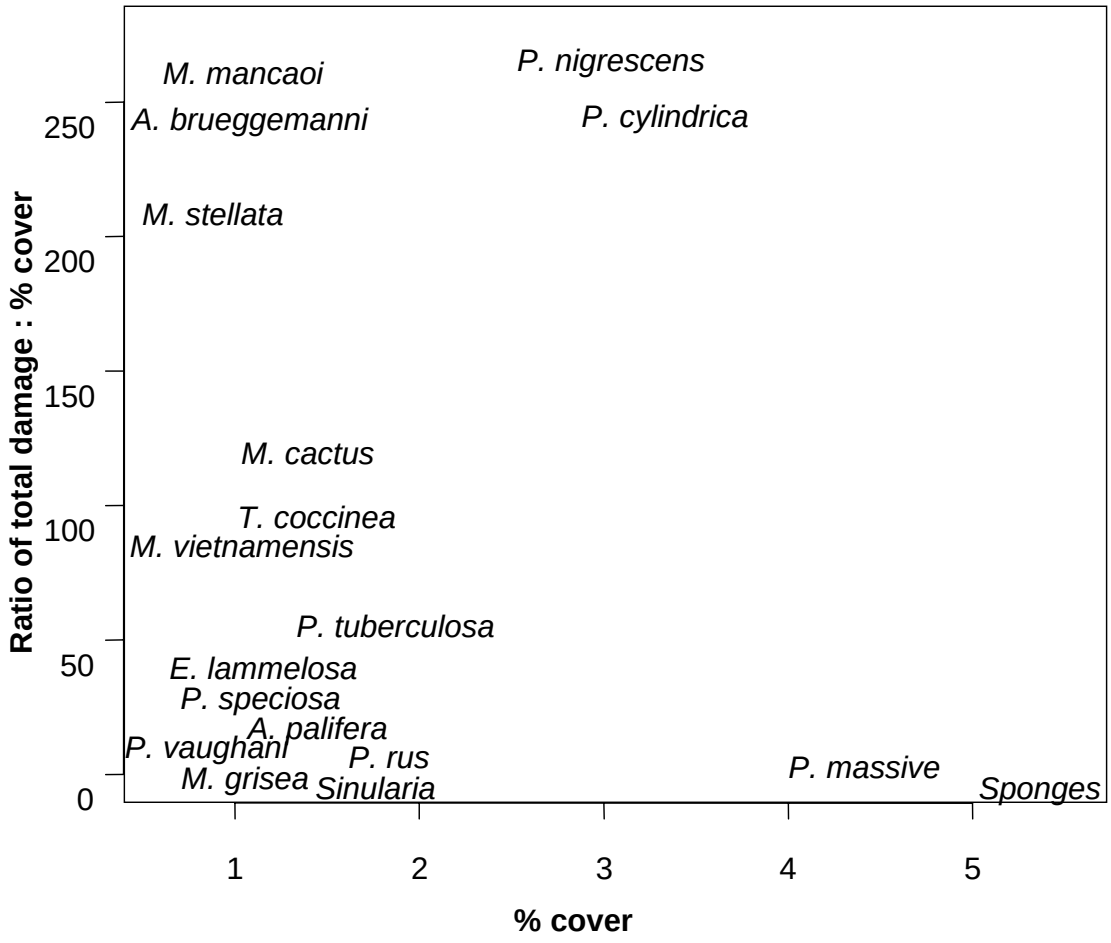

Figure 33. Relation between damage and cover for individual coral species.

The branching poritids *Porites nigrescens* and *P. cylindrica* were also highly susceptible, although with respectively higher percent cover (2 - 3%). Other highly susceptible species included the branching *Montipora cactus*, digitate - encrusting *Montipora vietnamensis*, both of which were badly damaged at Lekuan III, and ahermatypic dendrophyllid *Tubastraea coccinea*. *T. coccinae* occurs predominantly on walls / overhangs, and high impact to this species is consistent with physical abrasion by divers and possibly also bubble impacts running up the walls. Other species, by contrast, had relatively high cover and low levels of damage, including massive colonies of *Porites* spp. and sponges. For massive *Porites*, most damage occurred on the shallow slope - reef crest at Alung Banua, where substantial abrasion had occurred from finning and standing by snorkelers (Plate 2).

Many of these species (Table 6) are widespread and common and thus well represented outside dive sites. Others, however, are uncommon, and thus of more concern in relation to diver damage.

Dive boat impacts

During the survey period, three separate incidences of boat impacts were observed:

- Lekuan III - Chartered snorkeling boat had anchored on the shallow reef crest, in contravention of Bunaken NP regulations, with the anchor causing substantial breakage of shallow reef crest corals (Plate 4);
- Lekuan III - One dive boat was attached to the mooring. Two other boats were tied to the moored boat. Strong current flow carried one of the attached boat onto the reef crest, with breakage of shallow crest corals (Plate 3);
- Alung Banua - One chartered snorkeling boat was attached to the shallow reef crest rope mooring at low tide. The boat was hitting the reef crest, breaking shallow corals (Plate 1). The mooring was subsequently removed by Bunaken NP staff (R. Paat, pers. comm.).

These and similar incidents can cause more damage to a dive site in several minutes than hundreds of divers can do in many hours. Control of anchoring, and more appropriate use of moorings will markedly reduce physical breakage at the dive sites.

Further, there is a wide range in the quality of boat handling and control of dive vessels, with significant safety concerns regarding duty of care for divers, particularly at the beginning and end of dives. A few boat handlers exhibit a high degree of skill and care, although many are placing their own, and other operators', customers at significant risk, particularly where multiple operators may conduct drift dives simultaneously (e.g. Lekuan II, III, Muka Kampung, Pangalingan). Many dive boats are travelling much too fast in the immediate vicinity of surfacing divers, with significant risk of injury or death.

In summary, the four heavily dived sites all exhibit high levels of coral rubble, coral fragments and broken / damaged attached corals consistent with inappropriate and over-use. However, living coral cover and diversity remain high, testament to the excellent resilience and regenerative capacity of Bunaken NP at present.

3.7 Homestay R.E.A

Twenty cottages / homestays / resorts providing accommodation on the islands within Bunaken NP (19 on Bunaken Island itself) were interviewed in relation to their guest numbers, activities and waste disposal systems by Bunaken NP and NRM III staff (R. Paat, Bunaken NP, pers. comm.).

In total the 20 cottages have 172 rooms (range 3 - 20 rooms, median / mode 8 rooms), catering for some 389 guests, with a range of from 6 - 50 guests (median 16, mode 18 guests). Assuming that most guests stay for a period of one to two weeks, the homestays could accommodate between 10,000 (2 weeks) and 20,000 guests (1 week) per year, if always fully booked to present capacity.

The homestays and resorts are significant employers, with more than 300 staff (306, range 2 - 82, median 6, mode 2 staff), of which approx. half (144) are locals from Bunaken Island, a further 86 are locals from other islands within Bunaken NP, and 76 are from outside Bunaken NP.

There are significant waste disposal issues facing the island accommodation houses. Eighteen of the 20 homestays have septic wastewater treatment systems, one of which is an environmentally friendly 'Wastewater Gardens' system. Numbers of septic units per homestay range from 1 to 20 (median / mode 7 units). Most units are within close proximity to the beach, with significant attendant risks of leaching / seepage and eutrophication. The closest septic systems in four homestays are within just 10 m of the beach, a further four homestays have units within 20 m of the beach, a further eight homestays have systems within 50 m and the remaining two homestays have systems within 100 m.

Organic wastes are presently disposed of as animal feed (10 of the 20 homestays), composted (5 homestays) or burnt (4 homestays). Paper is either burned (18 homestays) or sent to Manado (2 homestays). Plastics are mostly burned (16 - 18 homestays) or sent to Manado (2 - 4 homestays). Batteries are either sent to Manado (9 homestays), buried (5 homestays) or burnt (2 homestays).

Most (14) homestays already make significant efforts in relation to minimizing physical impacts to the fringing reefs, transporting guests, loading / unloading supplies and

accessing dive sites via channels in the reef, thereby minimizing further reef damage and coral breakage. Most (17 homestays) also provide instructions to tourists regarding appropriate snorkeling and reef-walking behavior and reef access via the defined channels (16 homestays).

It is important to note that the data summarized above were provided by the homestay operators and managers themselves; some NSWA members expressed serious reservations as to the verity of the claims of most homestays in providing instructions to snorkelers and reef walkers (M. Erdmann, pers. comm.).

3.8 Impacts affecting Marine Tourism in North Sulawesi.

Marine tourism development, and the setting of sustainable limits (through CC and LAC), are highly contingent upon the status / condition of the marine environment. Impacts affecting the quality of the marine environment will also impact on marine tourism, and its sustainability. Impacts include those that are a direct result of tourism itself, and those that are independent or not directly related to tourism, yet have a deleterious effect.

Tourism-related impacts include:

- diver damage, including standing by snorkelers (Plates 2, 5 - 8);
- anchor damage (Plate 4);
- boat strike damage (Plates 2, 3) and propeller disturbance to shallow seagrass beds and fast boat speeds on shallow reefs and among divers (Plate 9);
- pollution from solid wastes (Plate 10);
- pollution from sewage - eutrophication;
- pollution from sediment mobilization during homestay construction;
- increased pressure on fisheries to supply tourists.

Non-tourism related impacts that can affect condition of the marine environment and thus marine tourism include:

- non-tourism related coastal developments;
- river flooding and run-off;
- storm waves;
- overfishing and destructive fishing - including blast and poison fishing (Plates 11, 12);

- poison fishing to supply the ornamental aquarium trade;
- pollution from Manado;
- coral predation by crown-of-thorns seastars or *Drupella* molluscs (Plate 13);
- coral bleaching from temperature fluctuations or other stressors.

Managing these impacts effectively is crucial to sustaining any CC limits.

Plate 5: Diver damage to *Montipora aequituberculata*, Lekuan III, Bunaken NP, North Sulawesi, 2003.

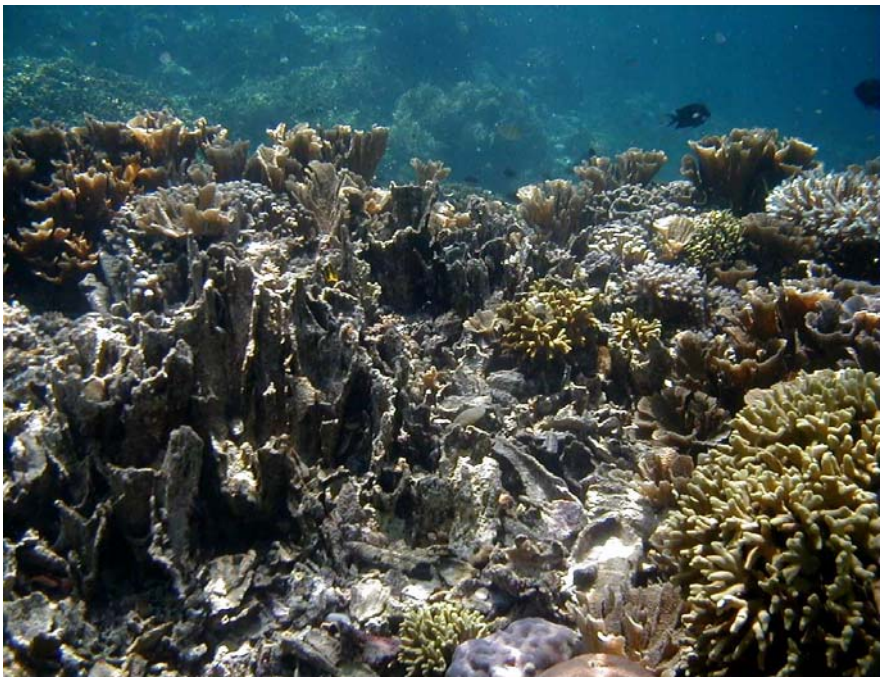

Plate 6. Diver damage to reef crest coral community, Alung Banua, Bunaken NP, North Sulawesi, 2003.

Plate 7. Diver damage to branching corals, including *Montipora cactus*, Lekuan III, Bunaken NP, North Sulawesi, 2003.

Plate 8. Broken colony of *Montipora aequituberculata*, Lekuan III, Bunaken NP. Some fragments are continuing to grow, fusing back with the parent coral.

Plate 9. Boat propeller disturbance to shallow seagrasses and reefs, Bunaken NP, North Sulawesi, 2003.

Plate 10. Pollution from solid wastes washing ashore at Pantai Liang, Bunaken Island, North Sulawesi, 2003.

Plate 11: Effects of recent blast fishing

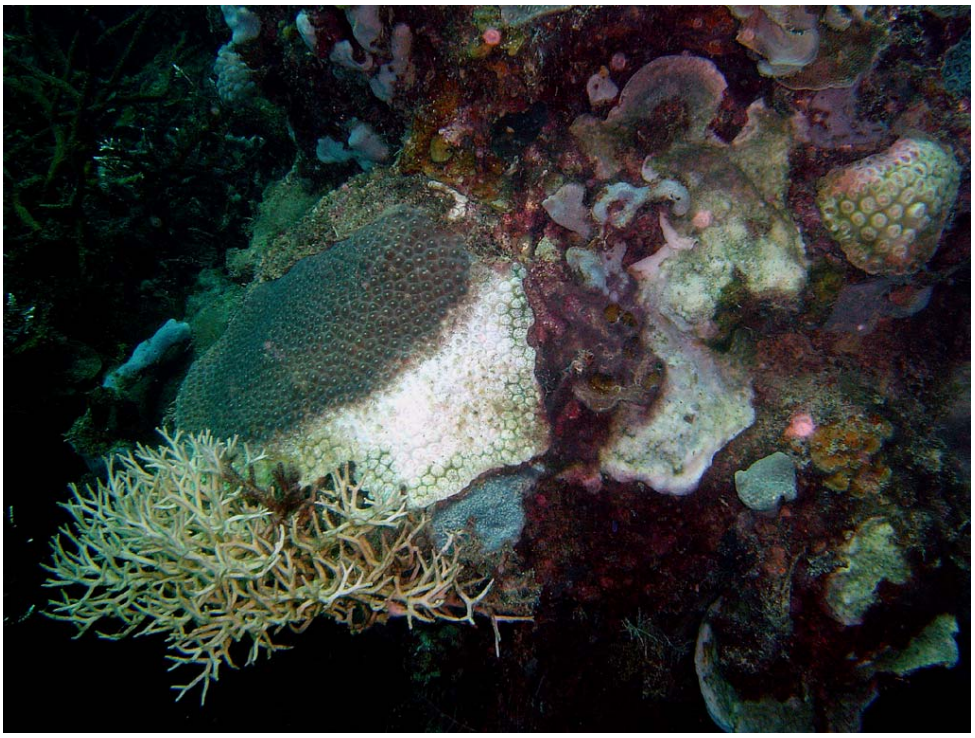

Plate 12: Effects of recent poison fishing

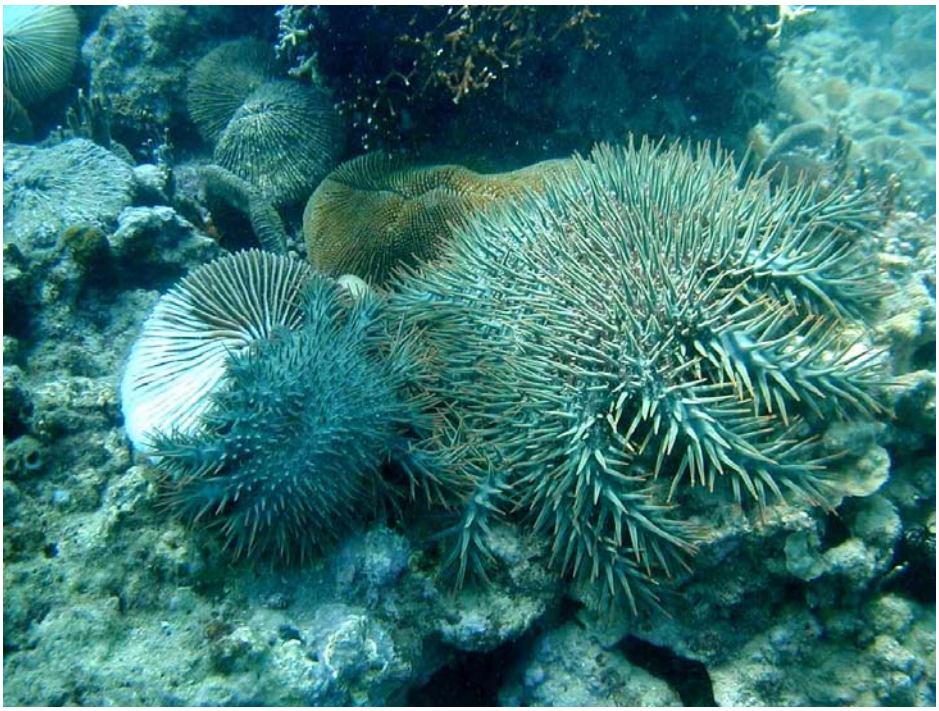

Plate 13. Population outbreak of crown-of-thorns seastars *Acanthaster planci* feeding on fungiid mushroom corals.

4. Discussion

The Discussion is divided into several sections, with specific policy recommendations.

4.1 Dive Sites and Levels of Use

At present (2003) there are some 120 recognized dive sites in North Sulawesi (Annex IV, Fig. 1). More are being 'discovered' and opened to diving on a regular basis. This has the capacity to spread the diver 'load' among more sites, which could, with appropriate management and regulation, reduce pressure on the more heavily used sites. However, care must be taken in the continual opening of new sites to diving, as several studies have suggested that most damage occurs soon after new sites are opened, rather than as a cumulative consequence of repeated use (e.g. see Rouphael and Inglis 2002).

There is a clear trade-off between having, on the one hand:

- too few dive sites for the number of divers (with increasing degradation at all sites, which in a sense become 'sacrificial'),
- as compared with
- continual opening of new sites that may take pressure of established sites but that may themselves be damaged during their initial opening to diving.

A flexible balance needs to be found between the two approaches.

Put at its simplest, environmental, socio-economic and aesthetic aspects of Marine Tourism Carrying Capacity - the total number of divers an area can support - are all directly related to the availability of high quality dive sites (Fig. 34). With a finite, limited number of sites, as heavily used sites become damaged or degraded, increasing pressure will focus on the remaining high quality sites. In this regard, the importance of maintaining sites in good condition cannot be over-emphasized.

With a flexible model incorporating both CC and LAC, overall maximums for diver / visitor numbers and infrastructure can be regulated, and fine-tuned through monitoring of LAC with amendments to regulation, in response to non-diving related, as well as diving related, impacts. This approach can allow individual sites to recover from disturbances.

Certain sites, because of their community structure, are more prone to injury than others, and use levels may be regulated in this regard.

As noted above, in practice, sites that have been badly damaged usually become less attractive to divers, facilitating / assisting reactive management measures such as temporary site closure. Options for consideration in this regard include a rotation system of use among heavily dived sites, to allow for recovery.

Effective monitoring and reactive management strategies should be established prior to the opening of new dive sites, and also established in relation to continued use of long-established sites. Dive companies themselves can play an important role in both monitoring and reactive management, as already occurs in the present study area, notably in relation to outbreaks of the coral predatory crown-of-thorns seastar *Acanthaster planci* (Box 4).

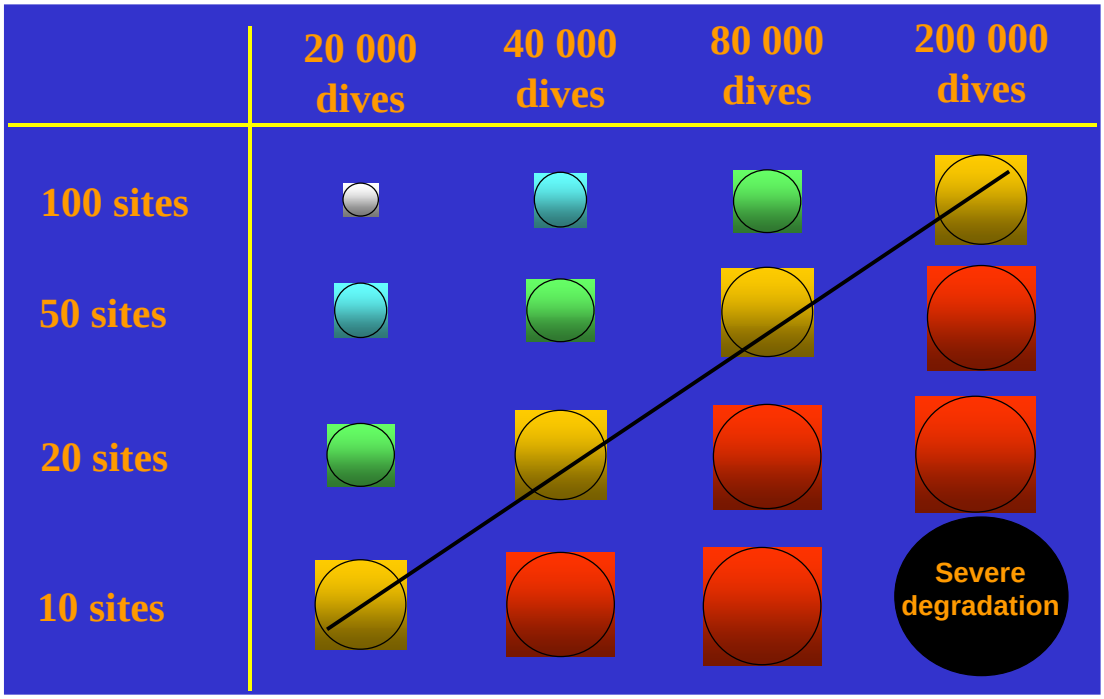

Figure 34. Simple model illustrating the relation between the quantity and quality of dive sites and total number of dives in a given area. Size and colour of circles indicates levels of use / damage. Assuming an *average* degree of site damage / impact per dive, more sites can support more dives without become severely degraded. As diver behavior improves, higher use / diving intensity can be accommodated. This model assumes that, *on average*, number of dives is a reasonably precise predictor of the total amount of damage caused by divers, and that diving intensity will be equally spread among dive sites – not the actual case in North Sulawesi.

Although the recommended Carrying Capacity limit of < 6,000 divers per site per year derived for other reef areas has been used herein for purposes of comparison, this is only an interim number, until specific site monitoring can provide relevant numbers for North Sulawesi. Ultimately it will be necessary to define unacceptable level(s) of damage (e.g. the proportion of damaged colonies or the mean number of broken branches per colony exceeding that found at 'control' sites by 10%, and / or changes in levels of cover of broken corals). Such figures would represent trigger levels for further investigation, rather than a rigid compliance level. The advantages of this approach are avoidance of the need to specify an absolute quantity, and that the trigger criterion can be updated to reflect extraneous factors such as climate variability that also affect 'controls' (T. Rouphael, pers. comm.).

From the aesthetic (social / amenity) perspective, controlling the number of divers to maintain amenity value may be based on the mean maximum number of divers that distract from the enjoyment of a dive. For many divers this occurs when divers from more than one dive operator dive the same site simultaneously. NSWA members already have a form of self-regulation at individual dive sites in this respect, which may be more formally regulated. This would also help to control maximum numbers of divers at the busiest sites.

Recommendations:

1. Great care should be taken in opening new sites to diving, with initial assessment, regular monitoring and dive use restrictions put in place:
    a. Individual dive site use-limits should be based on an initial site assessment and evaluation of the particular sensitivity of the proposed site to diving-related damage (e.g. types / morphology of corals etc.).

    b. Diving activity may be capped at present levels by licensing operators currently using the NP. Licenses may include a list the sites / reefs that operators may visit.

    c. Surveillance and regulatory measures may be developed in relation to the deliberate exceeding of CC limits by dive operators.

    d. Marine Park zoning schemes are a useful way of controlling / regulating the opening of additional dive sites.

2. A standard, simple site assessment and monitoring protocol should be developed and implemented, based on Global Coral Reef Monitoring Network protocols (English et al. 1997, Wilkinson 1998, 2000, 2002) and the field methods employed during the present study. Variables to be monitored include levels of coral damage (i.e. numbers of fragments, numbers and proportions of broken colonies).

3. For sites to be maintained in good condition, a high degree of cooperation among dive operators (as already exists within NSWA) is required, in relation to the setting of realistic Limits of Acceptable Change (LAC).

    a. LAC may be measured in terms of the levels of coral damage (i.e. numbers of fragments, numbers and proportions of broken colonies) and cover of living / broken / dead coral and rubble; fish diversity and abundance (and other indicators as appropriate), and by developing detailed, specific site inventories (e.g. notable features - spectacular fan corals etc.).

    b. Reactive management decision criteria need to be developed in relation to exceeding of LAC limits.

    c. In respect to LAC, careful vigilance / monitoring and reactive management will be required. The statistical detection and definite assignment of diver-caused change can be complex, in relation to within-site variability -natural changes.

    d. The use of 'control' or reference sites that are closed to diving, yet have similar community structure and other attributes is useful in terms of understanding source and impact of diving-related damage. However, in North Sulawesi there are significant difficulties associated with this approach (see Methods).

    e. This can also be expensive and a realistic monitoring and management budget needs to be allocated.

    f. Some aspects of monitoring and management can be achieved by the dive operators themselves, in association with Park management staff. This is particularly important, not just for diving related impacts, but also for other disturbances that may affect quality of dive sites (e.g. coral predation by crown-of-thorns seastars).

g. Sites that have been badly damaged (i.e. exceeding LAC limits), should elicit reactive management measures, such as temporary site closure to allow for regeneration, and a review of CC limits.

Box 4. Case study in proactive participation and reactive management: Voluntary maintenance of dive site quality by NSWA - Crown-of-thorns seastar (COTS) outbreak in North Sulawesi, 2003

A population outbreak of crown-of-thorns seastars (*Acanthaster planci*) was discovered in late October 2003 on a fringing reef at Mokupa area (Pasir Panjang) to the south of Manado by Lumba Lumba Divers (Plate 13). This NSWA member immediately notified other members and Bunaken MPA Authority via email, and began voluntary removal of the COTS population. Other NSWA members joined the control program on the fringing reef, ultimately collecting more than 500 COTS from several ha of reef slope. The COTS were mostly small adults (< 20 cm diam.), although some large individuals were present (> 40 cm). Most seastars were gravid (Plate 14), with spawning expected to occur during the full moon periods of the following several months.

Subsequently, during November and December 2003, COTS outbreaks were discovered at a further 26 dive sites, mostly on the islands of Bunaken NP. To date, a concerted effort by multiple NSWA members has removed more than 2,700 seastars, limiting damage to popular dive sites (e.g. Lekuan I - III where more than 500 COTS have been collected). This effort should also have reduced COTS' reproductive output (as seastars were removed prior to annual spawning). Large gravid female COTS can produce millions of eggs, and when aggregated in outbreak densities, high fertilization rates are also assured. Thus timing of the control program was particularly important, as the seastars would have reproduced in the following few months, with the potential to overwhelm the Park with the next generation of seastars.

Causes of the seastar outbreaks remain controversial, and some scientists caution against such 'interference' in what they consider to be a natural part of reef ecology. Others consider that outbreaks are linked to overfishing of their natural predators - various species of reef fish and shellfish - and to changes in water quality from river run-off. Both of these factors may be implicated in North Sulawesi, where extensive and intensive overfishing has depleted the fish and shellfish stocks, particularly outside Bunaken NP waters, and river runoff from the Sulawesi mainland also occurs.

COTS is one of the most common and widespread of all coral reef species, occurring from the Red Sea to Gulf of California and Lord Howe and Kermadec Islands (S. Pacific) to Japan. Since the 1960s COTS outbreaks have devastated coral communities on many reefs throughout the Indo-Pacific. This recent seastar decimation of reef corals is now exacerbated in many reef regions by a litany of other impacts, including destructive fishing, pollution, sedimentation and heat-induced bleaching. With the increasing array of other problems besetting reefs, the continuing seastar outbreaks are causing widespread losses of coral cover, biological diversity and ecological complexity.

The synergistic and cumulative effects of these impacts are exceeding any intrinsic resilience that reef communities have against individual impacts, with concomitant long-term changes in their biological structure and ecological function. Collectively, these impacts degrade reef attributes valued most highly by humans: biodiversity, high coral cover and structural complexity, and fish stocks. Managing coral reefs in a way that retains these values presents a major challenge for present and future human generations.

It is inconceivable that local control programs, such as that instigated by NSWA (Plates 14, 15), will cause any change in the seastar's overall population abundance globally. However, such local controls may help to protect crucially important reservoirs of reef biodiversity, such as those in Bunaken NP, and also locals' livelihoods reliant on reef production and tourism. In this regard local villagers should be actively encouraged to participate in such proactive management projects, developing a sense of stewardship for their local reefs. In places such as Bunaken NP, one of the most strategic MPAs on earth, it is crucially important to protect the good coral areas - both for their rich biodiversity and ecological function and for their economic value to locals and tourism. In so doing, NSWA members are acting to maintain as many dive sites as possible in good condition, contributing to sustainability of a high Marine Tourism Carrying Capacity.

Plate 14. Large mature crown-of-thorns seastar (COTS) with ripe egg bundles, collected prior to annual spawning by NSWA members.

Plate 15: COTS control team, NSWA members, North Sulawesi, November 2003

4.2 Quality of Dive Briefings - Guidance

The numbers of divers that individual sites and broader locations can accommodate depends on the behavior of the divers, in turn related to quality of dive briefings and underwater supervision (Medio et al. 1997). At present, there is a wide range in quality of dive briefings, from the cursory to the extremely detailed. There is also a wide range in the quality of dive guidance in relation to pre-dive briefings, underwater supervision and harassment. Some guides had the highest rates of harassing interactions, primarily on behalf of their clients, particularly photographers.

Recommendations

4. A standard audio-visual dive briefing presentation should be developed for use by all operators. The presentation should provide insights into the unique diving experiences of North Sulawesi (currents, walls, fragile corals etc.), and in an informative manner educate divers towards appropriate dive behavior and etiquette. The presentation need not be long (5 - 10 mins.) or 'heavy', but rather should be informative, 'light' and insightful, providing arriving divers with a sense of awe and wonder, respect and stewardship for the Park. This presentation should be mandatory viewing, with the option for an immediate question / answer session, prior to the signing of the Environmental Awareness Statement. Taken together, these simple steps may improve diver behavior substantially.

5. Because guests staying on island homestays frequently snorkel from the beach without guide oversight, an eye-catching and informative poster should be developed that instructs such snorkelers as to proper coral reef snorkeling behavior – centered upon a “Swim, don’t Stand” theme. This poster should include a map showing channels in the reef that should be used for access to the reef crest during extreme low tides. The poster should include both English and Indonesian text, and should be distributed in sufficient quantity for posting in each homestay room and all dive centers. It should also be distributed, perhaps in laminated form, to catamaran/glass bottom boat and local snorkel charter boat operators.

6. Dive guides should be trained and licensed to operate within Bunaken NP waters, particularly in relation to underwater supervision and harassment. At present, some guides are among the most destructive of all divers in North Sulawesi, while others

are exemplary. A standard training course, with a certificate of completion, and official license to operate within Bunaken and other NP waters may improve the quality of guidance substantially:

- develop training course and education materials;
- develop Diving Code of Behavior;
- certify guides to work in Bunaken NP;
- limit no. of divers / Guide;
- provide Guides with more power (e.g. capacity to ban divers in relation to bad diving behavior).

7. Regulate numbers of divers per dive guide, based on maximum ratio of four divers to one guide.

Most Guides appear in favor of these measures, but some are concerned for their jobs if they should offend difficult clients.

4.3 Diver and Dive-related Impacts and Dive Site Condition

Diver and diving-related impacts (e.g. boat strike, anchor damage) to heavily-dived sites are obvious and demonstrable (Figs. 19 - 32). These sites already exhibit high levels of coral rubble and large numbers of broken and damaged corals, and are arguably already over-used, particularly on the busiest days. At these sites, it may be appropriate to implement an Operator use-roster (e.g. random allocation of days per month to different operators) to reduce diver impacts.

Although there is a wide range in use among different dive sites in North Sulawesi, it is estimated that some 30% of all dive sites are already subject to heavy use. However, status of the vast majority of sites in relation to damage levels is not known at present. This lack of data requires a precautionary approach to future tourism expansion.

It is therefore recommended that limits are placed on the number of dive centers, number of divers per boat, size of boats, and ratio of divers/guide. This can be achieved through license systems that restrict the total number of operators and the numbers of divers per operator and boat, based loosely on the present *status quo* and with opportunities for review and consultation as more data become available.

Recommendations:

Divers

8. Improve education programs, including dive briefings and environmental awareness for divers and snorkelers, with dedicated audio-visual presentations (see later).

9. Restrict snorkel boats and snorkelers to waters > 3 m depth, where standing by snorkelers cannot occur, and promote the message 'swim don't stand'.

10. Develop improved regulation of diver activities (e.g. restrict numbers of dive centers and/or divers per Operator, based loosely on present *status quo*, through permit / license system through Bunaken NP & Local / Provincial Tourism Departments).

11. Implement Operator use-roster at busy sites (e.g. random allocation of days per month to different operators at busiest sites).

12. Improve surveillance & enforcement with 'In water' patrols to assess diver behavior, with options for warnings / bans for divers, Guides and / or Operators who consistently breach Code of Behavior. To work, this would require independent impartial surveillance & enforcement.

Boats

13. Develop improved regulation of boating activities (e.g. restrict numbers and sizes of boats and numbers of divers, based loosely on the present *status quo*, through permit / license system through Bunaken NP & Local / Provincial Tourism Departments).

14. Improve surveillance and enforcement with increased surface patrols for boating breaches of regulations.

15. Develop regulations to effectively manage the trend for foreign (primarily Thailand-based) dive liveaboard boat operators to set up seasonal operations in North Sulawesi during the "low season" in their respective areas of regular operation. These operators should be subject to strict licensing requirements that ensure employment of local guides and ship crew and compliance with all local regulations that North Sulawesi-based tourism operators must abide by.

16. Limit boat sizes within Park waters based on tonnage / capacity / length, to minimize potential for impacts re dragging of moorings and the exceeding of CC limits.

Moorings

17. Review and where necessary upgrade / remove moorings.

18. Remove all very shallow moorings and other moorings that allow boats to strike the reef crest with some current directions.

19. Restrict boats to one per mooring.

20. Provide better education for boat skippers in regard to correct mooring and driving safety procedures.

21. Provide more stringent surveillance and policing of mooring / anchoring offences.

4.4 Homestay Accommodation

There is significant potential for over-development on the Islands within Bunaken NP, with increased threat of localized eutrophication in coastal waters from inadequate sewage treatment. There is also the potential for soil erosion and sedimentation in coastal waters from poor landscaping practices on sloping coastal land.

Trampling from tourists walking over the reef flat remains an issue, particularly at low tides, although most homestays make an effort to educate guests. Channels cut in the reef to allow passage of boats to/from cottages help to minimize the latter problem, although any significant further channel construction and / or dredging of existing channels has the potential to change water flow patterns and coral community structure on the reef flats.

Most of these issues have already been discussed at the local level, yet there is as yet little effective regulation of development to prevent environmental degradation. There is an urgent need for regulation of the size / style of future developments through a permit / license system from Bunaken NP Authority and / or the Local and Provincial Tourism Departments.

Recommendations

22. All island-based accommodation providers should develop appropriate sewage disposal systems, to minimize potential for seepage / leaching of nutrient-rich wastes into coastal waters.

23. All accommodation providers within Bunaken NP should be licensed by the Bunaken NP Authority and / or local and provincial governments, with the licenses subject to review, restriction and ultimate revocation if significant breaches of Park and / or government regulations occur.

24. A maximum number of bed / guest numbers should be established for all accommodation providers within Bunaken NP, and regulated by the appropriate Park and / or local and provincial government authorities. These may be set initially at present levels, with opportunities for review.

25. Any further construction of accommodation should be subject to strict environmental codes, particularly in relation to:
    - vegetation clearance and soil erosion;
    - mangrove / seagrass disturbance - clearance. These are important natural filters and wildlife areas, including nursery grounds for commercially important species. No disturbance should occur unless specifically permitted and supervised by relevant authorities (e.g. Bunaken NP Authority, local and provincial governments);
    - sewage treatment - as noted above, all island resorts should upgrade to environmentally friendly systems approved by the Bunaken NP Authority. Systems should be set back as far as practicable from the coast;
    - disturbance and changes to shoreline, coastal vegetation and shallow reef communities in relation to construction.
26. Organic wastes should be composted or used as animal feed (as already occurs). Inorganic and other wastes should be transported to Manado for suitable disposal. However, at present, a major part of the inorganic wastes present on the Bunaken NP islands arrive as floating debris from Manado, such that there is a far greater waste disposal issue for the city itself.

27. Access to accommodation should not further compromise coastal ecosystems, such that existing boat channels should continue to be used as the main access points. These channels should not be significantly dredged below their present depths and **no further channels should be constructed**; both the Pangalisang and Liang Beach areas of Bunaken Island and Siladen Island already have a number of channels that provide access to these areas. Park authorities may want to consider installation of prominent channel markers for those channels which already exist. In the case of potential homestay expansion to other islands, careful construction of a limited number of piling-style jetties is ecologically highly preferable over further channel construction, which can negatively impact corals and seagrass beds by altering hydrology and especially reef flat water levels at low tide.

Domestic Tourism Arrivals

Although generally outside of the scope of this study, the recent tremendous increase in domestic tourist arrivals to Bunaken National Park (up nearly 78% from 2002, and accounting for ~75% of overall arrivals in 2003) should be carefully considered by park and tourism authorities. As these beach-going day visitors increasingly turn to snorkeling as a recreational activity, the potential for further reef degradation will increase markedly.

Recommendations

28. Carefully monitor the activities and environmental impacts of day-tripping domestic visitors, and consider an increase in domestic user fees in order to both limit expansion of this market and provide the additional financial resources that will be necessary to effectively manage its impacts.

Non-tourism Impacts

Some impacts are beyond direct local management or regulatory control (e.g. coral bleaching from thermal stress), other than in working to maintain the natural integrity of the ecosystems to provide resilience to disturbances. Other non-tourism related impacts are more amenable to management, including destructive fishing and population outbreaks of coral predators. Loss of coral cover and community structure from Crown-of-thorns seastars (COTS) is occurring in Bunaken NP, and is presently subject to control by NSWA (Box 4). Although causes of outbreaks remain controversial, evidence for increased survival of COTS larvae in nutrient-enriched waters and increased survival of

juveniles - adults from reductions in natural predators (including Giant Triton snail and lutjanid, lethrinid and ballistid fishes) suggest human influence. In areas heavily reliant on maintaining high coral cover for marine tourism, control of the predators is recommended.

Recommendations

29. Destructive fishing - improve surveillance and enforcement, particularly in more isolated / remote areas. Consideration may be given to licensing tourist operators as honorary rangers, following suitable training, and with limited powers to police activities within the Park.

30. Maintain vigilance / monitoring and continue community-based (NSWA) control programs of COTS as required (see Box 4).

31. Work with relevant local and provincial government authorities to develop better management of solids and other wastes in and around Manado, including effective implementation of integrated coastal and river catchment management.

Licensing and Legislation:

32. Develop comprehensive legislation that clearly and transparently establishes licensing procedures for dive centers, homestays, marine tourism boats, skippers, and dive guides. While a number of licensing systems already exist (e.g., the SIOPSUS license for marine tourism boats), many tourism operators expressed significant confusion over these systems, and feel that they are rarely applied evenly to all operators with respect to requirements and associated fees.

33. Specific licensing and legislation recommendations are detailed in the above list and include:

    - number of dive centers and/or boats licensed to operate in specific areas (eg., Bunaken National Park, Lembeh Strait, etc),
    - dive guide and skipper certification,
    - ratio of dive guides/divers (1:4 minimum),
    - number of divers per operator and/or per boat,
    - boat size/tonnage,

- number of boats per mooring,
- minimum requirements for homestay septic tank systems (for both present and planned homestays),
- strict environmental building codes for any new homestays,
- total number of beds in homestays within Bunaken National Park, and
- requirements for foreign liveaboard vessel operation in North Sulawesi.

Conclusions

Reef condition and biodiversity conservation

Coral and reef growth in much of Bunaken NP and North Sulawesi appear vigorous, with apparently rapid and strong recovery from the effects of bleaching in 1998 and 2002 and other disturbances (Turak and DeVantier 2003, and this study). This is in part attributable to natural resistance and resilience, and in part attributable to effective management, including local community consultation and involvement, awareness raising and surveillance and enforcement of MPA regulations.

Bunaken NP's reefs appear well connected oceanographically, lying in the path of both southerly and northerly flowing surface currents facilitating larval dispersal. The Park's coral communities are thus likely to act as both a source and a sink for larvae, enhancing connectivity locally and among other populations in the region. There are, nonetheless, significant differences in species composition and community structure of coral communities in Bunaken NP with other areas of North Sulawesi and Indonesia, lending additional support to the conservation of this coral fauna. Its selection as a flagship MPA in Indonesia's, and the Sulu-Sulawesi Sea's, developing MPA network provide a high degree of complimentarity with other functional and planned MPAs.

Carrying Capacity and Limits of Acceptable Change

However, future increases in use, including expanding marine tourism, threaten and may degrade these globally important attributes. There is clear evidence of high rates of negative diver interactions throughout the region, and related damage at heavily-dived sites.

Based on international experience and present dive use trends, broad limits to overall marine tourism carrying capacity, particularly for Bunaken NP, but also North Sulawesi

more generally, are already within reach. Thus a precautionary approach to any future expansion of tourism use is highly recommended.

Significant non-regulatory improvements can be made in diver behavior, dive guidance and boat-related impacts through training and education programs. Further, a licensing system for tourist operators and infrastructure through the Bunaken NP Authority and local and provincial governments, with regulation of diver numbers and boat sizes based loosely on present levels, should be implemented as a priority. MPA zonation is another useful tool in setting use limits.

Initial site assessment and ongoing monitoring are crucial in understanding site condition, setting / adjusting realistic LAC levels, and initiating appropriate reactive management responses.

If these measures are implemented, Bunaken NP and North Sulawesi should remain a highly biodiverse, attractive and unique destination for marine tourism into the future, and continue to provide strong socio-economic and ecological benefits for the region.

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Annex 1:
Dive Tourism Operations in Bunaken NP and North Sulawesi

Dive Operation	Max. no. divers
Bunaken Island	
TwoFish Divers	18
Froggies Divers	18
Living Colour Dive Center	18
ChaCha Dive Lodge	12
IndoPacificDivers (Bunaken Divers)	~20
Sulawesi Dive Quest	~15
MC Homestay	No diving specifically, but do send guests to Aquanaut
Sunsplash (Bastiano's Cottages)	20
Immanuel Dive Center (Daniel's Homestay)	~12
SCUBANA	~10
Samudera Indah ("Japanese Cottages")	~10
Siladen Island	
Siladen Spa	20
Onong Cottages (via Celebes Divers)	Figure included with Celebes Divers
Rick Lasut cottage (next to Onong)	Plans for possible diving, but nothing now
Tante Martha's Homestay (In July/August, occasional host to dive groups of Christian Feniez	~10
Mainland near Manado	
LumbaLumba	8 (expanding to 18)
EcoDivers	40
Minahasa Prima	30
Minahasa Lagoon	30
MUREX	40
Celebes/MAPIA	44
Aquanaut	~20, but also occasionally rents local boats, expanding upwards to 30
Blue Banter	Can technically accommodate up to 50 divers or snorkelers, but rarely has any guests at present. May change in future.
NDC (Nusantara Dive Center)	60
Barracuda	30
CumiCumi Dive Center Meras	6
Thalassa	60
Sedona Hotel (Tom Ho).	Will open at some point, possibly 2004, up to 100 divers
Waka Resort in Wori.	Will open soon, 30 divers
Bangka/Gangga area	
Gangga Island Resort	60
Pulisan Jungle Beach Resort	8
Thalassa branch?	Not currently operational, possible plans
MUREX branch	Included in MUREX overall number of 40
Paradise Resort	No diving now, but has offered in past

Benteng Resort	No diving now, but has offered in past
Lembeh Strait	
Kungkungan Bay Resort	20
Lembeh Resort	18, expanding to 22
Divers Lodge Lembeh (SW tip of Lembeh)	10
Sulawesi Dive Quest Lembeh	14
Liveaboards	
MUREX *Serenade*	12
MUREX *Symphony*	6
Froggies' "Sleepaboard" - *Clown*	5 + 2 divemasters
Mimpi (operated by Thalassa)	8
ChaCha's yacht (*Reclaim*)	6 (but not operational now)
Liburan	10
IndoPacific's liveaboard – *Olivia* II	12
Ocean Rover from Fantasea Divers, Thailand – in Manado in 2004	12
"Informal dive sector" (likely without licenses, but nonetheless occasionally operational, especially at peak seasons. Note – some of these boats are chartered by valid operators when they have overflow numbers, but sometimes they are seen operating apparently by themselves.	
Manado Polytechnic University boat	20
Terang Mulia boats	20
"Mr Oliver" – French dive master	8

Annex II:
Environmental Awareness Form of NSWA

North Sulawesi Watersports Association
ENVIRONMENTAL AWARENESS STATEMENT

Dear Guest,

Like you, we care about coral reefs. But did you know that many studies have proved that a significant amount of coral reef destruction is not only caused by pollution, over-fishing and destructive fishing techniques like the use of cyanide and explosives, but by divers and snorkelers themselves!!

Much of the damage to the marine environment of Bunaken National Park is caused by careless or unaware divers / snorkelers who are harming the very thing they have come so far to see!!

Thousands of divers and snorkelers visit Bunaken National Marine Park each year. Each day, each small infraction to the reef caused by individual visitors quickly adds up. Here are some of the infractions and their consequences that we would like you to be aware of and take care to avoid:

Fish feedings = animal behavior changes
Harassing marine life for photos or novelty = unnecessary stress to marine life that may cause injury, death or at least an acute fear of human presence.
Dangling dive gear and uncontrolled fin movements = breakage and death to fragile life forms such as corals and sponges.
Souvenir and food collecting = local extinction of certain corals, shells, lobsters, fish, etc

Stop and think before you act. Justifying a negative action with **"It's is only me....."** is a fallacy. We can assure you that you are **NOT** the only one. We all have the potential to prevent death and destruction to coral reefs and we must all agree to act responsibly if we want to preserve our underwater miracles for others to enjoy as we do.

Please, do not interpret our message as a way to deprive you of your holiday pleasure. We are not asking you to swim in a cage! We are simply asking you to pledge your kindness to the reef with the following statement. If you have any questions we are more than willing to answer them and help you develop skills in order to become more environmentally friendly.

I ....., am aware that I will be diving in a sensitive eco-system. In order to minimize my impact on the marine environment:

- ✓ **I will not touch any marine organism or their habitat and will not wear gloves;**
- ✓ **I will be aware of my underwater movements and equipment at all times so as to avoid contact with the reef;**
- ✓ **If I take pictures I will not manually manipulate marine life in order to compose scenes and neither instruct my buddy to do so.**
- ✓ **I agree to act in an environmentally responsible manner unless in an emergency situation where I must act to protect myself or others from danger.**

If I observe anyone violating these rules, I will immediately report this to a dive guide or the management.

In accordance with the North Sulawesi Watersports Association charter I understand that I can be excluded from further diving activities if I ignore this statement with no right to a refund. In repeat cases or if I display a blatant disregard for the marine environment I understand that I can be blacklisted from other dive centers as an eco-terrorist.

Signature:_____

Date:_____

Annex III: Example of Data-sheets

a) For assessing quality of dive briefing

date	Company name	site no
No of divers	No of dive guides	

	yes	no		yes	no
Briefing at resort			Audio visual		
EAS Form			Talk		
Pre dive briefing			Length of briefing		

Resort	yes	no	Pre dive	yes	no
Coral fragility			Coral fragility		
Harassment			Harassment		
Dive gear control			Dive gear control		
Finning control			Finning control		
Buoyancy control			Buoyancy control		
Fish feeding			Fish feeding		
Souvenir collection			Souvenir collection		

Comments

Diver 1	yes	no	Diver 2	yes	no
Did you receive a briefing			Did you receive a briefing		
Resort			Resort		
Adequate			Adequate		
Pre dive			Pre dive		
Adequate			Adequate		
Did you complete EAS			Did you complete EAS		

Comments

Comments

Diver 3	yes	no
Did you receive a briefing		
Resort		
Adequate		
Pre dive		
Adequate		
Did you complete EAS		

Comments

Diver 4	yes	no
Did you receive a briefing		
Resort		
Adequate		
Pre dive		
Adequate		
Did you complete EAS		

Comments

Annex III. b) for recording diver impacts and site condition.

SITE	Name:			Date:		Time:	Obs:
Lat:	long:	Depth:	Vis:	Tide:		Temp. sea:	T. air:

Dive type **D**rift, **A**nchor or **M**ooring	Profile/map
Touch photographer, **g**uide or **r**ecreation	
Hold p/g/r	
Accidental break p/g/r	
Deliberate break p/g/r	
Sediment disturbance p/g/r	
bubbles on reef wall p/g/r	

max depth	min depth	slope	Hard Subst	Hard Coral	Soft Coral	Macro Algae	Turf Algae	Corall ine Al	Dead Coral	Cont. Pave	Large Block	Small Block	Rubbl e	Sand	Expos ure	Reef Dev.

Comm.Type	Current	Distance	No. camera flashes
A, B, C or D	0-3	in m	ticks

Breakage to coral sp. / damage

Taxon, proportion

(eg.. Stylophora pistillata, 0.3; Pocillopora damicornis, 0.1)

Annex IV: Dive Sites of North Sulawesi.

Site Name	Slope characteristics	Particular susceptibility	Estimated level of use	Snorkel
Bunaken Island				
Lekuan I	Wall	Gorgonians, sponges, bubbles trapped in overhangs	heavy	y
Lekuan II	Wall	Gorgonians, sponges, bubbles trapped in overhangs	heavy	y
Lekuan III	Wall	Gorgonians, sponges, bubbles trapped in overhangs	heavy	y
Cela-Cela	Wall	Gorgonians, sponges, bubbles trapped in overhangs	heavy	y
Alung Banoa	Wall	Gorgonians, sponges, bubbles trapped in overhangs	heavy	y
Fukui	slope area	hard coral damage, beginners/courses	heavy	y
Rons Point	wall/slope		moderate	
Mandolin	wall/slope		heavy	y
Tengah	wall		moderate	
Raymonds	wall		moderate	
Mike's Point	wall/slope	Gorgonians, sponges, bubbles trapped in overhangs	moderate	
Satchiko's	wall/slope	gorgonians	heavy	
Pangalisang	wall	Nice coral on reef crest	heavy	y
Bunaken Timur	wall	Nice coral on reef crest	heavy	y
Muka Kampung/Tanjung Pasir	wall	strong currents (corner), grabbing divers	heavy	y
Manado Tua Island				
Bualo Muka Gereja	wall	nice coral on very shallow reef crest	heavy	y
Negeri	wall/slope	nice coral on very shallow reef crest	moderate	
Benny's Point (Papindang)	wall	Gorgonians, sponges, bubbles trapped in overhangs	occasional	
Tanjung Kopi/Pangalingan	deep plateau	Extremely strong currents - divers grabbing	heavy	
Mantehage Island				
Bango	alternating slope/wall		occasional	
Gorango	steep wall		occasional	
Barracuda Point	wall with terraces		occasional	
barracuda Point B	steep slope	lots of coral damage from nets	occasional	

East Mantehage ("Tangkasi")	slope with terraces		occasional	
Nain Island				
Jl Masuk Nain	wall/slope		occasional	
Batu Kapal	deep pinnacle		occasional	
Helga Point (Nain Kecil)	slope		occasional	
Siladen Island				
Siladen	wall/slope	fish cages anchored with huge ropes, delicate corals	heavy	y
Sunken Garden/Siladen Utara/Spaghetti crossing	deep "rolling hills"	flat bottom	moderate	
Siladen Timur	wall/slope		occasional	
Mainland Manado Side				
DJ Point	slope	nice coral	occasional	y
Wori	slope		moderate to occasional	
Tiwoho	slope		moderate to occasional	
Bahowo	slope	Thalassa's sunken boat	occasional	
Gabet	wall		occasional	
Abang Point	slope and deep reef		occasional	
Tanjung Pisok Utara/Engine Point	slope/wall	*Tubastraea micrantha*	moderate (wide range)	
Tanjung Pisok Selatan	slope/wall	*Tubastraea micrantha* - lots of net, compressor fishing	moderate (wide range)	
Meras	slope		moderate	
Batu Hitam	sandy slope	big cabbage corals	heavy	
Molas Wreck	sandy slope	some big foliaceous colonies	heavy	
NDC	slope		moderate	
Reclamation Point	wall		occasional	
Blue Banter Marina	muddy		occasional	
Celebes	slope		moderate	
MUREX	slope		moderate	
45 bananas	patch reef	200m from LumbaLumba	occasional	
new Mandarin Point	shallow wall	in front of Pasir Panjang	occasional	
LumbaLumba	slope		occasional	

Circus Critter	slope		heavy	
Tasik Ria house reef	sandy slope		heavy	
Pygmy point	slope		moderate	
Bunaken NP Southern				
Poopoh (Tj Arakan)	slope into wall		occasional	
Minahasan Lagoon	slope		moderate	
Tatapan	slope, lagoon		occasional	
Gangga/Bangka				
Gangga "Lake"		training site for Gangga	occasional	
Sahaung	pinnacle	table corals - often bombed	heavy	
Sahaung 2	pinnacle	table corals - often bombed	heavy	
Sahaung Bay	sandy slope		occasional	
Tanjung Usi (Kahuku, Tg. Sahaung)	slope		heavy	
Sabina Timur	sandy slope	Gangga's checkout dives, courses	heavy	
Tanjung Totok	pinnacles and slope		moderate	
Batu Gosok	pinnacles and slope		moderate	
Batu Pendeta ("lionhead")	pinnacles and slope		moderate	
Pulisan Batu Mandi, Matchiko	pinnacle		heavy	y
Tanjung Slop	slope		moderate	y
Paradise Jetty	slope		heavy	y
Lihaga SE	sandy slope	snorkelling trips from Gangga	very heavy	y
Lihaga NE	sandy slope	snorkelling trips from Gangga	heavy	y
Airplane wreck Bangka	slope		occasional	
Tanjung Arus Talise	wall		moderate	
North Talise pinnacles	pinnacles and slope		occasional	
Tanjung Torowitan	wall		moderate to heavy	
Teluk KoraKora	sandy slope		occasional	

Lembeh Strait	**courtesy Bruce Moore**			
Batu Angus	hard coral lava bowls	delicate - much anchor damage	Occasional	Yes

Aw Shucks	coral shallows, sand slope	net cleaning (seasonal dead fish dumping)	Moderate	Rarely
Hairball	sand	net dragging & net cleaning, diver impact, seasonal swell	Heavy	Rarely
Hairball Too!	sand, some coral		Moderate	Rarely
TK	sand	net cleaning, anchor dragging	Moderate	Rarely
Retak Larry	sand, some shallow coral	net dragging, net cleaning	Heavy	Occasional
Slow Poke	sand	net cleaning, anchor dragging	Occasional	Rarely
Magic Crack	good hard coral in shallows, sand & coral outcrops deeper		Occasional	Occasional
Magic Rock	good hard coral in shallows, sand slope, coral wall from 21-40 m.	seasonal swell	Occasional	Occasional
Nudi Retreat	good hard & soft corals, walls, sand/coral slope	diver impact, anchor damage	Heavy	Occasional
Makawide	good corals in shallows, wall, sand slope		Occasional	Rarely
Jahir (Jiko Aras)	sand	net dragging, diver impact	Heavy	Rarely
Air Prang	sand, some shallow coral	net dragging, anchor dragging	Moderate	Rarely
Nudi Falls	wall, rockpile, sand slope, weedy/soft coral in channel	diver damage, anchor damage	Heavy	Occasional
Police Pier	rubble/sand slope, coral bommies	anchor damage, diver damage	Heavy	Rarely
Pantai Kecil	sand slope, coral bommies	anchor damage	Moderate	Rarely
Rina Wreck	wreck	none - strong currents & hard to find	Occasional	No
Critter Hunt	rubble/sand slope, coral bommies		Moderate	Occasional
Serena North	rubble/sand slope, coral bommies		Occasional	Rarely
Serena West	rubble/sand slope, coral bommies		Occasional	Rarely
Bimoli Wreck	WWII wreck	fishing, scrap cutting	Moderate	No
Madidir	sand		Occasional	No
Goby A'Crab	rubble/coral/sand slope		Occasional	Rarely
Kapal Indah	wreck	diver damage	Moderate	No
Pulau Abadi	coral slope	diver damage	Moderate	Rarely
Mawali Wreck	wreck	diver damage	Heavy	No
Pintu Kota	weed, rubble slope	anchor damage	Occasional	No
Pintu Kolada	coral penninsula		Occasional	Occasional

Pantai Parigi	coral shallows, sand slope	anchor dragging	Heavy	Occasional
Tanjung Tebal	coral/boulders	none - strong currents & hard to find	Occasional	No
Batu Sandar	coral/sponge garden, sand slope	diver damage	Moderate	Yes
Angel's Window	pinnacle	diver/storm/anchor damage	Heavy	Rarely
Batu Merah	sand/coral slope	diver damage	Moderate	Rarely
Pulau Putus	coral/sponge garden	anchor/diver damage	Occasional	Occasional
California Dreaming	soft/hard coral slope/wall/boulders	anchor/diver damage	Moderate	Rarely
Kaina's Treasure	coral slope/wall		Occasional	Rarely
Jiko Yansi	coral wall		Occasional	Rarely
Batu Kapal	pinnacles	diver damage, fishing	Occasional	No
Pulau Dua			Occasional	

Annex V: Anecdotal Information from Dive Operators

Question 1. What changes in corals and other reef-attached (sessile) species have you noticed while diving around Bunaken NP and adjacent waters over the past decade?

Bunaken Island

- At Lekuan I - III and Alung Banua (Tawara lagoon forereef slope), snorkelers and boat anchoring have caused substantial breakage to shallow water corals, while divers have damaged / broken wall fauna, such as sea fans, with second-order impacts to associated species of pygmy seahorses, cowries, shrimps (Box 1).

- At Fukui, incorrect buoyancy control, particularly among trainee divers, has damaged shallow water corals, although much of the rubble present was caused previously by destructive fishing practices.

- At Tawara Lagoon - Alung Banua, the delicate corals have been broken by anchoring, diving and from poison and spear-gun fishing (local villagers). Corals were also injured and killed there by bleaching from temperature fluctuations in 1998 (ranging from 25 - 31^{o} C from February - July).

Siladen Island

- At West and South Siladen Is. in 1996-98 coral cover was excellent. This has deteriorated markedly, particularly at South Siladen Is., from the combined effects of anchor damage and fish cages, which moved in strong currents, smashing corals. Building of the resort 'Siladen Spa' also is believed to have caused damage to the reef, notably through clearing of the pandanus trees fringing the beach, their subsequent dumping in the sea and breaking of corals, and from related beach erosion, with significant changes in the beach profile. Second-order effects also arose when:

- villagers employed during resort construction changed fishing methods, switching to spear-fishing the shallow reef, with notable reductions in reef fish stocks locally;

- well waters became more salty, attributable to changes in water table following the tree clearing.

Nain and Mantehage Islands

- Heavy fish bombing caused major damage in the past decade. This has declined recently, although it is still occurring in more remote sites. There are few if any recreational diver-related impacts.

Lembeh Strait

- At 'Nudi Falls' and 'Nudi Retreat', intense diving activity, including accidental and deliberate breakage and bubble impacts, has resulted in damage to wall fauna - gorgonians etc. - and changes in abundance of associated species.

Bunaken NP

- Reef shark abundances at several heavily dived sites, notably Lekuan I - III, appear to have declined from the regular sightings of 10 - 20 sharks of the mid - late 1990s, to occasional sightings of one - four sharks today.

- A general decline in shark numbers, for both reef sharks and hammerheads, around Bunaken NP was reported by most respondents, attributed in part to diving harassment, and also potentially to fishing. Other respondents suggested that the sharks were still present, but had moved to other sites.

- Some respondents reported similar declines for Eagle rays (*Aetobatus* spp.), bumphead parrot fish (*Bulbometapon muricatum*), Napoleon wrasse (*Cheilinus undulatus*) and Green and Hawksbill turtles (*Chelonia mydas, Eretmochelys imbricata*), although other respondents suggested that numbers had remained relatively stable, but sites of occurrence had shifted:
- Fukui 1998-99: regular sightings of five Napoleon wrasse have declined to two - three today, although for other species, numbers have increased, partly attributable to fish feeding.
- Barracuda Point 1996-98: regular sightings of large school(s) of barracuda (*Sphyraena barracuda*) have declined to occasional sightings of small schools today. Coincidentally, coral cover has declined, attributable to illegal destructive fishing.

- Other respondents reported little apparent change in abundances of large fish during the 1990s, although noting that some species have become less abundant in some places, and more abundant in others (Box 3).

Lembeh Strait

- On the fine sand bottoms, finning disturbance of sediments, particularly by novice divers and underwater photographers, has damaged or destroyed burrows of sand gobies / shrimps, partially or completely buried other species, and may have disturbed anaerobic sub-surface sediments.

- At most heavily-dived sites, a reduction in the much sought-after photo 'critters', including mimic octopus, flamboyant cuttlefish, harlequin shrimps, frog fish and pygmy seahorses, has occurred over the past five years, attributable to diver impacts and to net fishing. Netting in several sites has been conducted by both local and itinerant fishermen, and may have been a response to the increasing dive use.

- Potential impacts of repeated flash photography. Several respondents raised the issue of potential for damage to the eyes of cryptic species from repeated exposure to intense camera strobe flashes during macro-photography. In the most heavily dived photo sites (e.g. Nudi Falls, Nudi Retreat and Hair Ball), tens to hundreds of intense flashes are fired each day, many on the same 'critter'. Indeed, a line of macro-photographers from each of several dive parties, patiently waiting their turn to photograph particular animals, is the norm at these sites (see later). Each 'macro-photo critter' may be exposed to tens of flashes daily. The impact on the vision of these animals is unknown, although preliminary results of an unrelated study on vision in cryptic scorpionfishes and frogfishes did not detect damage to the eyes of several species sampled from these sites (M. Erdmann, NRM, pers. comm.). Nonetheless, this remains a concern among some dive operators, and there are also second-order effects relating to this activity.

- *Second-order effects - Changes in fish behavior:* In some of the more frequently dived sites in Lembeh Strait, species of predatory fishes (e.g. Hawkfish, family Cirrhitidae) have discovered that dive guides will unintentionally reveal the location of their favored prey on sea fans. In showing cryptic species of pygmy seahorses, shrimps, molluscs etc. on the sea fans to underwater photographers, guides inadvertently also display the prey to Hawkfish that quickly consume it. The behavior of the fish has changed in response to the dive activity, also affecting abundances of their prey.