PROCEEDINGS FROM WORKSHOPS ON MANAGEMENT STRATEGY EVALUATION OF DATA-LIMITED FISHERIES

Towards Sustainability – Applying the Method Evaluation and Risk Assessment Tool to Seven Indonesian Fisheries

Participants in Workshop 1 of the Crawford workshops on
“Management Strategy Evaluation for Data-limited Fisheries”.
Institut Pertanian Bogor Techno Park, Bogor Indonesia. September 2019.

Participants in Workshop 2 of the Crawford workshops on
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Proceedings from Workshops on Management Strategy Evaluation of Data-Limited Fisheries: Towards Sustainability – Applying the Method Evaluation and Risk Assessment Tool to Seven Indonesian Fisheries

Editors

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ANCORS	Australian National Centre for Ocean Resources and Security
APRI	*Asosiasi Pengelolaan Rajungan Indonesia* (Association of Blue Swimmer Crab Producers in Indonesia)
BRPL	*Balai Riset Perikanan Laut* (Research Institute for Marine Fisheries)
BSC	Blue Swimmer Crab
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora; also known as the Washington Convention
CL	carapace length
CPUE	catch per unit effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CW	carapace width
DBSRA/DBSRA-40	depletion-based stock reduction analysis; second option assumes current stock biomass is 40% of unfished levels
DCAC	depletion corrected average catch
DGCF	Directorate General of Capture Fisheries
DLMtool	data-limited methods toolkit
EEZ	exclusive economic zone
FAD	fish aggregating device
FAO	Food and Agriculture Organization (of the United Nations)
FL	fork length
FMA	Fisheries Management Area
GPS	global positioning system
IAC	inter-annual catch
IAW	Indonesian archipelagic waters
IT10	a version of total allowable catch (TAC) that allows a maximum of 10% variation in TAC annually
ITe10	a version of total allowable effort (TAE) with a maximum variation of 10% in effort annually
IPB University	Institut Pertanian Bogor
KKP	*Kementarian Kelautan dan Perikanan* (Ministry of Marine Affairs and Fisheries)
LBSPR	length-based spawning potential ratio
LIPI	*Lembaga Ilmu Pengetahuan Indonesia* (Indonesian Institute of Science)
Matlenlim	size limit based on the size at maturity

Matlenlim10	size limit based on 10% longer than the size at maturity
MCD	mean catch depletion
MDPI	*Masyarakat Dan Perikanan Indonesia*
MERA	Management Evaluation and Risk Assessment application
MMA	marine management area
MMAF	Ministry of Marine Affairs and Fisheries
MP	management procedure
MPA	marine protected area
MRnoreal	marine reserve with no reallocation of fishing effort outside the reserve
MRreal	marine reserve with reallocation of fishing effort outside the reserve
MSE	management strategy evaluation
MSY	maximum sustainable yield
NGO	nongovernment organisation
NPOA	National Plan of Action (for the Conservation and Management of Sharks)
PSA	productivity susceptibility analysis
RBYF	Redbelly Yellowtail Fusilier
RFMO	Regional Fisheries Management Organisation (e.g. tRFMOs for tuna fisheries)
SEAFDC	Southeast Asian Fisheries Development Center
SL	size limit
SPR	spawning potential ratio
TAC (JTB)	total allowable catch
TAE	total allowable effort
TL	total length
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	western and central Pacific Ocean
WCS-IP	Wildlife Conservation Society – Indonesia Program
WNT	West Nusa Tenggara province
WPEA project	West Pacific East Asia project (a collaboration between the Center for Fisheries Research, Ministry of Marine Affairs and Fisheries, and the WCPFC)

Biological and fisheries parameters

A_{50}	age at 50% maturity
B	biomass
B_{MSY}	biomass corresponding with maximum sustainable yield
E	exploitation rate
F	fishing mortality
k	instantaneous growth rate
$L(t)$	length at age t (years)
L_{50}	total/fork length at 50% maturity (also L_M)
L_{95}	total/fork length at 95% maturity
L_∞	asymptotic length
L_{MAX}	maximum recorded total length
M	natural mortality
SB	spawning biomass
SL_{50}	length at 50% selectivity
SL_{95}	length at 95% selectivity
t_0	estimated age at 0 length

1. Executive Summary

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Indonesian capture fisheries are among the most productive fisheries worldwide; several feature in the five highest-producing fisheries globally. Statistics for 2018 from the Food and Agriculture Organization of the United Nations (FAO) show that the overall landings of marine fish in Indonesia rank a global second. Moreover, the importance of small-scale Indonesian fisheries is underscored by the number of livelihoods they support. These proceedings report the findings from two workshops held to consolidate the available information on and evaluate management strategies for seven data-limited fisheries in Indonesia. The work builds on previous Australia–Indonesia collaborations in marine fisheries research, including three projects conducted by the Australian Centre for International Agriculture Research (ACIAR): (1) *Capacity development to monitor, analyse and report on Indonesian tuna fisheries*; 2005–2010 (ACIAR Project FIS/2002/074), (2) *Developing new assessment and policy frameworks for Indonesia's marine fisheries, including the control and management of Illegal, Unregulated and Unreported Fishing* (ACIAR Project FIS/2006/142), and (3) *Developing research capacity for management of Indonesia's pelagic fisheries resources* (ACIAR Project FIS/2009/059).

The focus of the workshops also aligns with the priorities identified by the *Strategic plan for ACIAR engagement in developing Indonesia's capture fisheries research and management capacity* (ACIAR Project FIS/2011/030), and with research priorities for the emerging Fisheries Resources Centre Network of Indonesia.

The workshops aimed to give participants an understanding of the general framework of fisheries management, and how to use various sources of data for managing stocks and assessing alternative management strategies, particularly for data-limited fisheries. The workshops also highlighted the value of 'data-rich' fisheries and how to move fisheries toward this status over time. The training was designed to give participants experience in evaluating data-limited fisheries using sources of information and tools for assessing and evaluating management options. Participants included professionals in the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), academics and research students in Indonesian universities, and professionals in marine non-government organisations (NGOs). Training progressed in two workshops. Workshop 1 introduced several topics and concepts: the process of evaluating management strategies and the use of the data-limited methods toolkit (DLMtool, https://www.datalimitedtoolkit.org/); synthesising data and information; current and potential regulations for future management of priority fisheries in Indonesia; potential methods of data-limited assessment to apply to these fisheries (i.e. length-based spawning potential ratio); and identifying management options that might be implemented for the fisheries. In Workshop 2, participants were trained in the approach and use of the Method Evaluation and Risk Assessment application (MERA, https://www.merafish.org/) in DLMtool in order to evaluate management options for the focus fisheries from Workshop 1.

Seven working groups each investigated one fishery. The seven fisheries were chosen on the basis of the intensity of fishing, the value of the fishery, the conservation status of the stocks, and/or the collection of fishery-independent data on the fishery or the biology of the target species. The fisheries comprised Blue Swimmer Crabs (*Portunus pelagicus*) in the Java Sea; Scalloped Spiny Lobster (*Panulirus homarus*) in the waters of southern Java; Scalloped Hammerhead Shark (*Sphyrna lewini*) from Tanjung Luar, Lombok; Redbelly Yellowtail Fusilier (*Caesio cuning*) in the waters of the Karimunjawa Islands in the Java Sea; Skipjack Tuna (*Katsuwonus pelamis*) in central Indonesian waters; Leopard Coral Grouper (*Plectropomus leopardus*) in Sumbawa waters; and Humpback Red Snapper (*Lutjanus gibbus*) in the waters of Banten province, southwestern Java. Data on the fish stocks, the fisheries, current management regulations in the fisheries, and future management options were assimilated in a standard template. The discussions and working groups were guided by a series of overview presentations: evaluating management strategies in fisheries; the stock assessment process in Indonesia; data-collection systems for Indonesian tuna fisheries; socioeconomic dimensions and traditional practices in Indonesian fisheries; small-scale fisheries and assessing grouper and snapper in eastern Indonesia; and the initiative for developing harvest strategies for grouper fisheries on Sumbawa and associated fish sampling by the Wildlife Conservation Society – Indonesia Program (WCS-IP).

1.1. Biology, fisheries and evaluation

The Indonesian archipelagic waters are divided into 11 Fisheries Management Areas (FMAs). Each FMA is considered a geographical unit; within the FMAs, nine main species groups are evaluated by the National Commission on Fish Stock Assessment of Indonesia: crabs, Blue Swimmer Crabs, lobsters, squid, small pelagics, large pelagics, demersal species, reef species, and penaeid shrimp. Large tuna are assessed separately following the protocols of the Western and Central Pacific Fisheries Commission (WCPFC). The current method of assessment for the nine species groups uses a surplus production model to determine a total allowable catch and optimal fishing effort for each of the groups in each FMA (i.e. 99 assessments).

The species examined in these workshops have diverse life-history strategies and are found in a variety of areas within the 11 FMAs. The Blue Swimmer Crab has a maximum age of 2–3 years, while the Scalloped Spiny Lobster, Redbelly Yellowtail Fusilier and Skipjack Tuna live for about 10 years. The Scalloped Hammerhead Shark (*S. lewini*) and some of the groupers (*P. leopardus*) and snappers (*L. gibbus*) live for more than 20 years. The types of fisheries for these species also differ markedly, ranging from those using traps and gillnets (*P. pelagicus*, *P. homarus*) to those using longlines (*S. lewini*), a variety of handlines, and spearguns (*C. cuning*, *P. leopardus* and *L. gibbus*). Skipjack Tuna are captured with the greatest diversity of methods: longlines, purse seines, handlines, pole and line, and gillnets (with or without fish aggregating devices).

Each working group completed the information on their fishery, including summarising new management strategies that might be applied to their fishery. The groups built an operating model for their fishery with the MERA application; 20 management procedures (e.g. catch controls, effort controls, spatial management) were evaluated in the management planning mode in MERA. Although MERA usually evaluates each procedure as a stand-alone procedure, multiple measures can be considered; for example, total allowable effort (TAE), size limit and spatial closures could be combined as one management procedure (written as *R* functions) and imported into MERA for evaluation.

Working groups discussed the results of the simulations and considered which management approaches were likely to be most suitable for achieving the objectives of the fishery. This information was documented systematically within the MERA application and forms the basis for constructing a fisheries operational model. The model simulates different management strategies over time and assesses the effects of these strategies on both long-term sustainable fishing and short-term yield of the fishery. Information on the biology of the stocks, their current status, the fishery, and the fishery's current and potential management are documented as part of the information-gathering phase within MERA (following the MERA questionnaire). This information is used to conduct a quantitative risk assessment that evaluates the probability of overexploiting the resource. In addition, the information is used to evaluate a range of potential management options to determine which approaches are most likely to meet the management objectives. A key part of the MERA approach is to develop a transparent and reproducible framework for decision making in fisheries management in which (a) all decisions and assumptions are documented and (b) all sources of uncertainty are accounted for in the analyses.

Small-scale fisheries form a significant component of fishing in all seven case studies. In Indonesia, such fisheries operate under unique conditions – they are not required to pay a license fee or to land fish at an official landing site, and can fish in all waters (inshore of 4 nautical miles and offshore). Consequently, unreported catch from these fisheries is considerable, and data from official landings possibly represents under 60% of the total catch. These attributes of small-scale fisheries make management procedures based on total allowable catch (TAC) difficult to implement. The MERA simulations and working-group discussions indicated that procedures based on total allowable effort (TAE), size limits and spatial closures are more likely feasible in these seven fisheries. However, more data on size at maturity and the spatial dynamics of the fish stocks are needed to build confidence in these measures. To implement new regulations, authorities would need to consult with fishers and the fishing industry to ensure that both parties understand the reasons for these regulations and that fishers will comply with them. Here NGOs can play a vital role by acting as an interface between government, fishers and the fishing industry. Further, because small-scale fisheries are so important in Indonesia, socioeconomic indicators should be included when evaluating fisheries and their management – topics for future research and workshops.

The workshops have strengthened existing collaborations and networks in Indonesia and provided a greater understanding of the research, management processes and harvest strategies in Indonesian fisheries. Priority areas for research and management were identified for each fishery. In addition, the workshops highlighted an important area for development: the need to communicate science and the implications of stock assessments to fishers and industry stakeholders. NGOs such as the WWF, the Wildlife Conservation Society – Indonesia Program, *Yayasan Konservasi Alam Nusantara* (YKAN) and *Yayasan Masyarakat Dan Perikanan Indonesia* (MDPI) play a vital role in educating fishers and the fishing industry about the practical application of research and policy.

1.2. Recommendations

The following recommendations were developed from the workshop findings and discussions during the workshops:

1. Develop and test protocols to collect data for estimating the scale of unreported catches in the fisheries examined.
2. Inform government of the extent of small-scale fishing and the likely consequences for catch statistics, assessing stock and evaluating management strategies.
3. Develop custom management procedures by combining several management measures (e.g. effort controls, spatial closures and size limits) into one procedure and evaluating its performance through further development of the MERA platform.
4. Develop priorities for biological research on selected species in the Fisheries Management Areas of Indonesia, and implement research on the age, growth and reproduction of priority species in Indonesian waters.
5. Identify training priorities for achieving sustainable fisheries in Indonesia.
6. Incorporate socioeconomic factors when assessing fisheries and evaluating management options.
7. Investigate collecting new socioeconomic information. For example: fishery networks in the fisheries and key actors in these networks (including supply and value chains); perceptions of fishers (and other associated people) about their

fishery, its current management and future management options; and fishers' likely responses to changes in management.

8. Identify potential pathways to develop and implement modern fisheries management rights, based on traditional tenure and measures, for small-scale fisheries in communities with the enabling conditions.
9. Foster ongoing partnerships between government, academics and nongovernment agencies that further the goals of sustainable fisheries management, and identify mechanisms for long-term funding of these partnerships.

1.3. Ringkasan Eksekutif

Perikanan tangkap di Indonesia merupakan salah satu perikanan di dunia yang paling produktif; beberapa diantaranya berada pada posisi lima tertinggi dalam produksi perikanan global. Data statistik sejak tahun 2018 dari Organisasi Pangan dan Pertanian Perserikatan Bangsa-Bangsa (UN-FAO) menunjukkan bahwa jumlah seluruh ikan-ikan laut yang didaratkan di Indonesia menduduki peringkat ke-dua dunia. Selanjutnya, pentingnya perikanan skala-kecil di Indonesia dikuatkan dengan banyaknya mata pencaharian yang disediakannya. Prosiding ini melaporkan temuan-temuan dari dua lokakarya yang dilakukan untuk mengkonsolidasikan informasi yang tersedia dan mengevaluasi strategi pengelolaan untuk tujuh perikanan data-terbatas di Indonesia. Kegiatan ini dibangun dari kerjasama sebelumnya antara Australia-Indonesia dalam penelitian perikanan laut, termasuk tiga proyek yang dilaksanakan oleh Australian Centre for International Agriculture Research (ACIAR): *(1) Capacity development to monitor, analyse and report on Indonesian tuna fisheries; 2005–2010 (ACIAR Project FIS/2002/074), (2) Developing new assessment and policy frameworks for Indonesia's marine fisheries, including the control and management of Illegal, Unregulated and Unreported Fishing (ACIAR Project FIS/2006/142), and (3) Developing research capacity for management of Indonesia's pelagic fisheries resources* (ACIAR Project FIS/2009/059.

Fokus dari lokakarya juga selaras dengan prioritas yang diidentifikasi di dalam *Strategic plan for ACIAR engagement in developing Indonesia's capture fisheries research and management capacity* (ACIAR Project FIS/2011/030), dan dengan prioritas penelitian dari Jejaring Pusat Sumberdaya Ikan Indonesia.

Lokakarya bertujuan untuk memberikan pemahaman kepada peserta mengenai kerangka umum pengelolaan perikanan, dan bagaimana menggunakan berbagai sumber data untuk mengelola stok dan mencari tahu strategi pengelolaan alternatif, khususnya untuk perikanan dengan data terbatas. Lokakarya juga menyoroti pentingnya perikanan 'data-kaya' dan bagaimana menggerakkan perikanan menuju kepada status tersebut seiring perjalanan waktu. Pelatihan dirancang untuk memberikan peserta pengalaman dalam mengevaluasi perikanan data-terbatas menggunakan sumber-sumber informasi dan alat-alat untuk menilai dan mengevaluasi pilihan-pilihan pengelolaan. Peserta meliputi para profesional di Kementerian Kelautan dan Perikanan (KKP), akademisi dan mahasiswa yang melakukan penelitian di universitas di Indonesia, dan para profesional di lembaga-lembaga non pemerintah (LSM) bidang kelautan. Pelatihan dilaksanakan di dalam dua lokakarya. Lokakarya 1 memperkenalkan beberapa topik dan konsep: proses-proses mengevaluasi strategi pengelolaan dan penggunaan perangkat untuk metoda-metoda data-terbatas (DLMtool, https://www.datalimitedtoolkit.org/); melakukan sintesa data dan informasi; peraturan-peraturan saat ini dan yang potensial untuk pengelolaan perikanan prioritas di Indonesian dimasa yang akan datang; metoda-metoda yang potensial untuk pendugaan data-terbatas yang diterapkan dalam perikanan tersebut (yaitu: rasio potensi pemijahan berbasis panjang), dan mengidentifikasi pilihan-pilihan pengelolaan yang mungkin bisa diterapkan untuk perikanan tersebut. Pada Lokakarya 2, peserta dilatih dalam menggunakan dan menerapkan sebuah aplikasi Method Evaluation and Risk Assessment (MERA, https://www.merafish.org/), didalam perangkat DLM untuk mengevaluasi pilihan-pilihan pengelolaan untuk perikanan yang menjadi fokus pada Lokakarya 1.

Tujuh kelompok kerja dibentuk yang masing-masing menelaah satu jenis perikanan. Ketujuh jenis perikanan dipilih berdasarkan intensitas penangkapan, nilai dari perikanan, status perlindungan dari stok, dan/atau pengumpulan data survei perikanan (*fishery-independent data*) terkait, atau informasi biologi dari spesies target. Perikanan tersebut terdiri dari Rajungan (*Portunus pelagicus*) di Laut Jawa; Lobster pasir (*Panulirus homarus*) di perairan selatan Jawa; Hiu martil (*Sphyrna lewini*) dari Tanjung Luar, Lombok; Ekor kuning (*Caesio cuning*) di perairan Kepulauan Karimunjawa di Laut Jawa; Cakalang (*Katsuwonus pelamis*) di perairan Indonesia tengah; Kerapu sunu (*Plectropomus leopardus*) di perairan Sumbawa dan Kakap merah (*Lutjanus gibbus*) di perairan propinsi Banten, barat daya Pulau Jawa. Data dikumpulkan kedalam format baku stok ikan, perikanan, aturan-aturan pengelolaan yang berlaku untuk perikanan saat ini, dan potensi pilihan-pilihan pengelolaan dimasa datang. Jalannya diskusi dan kelompok kerja diperkaya dengan presentasi tinjauan mengenai penilaian strategi pengelolaan perikanan, proses-proses pendugaan stok di Indonesia, sistem pengambilan data untuk perikanan tuna Indonesia, perikanan skala kecil dan penelitian kerapu dan kakap di Indonesia timur, dan inisiatif untuk mengembangkan strategi tangkap (*harvest strategy*) untuk perikanan kerapu di Sumbawa serta pengambilan sampel perikanan yang terkait oleh *Wildlife Conservation Society – Indonesia Program* (WCS-IP).

1.4. Biologi, perikanan dan evalusi

Perairan kepulauan Indonesia terbagi dalam 11 Wilayah Pengelolaan Perikanan (WPP). Setiap WPP dianggap sebagai satu kesatuan geografis; di dalam WPP, sembilan kelompok spesies utama dievaluasi oleh Komisi Nasional Pengkajian Sumberdaya Ikan: kepiting, rajungan, lobster, cumi-cumi, ikan pelagis kecil, ikan pelagis besar, ikan demersal, ikan karang, dan udang penaeid. Spesies tuna berukuran besar dievaluasi secara terpisah mengukuti protocol dari Komisi Perikanan Pasifik Barat dan Tengah (*Western and Central Pacific Fisheries Commission/WCPFC*). Metoda pendugaan terhadap sembilan kelompok spesies saat ini menggunakan *surplus production model* untuk menetapkan total tangkapan yang dibolehkan dan upaya tangkapan yang optimal untuk setiap kelompok disetiap WPP (99 pendugaan).

Spesies yang diteliti dalam lokakarya ini memiliki strategi riwayat kehidupan (*life history*) yang beragam dan ditemukan di berbagai kawasan di dalam 11 WPP. Rajungan memiliki usia maksimal 2–3 tahun, sementara Lobster pasir, Ekor kuning dan Cakalang hidup selama sekitar 10 tahun. Hiu martil (*S. lewini*) dan jenis kerapu (*P. leopardus*) and kakap (*L. gibbus*) hidup lebih dari 20 tahun. Jenis perikanan untuk spesies tersebut juga sangat berbeda, berkisar dari menggunakan perangkap dan jaring insang (*P. pelagicus*, *P. homarus*) hingga rawai (*S. lewini*), berbagai jenis pancing, dan panah (*C. cuning*, *P. leopardus* and *L. gibbus*). Cakalang ditangkap menggunakan metoda yang sangat berbeda-beda: rawai, jarring lingkar, pancing ulur, huhate dan jarring insang (dengan atau tanpa rumpon).

Setiap kelompok kerja melengkapi informasi mengenai perikanan, termasuk meringkas strategi pengelolaan yang baru yang mungkin bisa diterapakn untuk perikanan tersebut. Setiap kelompok mengembangkan sebuah model operasional untuk perikanannya masing-masing, menggunakan MERA Shiny-App; 20 prosedur pengelolaan (sebagai contoh kendali penangkapan, kendali upaya, pengelolaan spasial) dievaluasi di dalam moda perencanaan pengelolaan MERA. Meskipun MERA biasanya mengevaluasi setiap prosedur sebagai prosedur yang berdiri sendiri, berbagai opsi pengelolaan dapat dipertimbangkan; sebagai contoh, total upaya yang diperbolehkan (*total allowable effort/TAE*), pembatasan ukuran, dan penutupan spasial bisa dikombinasikan kedalam satu prosedur pengelolaan (ditulis sebagai fungsi-fungsi dari *R*) dan diimpor kedalam MERA untuk dievaluasi.

Kelompok kerja membahas hasil-hasil simulasi yang dilakukan dan mempertimbangkan pengelolaan mana yang kemungkinan besar paling sesuai untuk mencapai tujuan-tujuan dari perikanan. Informasi ini didokumentasikan secara sistematis ke dalam aplikasi MERA, yang membentuk landasan untuk membangun sebuah model operasional perikanan. Model mensimulasikan beberapa strategi pengelolaan dengan jangka waktu tertentu dan menilai pengaruh dari strategi-strategi tersebut terhadap penangkapan ikan berkelanjutan jangka panjang dan hasil jangka pendek dari perikanan. Informasi perihal biologi dari stok, statusnya saat ini, perikanan, dan pengelolaan perikanan yang ada dan yang potensial, didokumentasikan sebagai bagian dari fase pengumpulan informasi didalam MERA (sesuai dengan daftar pertanyaan MERA). Informasi digunakan untuk melakukan pendugaan resiko secara kuantitatif yang mengevaluasi probabilitas dari pemanfaatan sumberdaya secara berlebihan. Informasi juga dipergunakan untuk mengevaluasi kisaran dari potensi opsi-opsi pengelolaan guna menentukan pendekatan mana yang paling mungkin memenuhi tujuan-tujuan pengelolaan. Satu bagian kunci dari pendekatan MERA adalah mengembangkan kerangka yang transparan dan bisa disusun kembali (*reproducible*) untuk pengambilan keputusan di dalam pengelolaan perikanan dimana (a) semua keputusan dan asumsi-asumsi terdokumentasikan dan (b) semua sumber-sumber ketidakpastian dipertimbangkan di dalam analisa.

Perikanan skala-kecil menjadi komponen perikanan yang sangat signifikan di dalam ke-tujuh studi kasus. Di Indonesia, perikanan tersebut beroperasi dibawah kondisi yang unik – mereka tidak diwajibkan untuk membayar biaya perizinan atau mendaratkan ikan di suatu tempat pendaratan resmi, dan bisa menangkap ikan diseluruh perairan (dibawah 4 mil dan lepas pantai). Konsekuensinya, tangkapan yang tidak dilaporkan di dalam perikanan ini sangat besar, dan data dari tempat pendaratan resmi barangkali mewakili dibawah 60% dari total tangkapan. Atribut dari perikanan skala-kecil, membuat penerapan prosedur pengelolaan berbasis total tangkapan yang diperbolehkan (*total allowable catch/TAC*) sulit diterapkan. Simulasi MERA dan diskusi kelompok kerja menunjukkan bahwa prosedur yang berbasis pada total upaya yang diperbolehkan (*total allowable effort/TAE*), pembatasan ukuran tangkapan, dan penutupan spasial telihat paling mungkin bisa diterapkan pada ke-tujuh perikanan tersebut. Meskipun demikian, diperlukan lebih banyak data mengenai ukuran saat dewasa dan dinamika spasial dari stok ikan untuk membangun kepercayaan terhadap langkah-langkah pengelolaan tersebut. Untuk menerapkan aturan baru, otoritas pengelola perlu berkonsultasi dengan nelayan dan industri perikanan untuk memastikan bahwa keduanya memahami alasan dibalik regulasi tersebut dan nelayan akan patuh terhadapnya. Disini LSM bisa memainkan peran penting dengan bertindak sebagai titik temu antara pemerintah, nelayan dan industri perikanan. Kemudian, oleh karena perikanan skala-kecil sangat penting di Indonesia, indikator-indikator sosial ekonomi harus disertakan pada saat melakukan evaluasi perikanan dan pengelolaannya – topik untuk penelitian dan lokakarya dimasa mendatang.

Lokakarya-lokakarya ini telah memperkuat kerjasama dan jejaring yang ada di Indonesia dan memnerikan pemahaman yang lebih dalam tentang penelitian, proses-proses pengelolaan dan strategi penangkapan pada perikanan Indonesia. Area-area prioritas untuk penelitian dan pengelolaan diindentifikasi untuk masing-masing perikanan. Sebagai tambahan, lokakarya juga menyoroti sebuah area untuk pengembangan: perlunya mengkomunikasikan sains dan implikasi dari pendugaan stok kepada pemangku kepentingan nelayan dan industri. LSM-LSM seperti WWF, the Wildlife Conservation Society – Indonesia Program, Yayasan Konservasi Alam Nusantara (YKAN) and Yayasan Masyarakat Dan Perikanan Indonesia (MDPI) memainkan peran yang sangat penting dalam memberikan pembelajaran kepada nelayan dan industri perikanan mengenai penerapan secara praktis dari penelitian dan kebijakan.

1.5. Rekomendasi untuk dipertimbangkan

Rekomendasi berikut, berhasil dikembangkan dari temuan dan diskusi selamat lokakarya:

1. Mengembangkan dan menguji protokol pengumpulan data untuk menduga skala besaran tangkapan yang tidak dilaporkan pada perikanan yang dikaji.
2. Menginformasikan kepada pemerintah mengenai cakupan dari perikanan skala-kecil dan konsekuensinya bagi pendataan statistik hasil tangkapan, pendugaan stok dan evaluasi strategi pengelolaannya.
3. Menyusun prosedur pengelolaan yang disesuaikan dengan mengkombinasikan sejumlah langkah-langkah pengelolaan ke dalam satu prosedur (sebagai contoh, kendali upaya, penutupan spasial, dan batasan ukuran) dan mengevaluasi kinerjanya. Catatan: pengembangan platform MERA akan bermanfaat sebagai bagian dari kegiatan ini.

4. Menyusun prioritas penelitian biologi untuk spesies yang ditentukan di WPPNRI dan melakukan penelitian mengenai umur, pertumbuhan dan reproduksi dari jenis jenis ikan prioritas di perairan Indonesia.
5. Mengidentifikasi prioritas pelatihan untuk pencapaian perikanan yang berkelanjutan di Indonesia.
6. Menyertakan pertimbangan sosial-ekonomi ke dalam pendugaan perikanan dan evaluasi alternatif pengelolaan.
7. Melakukan penelitian dan pengumpulan informasi sosial-ekonomi terkait dengan, sebagai contoh, (a) jejaring dalam perikanan tangkap, dan aktor kunci di dalam jejaring (termasuk rantai pasok dan nilai), (b) persepsi dari nelayan dan pihak terkait dengan nelayan pada perikanan terkait, pengelolaan yang ada saat ini, dan potensi pilihan-pilihan pengelolaannya di masa mendatang, dan (c) kemungkinan perubahan respon mereka di dalam pengelolaan.
8. Mengidentifikasi cara mengembangkan dan menerapkan hak pengelolaan perikanan berdasarkan tradisi dan kebijakan lokal,bagi masyarakat dengan mempertimbangkan berbagai kondisi yang memungkinkannya.
9. Mendorong secara terus-menerus kemitraan antara pemerintah, akademisi, lembaga non-pemerintah untuk memperbaiki perikanan dan mengidentifikasi berbagai mekanisme untuk pembiayaan kerjasama tersebut dalam jangka panjang.

2. Overview: Assessing and managing data-limited fisheries, the Indonesian context, and the workshops

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2.1. Introduction

Indonesia is an archipelagic nation, with over 13,466 islands within one of the largest exclusive economic zones (EEZs) in the world. Indonesian capture fisheries are among the most productive fisheries worldwide, with several fisheries in the top five by production globally. Statistics from the Food and Agriculture Organization of the United Nations (FAO) show that the overall production of fish products in Indonesia is second globally (FAO, 2020). Indonesian fisheries become even more significant when considering the number of livelihoods supported by small-scale fisheries.

Currently, Indonesian small-scale fishers are exempted from management measures for capture fisheries: they are not required to hold a fishing license or submit to the requirements of a monitoring system for fishing vessels, nor do they pay fisheries fees (Halim et al., 2019). If implemented, such management measures would be extremely challenging to apply because Indonesian small-scale fisheries are scattered across more than seventy thousand villages along the coasts of the Indonesian archipelago and the fishers often land their catch in areas with little or no enforcement presence (Halim et al., 2019). Consequently, Indonesian small-scale fisheries contribute significantly to unregulated fisheries and unreported landings, similar to small-scale fisheries in other Southeast Asian countries (Teh and Pauly, 2018).

Indonesian waters are divided into 11 Fisheries Management Areas (FMAs) (*Wilayah Pengelolaan Perikanan/WPP*) (Figure 2.1) and all FMAs extend across more than one provincial border. The FMA is considered a geographical unit for developing fisheries management plans and programs that are expected to be implemented through a designated technical unit under the Ministry of Marine Affairs and Fisheries (MMAF) (Muawanah et al., 2018). The 'level of utilisation' (*tingkat pemanfaatan* = $F_{\text{current}}/F_{MSY}$) is determined for nine main species groups: crabs, Blue Swimmer Crabs, lobsters, squid, small pelagics, large pelagics, demersal species, reef species, and penaeid shrimp. Note that the large tuna are considered separately as part of Indonesia's commitment to regional forums on tuna (Hoshino et al., 2020; see also below). The level of utilisation is mostly 0 to 1; values <0.5 are considered moderate utilisation; 0.5 to <1, fully exploited; and ≥1, overexploited (see Ministerial Decision 50/2017). These determinations of the level of utilisation are formally declared by the Minister of Marine Affairs and Fisheries based on recommendations from the National Commission on Fish Stock Assessment of Indonesia, which meets biannually. This Commission has been in operation since 1985, hosted under the Indonesian Institute of Science (*Lembaga Ilmu Pengetahuan Indonesia/LIPI*) (Halim, 2020). However, the Commission was 'officially' established in 2005 through the Regulation of the Minister of Marine Affairs and Fisheries No.PER.14/MEN/2005, one year after the enactment of Fisheries Law No. 31/2004, which in Article 7(4)(5) [1] explicitly mandated the creation of the Commission. The Centre for Fisheries Research and its associated research institutes (particularly the Research Institute for Marine Fisheries and the Research Institute for Tuna Fisheries) under the MMAF's Agency of Marine and Fisheries Research and Human Resources, complete the analyses of the data and provide reports to the National Commission. Four sources provide the input data for these assessments:

- port sampling data (by enumerators); *Kementerian Kelautan dan Perikanan* (KKP, Ministry of Marine Affairs and Fisheries) has three forms for completion; most data are in aggregated form
- on-board data collection by designated observers
- landing data from fishing-boat log books; recorded by boat captain (mandatory for all fishing boats >5 GT before 2016 and >10 GT since then)
- acoustic surveys of biomass in different areas of the Indonesian EEZ (3/year).

The current method of assessment uses a surplus production model, which is based on catch and effort data aggregated across all species within each of the nine species groups in an FMA to estimate the maximum sustainable yield and optimal fishing effort for each species group in each FMA (i.e. total of 99 assessments; Jaya, 2019). The fish stock assessments to determine the maximum sustainable yield (MSY) and total allowable catch (TAC) are mandated under Article 7(1) of the fisheries law and Article 27 of Law No. 11/2020 on Job Creation, and are also part of the mandatory reporting requirements to the FAO.

[1] Recently, these articles have been annulled by Law No.11/2020 on Job Creation (also known as the Omnibus Law); however, the mandates for establishing the Commission are accommodated under the current draft Government Regulation concerning Capture Fisheries Affairs, which is an implementation regulation of the Job Creation Law.

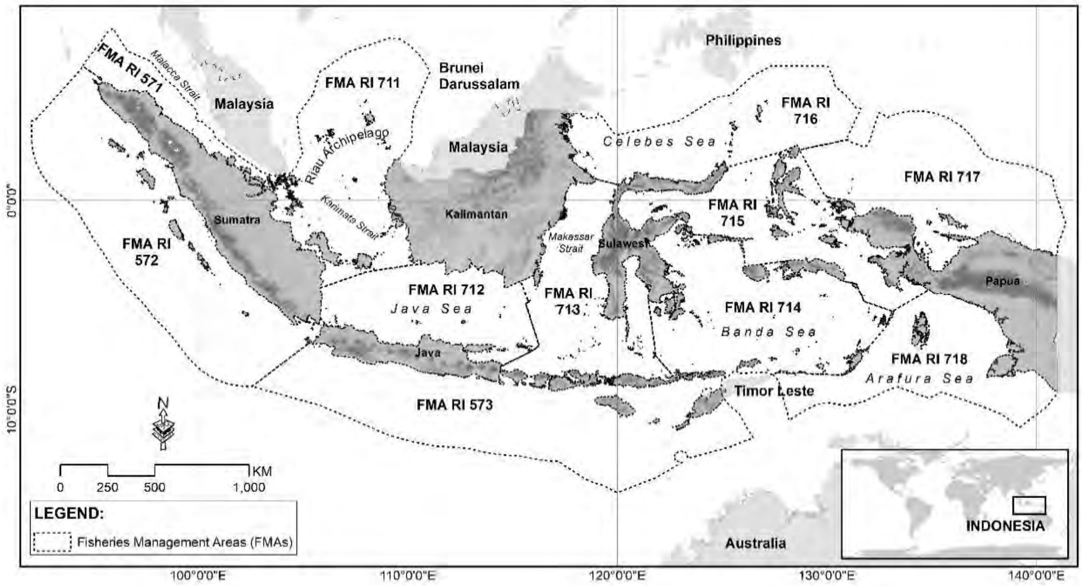

Figure 2.1. Map of Indonesian Fisheries Management Areas (FMAs), adapted from the Ministry of Marine Affairs and Fisheries (MMAF, 2017).

As noted above, large tuna are assessed as part of Indonesia's commitment to regional fishing forums (Hoshino et al., 2020). For example, the state of tropical tuna stocks, such as Skipjack Tuna (*Katsuwonus pelamis*) in the western and central Pacific Ocean, are assessed by the Western Central Pacific Fisheries Commission (WCPFC), with data provided from various nations. The catches of tuna within FMAs 713, 714 and 715 are within Indonesia's archipelagic waters and do not come under the regulation of the WCPFC. However, as part of Indonesia's commitment to the WCPFC, large tuna stocks, including *K. pelamis*, are assessed using methods compatible with those of the WCPFC. Indonesia's plans for developing its national tuna management plan and harvest strategy for tropical tuna in the archipelagic waters are reviewed and discussed at all regular WCPFC meetings.

Indonesia has developed, or is developing, fisheries management plans (FMPs) and harvest strategies for some fisheries (Taurusman, 2019), including FMPs for crabs (Kepmen KP No. 70/KEPMEN-KP/2016), lemuru (Kepmen KP No. 68/KEPMEN-KP/2016), flying fish (Kepmen KP No. 69/KEPMEN-KP/2016) and tuna (Kepmen KP No. 107/KEPMEN-KP/2015). Draft plans are being developed for snapper (Lutjanidae) and groupers (Serranidae). As part of the FMPs, harvest strategies are being developed for blue swimmer crabs in FMA 712, snapper (FMAs 713 & 715), groupers (FMAs 713 & 715), and tuna. The harvest strategy for Indonesia's tuna fisheries has been in development since late 2014 and focuses on FMAs 713, 714 and 715. A National Fisheries Management Plan for Skipjack and neritic tuna was launched by the MMAF in November 2014, followed by the Interim Harvest Strategy Framework for Yellowfin Tuna, Bigeye Tuna and Skipjack in FMAs 713, 714 and 715 in May 2018.

In 2016, based on a recommendation from the National Scientific Commission on Stock Assessment, the MMAF declared that overfishing was occurring for several groups of species in Indonesian waters, including small pelagic, sedentary, demersal and reef-associated species (Halim et al., 2020). Further, overfishing was recognised as occurring throughout the 11 FMAs (through decision number 47/KEPMEN-KP/2016). This declaration of the scale of overfishing throughout Indonesian waters places increasing importance on the questions of how fisheries are evaluated and how alternative management options are assessed to ensure their long-term sustainability and production.

2.2. Overview of assessment and management of data-limited fisheries

Quantitative stock assessment models use time-series data of historical catches together with an index of abundance to estimate the current biomass of the stock relative to biological reference points such as the equilibrium unfished biomass (B_0) or the biomass corresponding with maximum sustainable yield (B_{MSY}) (Hilborn and Walters, 1992). When insufficient data are available to estimate the current stock status of a fishery, it is called a data-limited fishery. The vast majority of the world's fisheries are data limited, with no estimates of current stock abundance or biological reference points (Costello et al., 2012). Several methods, such as the length-based spawning potential approach (LBSPR) (Hordyk et al., 2015, 2016) and other length-based approaches (e.g. Rudd and Thorson, 2017; Huynh et al., 2018), have been developed to determine the condition of data-limited fisheries. These approaches often rely on strict assumptions such as equilibrium conditions and constant fishing mortality, which are likely to be violated in most fishery settings. However, these approaches have the advantage of requiring only minimal data and can be used to provide both an initial estimate of the impact of fishing on the sustainability of the stock and an index of the stock condition over time. They can also be used in a management procedure approach to provide recommendations for management of the fishery.

The management procedure approach involves managing a fishery with an agreed management procedure, sometimes called a 'harvest strategy'. The harvest strategy specifies how fishery data are converted to a management action (Figure 2.2). Management procedures are objective and reproducible – that is, a management procedure will return the same management recommendation when provided with the same set of data. In other words, there is no subjectivity in the conversion of data to management advice.

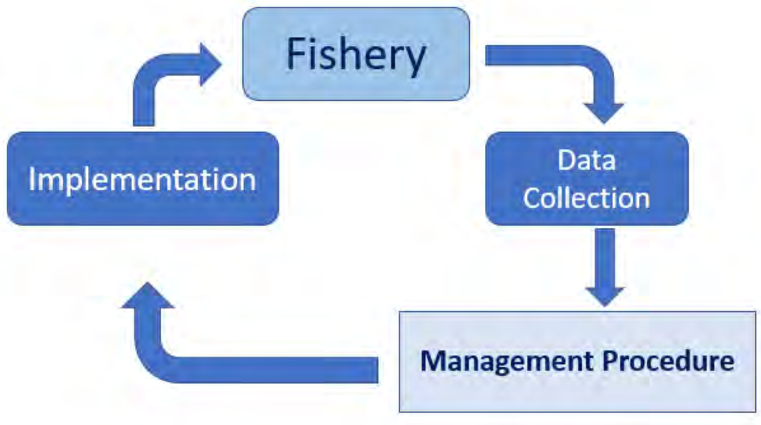

Figure 2.2. Schematic of the fishery management cycle using the management procedure approach. Data are collected regularly (e.g. every year) and provided as input to a management procedure to determine a management recommendation (e.g. an adjustment to catch limit or season length), which is then implemented in the fishery.

A second component of the management procedure approach involves closed-loop simulation testing. Data can be converted into management advice in many different ways, and a system must be developed to identify the potential management approaches that are unlikely to result in meeting the management objectives of the fishery (Punt, 2015). Closed-loop simulation testing involves building a computer model of the fishery system that includes the stock and fleet dynamics, the data-collection process, and the implementation of the management advice. This system, often called management strategy evaluation (MSE), is now widely regarded as best practice for fisheries management (Punt et al., 2016).

While closed-loop simulation testing and MSE were initially developed in the context of data-rich fisheries, they can also be applied to smaller-scale and data-limited fisheries. Moreover, in the absence of regular and reliable estimates of the status of a stock, the management procedure approach offers the only principled and transparent method for determining an appropriate mode of management for a data-limited fishery (Hordyk and Carruthers, 2018).

Closed-loop simulation testing requires the construction of an operating model, which includes the current state of knowledge, including the uncertainties of the fishery (Figure 2.3). Once an operating model is constructed, it can be used in the simulation-testing framework to identify modes of management that will likely meet the management objectives for the fishery, as well as identify the sources of data that are most important for managing the fishery. An operating model contains a description of the stock characteristics (e.g. growth, mortality, recruitment dynamics) and the properties of the fishing fleet exploiting the stock (e.g. selectivity pattern, historical fishing mortality). The observation model is used to apply observation error and bias to the simulated fishery data to represent the typical data observed in the fishery. A suite of alternative management procedures is applied in parallel to the data in each time step of the model to generate management advice based on the specific rules in the management procedure. An implementation model is then used to apply any likely implementation error, for example, catch exceeding the total allowable catch (catch overages) or non-enforcement of a size regulation. These errors are fed back into the operating model, which updates the system dynamics for the next time step (Figure 2.3; Carruthers and Hordyk, 2018).

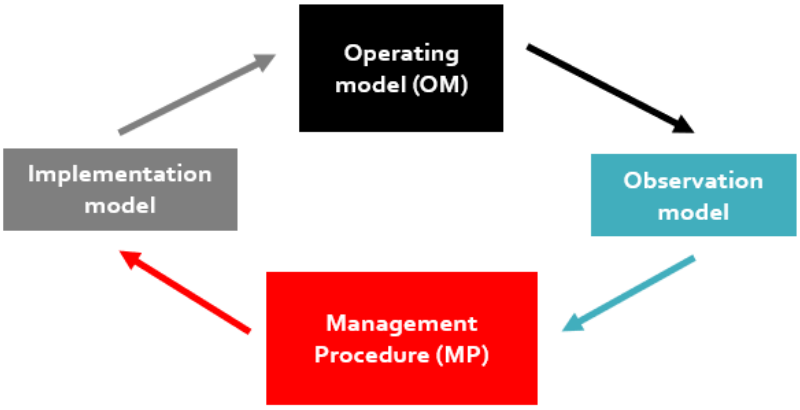

Figure 2.3. Flowchart showing the components of a management strategy evaluation using closed-loop simulation testing.

2.3. Focus of the training and the selected fisheries

The aim of this training was to provide participants with an understanding of the general framework of fisheries management, and how to use different sources of data for managing stocks and assessing alternative management strategies, with a focus on data-limited fisheries. The workshops also highlighted the value of understanding those data that are most important for improving the management of a fishery. The training provided participants with experience in evaluating data-limited fisheries and sources of information and tools that can be used to make assessments and evaluate management options. Participants included personnel from the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), university academics and research students, and professionals in nongovernment organisations (NGOs: Wildlife Conservation Society – Indonesia Program [WCS-IP]; *Yayasan Masyarakat Dan Perikanan Indonesia* [MDPI]; and *Yayasan Konservasi Alam Nusantara* [YKAN]).

Two workshops were held. The first workshop introduced the concept of management strategy evaluation and operational models for fisheries, and synthesising data and information for priority fisheries in Indonesia, including invertebrate fisheries. The species selected were the Blue Swimmer Crab (*Portunus pelagicus*), Scalloped Spiny Lobster (*Panulirus homarus*), Scalloped Hammerhead Shark (*Sphyrna lewini*), Redbelly Yellowtail Fusilier (*Caesio cuning*), Skipjack Tuna *(Katsuwonus pelamis)* and the demersal and reef-associated species, Leopard Coral Grouper (*Plectropomus leopardus*) and Humpback Snapper (*Lutjanus gibbus*). The second workshop introduced a methodology for completing quantitative risk assessments and evaluating different management controls using the Method Evaluation and Risk Assessment (MERA) application (https://www.merafish.org/). The species chosen for the workshop form the basis of significant fisheries, were priorities for the MMAF, and also had several sources of data to supplement the standard data collected by the MMAF, particularly length-frequency data. In some cases, these data were collected by NGOs such as the WCS-IP (Leopard Coral Grouper in Saleh Bay), YKAN (Humpback Red Snapper), and MDPI (Skipjack Tuna).

The MERA framework is an interactive, browser-based application designed as an open-source tool for analysing risk, guiding projects to improve fisheries, and evaluating alternative strategies for managing fisheries. Developed as an ongoing collaboration between the Marine Stewardship Council, the Institute for Oceans and Fisheries at the University of British Columbia and the Natural Resources Defence Council, MERA was built with the DLMtool (Carruthers and Hordyk, 2018, 2019) and MSEtool (Huynh et al., 2019), and *R* freeware packages for statistics, modelling and graphics (https://www.r-project.org/). The purpose of the MERA analyses for each working group was to explore how quantitative analysis with simulation modelling can be used to objectively determine a suitable management approach for a fishery. The MERA application allows users to rapidly evaluate management strategies by assessing 20 management procedures, one at a time. Different management measures such as total allowable effort, size limits and spatial closures can be evaluated as one combined procedure (using *R*) and then importing them into MERA. In the second workshop, each working group used MERA to evaluate management strategies for their fishery by:

1. Building an operating model by completing the MERA questionnaires.
2. Testing 20 example management procedures (e.g. catch controls, effort controls, spatial management) in the management-planning mode in MERA.
3. Determining which management approaches were most suitable for achieving the objectives of the fishery.

The MERA website (https://www.merafish.org/) contains more information on MERA and a web-based version of the application (Carruthers and Hordyk, 2019).

Information on the biology of the stocks, their current status, the fishery and its current and potential management are documented as part of the information-gathering phase within MERA (following the MERA questionnaire). This information is used to conduct a quantitative risk assessment to evaluate the probability of overexploitation. In addition, the information is used to evaluate a range of potential management options to determine which approaches are most likely to meet the management objectives. A key part of the MERA approach is to develop a transparent and reproducible framework for decision making in fisheries management in which (a) all decisions and assumptions are documented and (b) all sources of uncertainty are accounted for in the analyses.

The species examined in these workshops have diverse life-history strategies and are found in a variety of areas within Indonesia's 11 FMAs (Table 2.1). For example, the Blue Swimmer Crab (*Portunus pelagicus*) has a maximum age of about 2–3 years, while the Scalloped Spiny Lobster (*Panulirus homarus*), Redbelly Yellowtail Fusilier (*Caesio* *cuning*) and Skipjack Tuna (*Katsuwonus pelamis*) live for about 10 years, and the Scalloped Hammerhead Shark (*Sphyrna lewini*) and some of the groupers (e.g. *Plectropomus leopardus*) and snappers (e.g. *Lutjanus gibbus*) live for more than 20 years (Table 2.1). The types of fisheries selected for evaluation with MERA also differ markedly, ranging from those using traps and gillnets (*Portunus pelagicus, Panulirus homarus*) to those using longlines (*S. lewini*) and a range of other gears (*Plectropomas leopardus, K. pelamis*) (Table 2.1). Despite these differences in the biology of the fish populations and the methods of capture, small-scale fishers form a significant component of all seven fisheries.

Table 2.1. Summary of biology and fishery information for focus species and fisheries

Section. Species	~Max. age (y)	Max. length (mm)	Length at 50% maturity (mm)	FMA, location	Main capture method
3. Blue Swimmer Crab (*Portunus pelagicus*)	2–3	190	100	FMA 712, coastal Java and eastern Lampung	Trap, gillnet, trawl
4. Scalloped Spiny Lobster (*Panulirus homarus*)	10	96.6	58.5	FMA 573, southern central Java	Trap, gillnet
5. Scalloped Hammerhead (*Sphyrna lewini*)	35	3700	2150	FMAs 713, 573, Tanjung Luar, Lombok	Longline
6. Redbelly Yellowtail Fusilier (*Caesio cuning*)	10	390	238	FMA 712, Karimunjawa Islands	Speargun, trap, handline
7. Skipjack Tuna (*Katsuwonus pelamis*)	12	1110	400	FMAs 713, 714,715	Purse seine, pole and line, longline, handline, troll line, gillnet
8. Leopard Coral Grouper (*Plectropomus leopardus*)	25	970	370	FMA 713, Saleh Bay, Sumbawah	Speargun, handline, bottom longline, troll line, dropline, trap
9. Humpback Red Snapper (*Lutjanus gibbus*)	20	400	270	FMAs 573, 713	Dropline, longline

For more detailed information, see relevant sections of the report. FMA = Fisheries Management Area.

2.4. Objectives of the workshops

Objectives of Workshop 1 on management strategy evaluation for data-limited fisheries (17–19 September 2019):

1. Gain an understanding of management strategy evaluation and its application to fisheries.
2. Evaluate different sources of data for managing fish stocks.
3. Synthesise data, information and assessments of the seven fish stocks.
4. Identify potential management options for chosen species.
5. Introduce participants to closed-loop simulation testing and management strategy evaluation (MSE).

Objectives of Workshop 2 on evaluating the seven fish stocks (22–24 October 2019):

1. Become familiar with and apply the Method Evaluation and Risk Assessment application (MERA) to chosen fisheries.
2. Construct operating models for each fishery.
3. Conduct quantitative risk assessment for each fishery using MERA.
4. Understand the importance of well-defined performance metrics for MSE.
5. Determine performance metrics for evaluating alternative management methods.
6. Use MERA to evaluate different management approaches.
7. Understand MSE results in trade-offs and projection plots.
8. Use the findings of the MERA analyses to identify potential management options most likely to meet the management objectives of the chosen fisheries.
9. Identify areas for research that will improve the information for management and policymakers to reduce uncertainty in fisheries assessments and management actions.

Workshop 1 included the following presentations (See Appendix 2.1):

1. The Stock-Assessment Process for Fisheries Management (Professor Indra Jaya, IPB University)
2. Data Systems for Tuna Fisheries (Craig Proctor, CSIRO)
3. Traditional Fisheries and Their Management in Indonesia (Dr Dedi Adhuri, LIPI)
4. The Wildlife Conservation Society – Indonesia Program for Sustainable Grouper Fisheries in Saleh Bay, Sumbawa (Dr Irfan Yulianto)
5. An Introduction to MSE and the Application of Management Evaluation and Risk Assessment (Professor Neil Loneragan, Murdoch University)

Workshop 2 included a presentation on the development of management plans and harvest strategies for fisheries (Associate Professor Azbas Taurusman, IPB University) (See Appendix 2.2).

2.5 Structure of the workshop proceedings

Each working group wrote a report for their species (sections 3 to 9 of these proceedings) based on the work they completed during both workshops. The structure of the reports is based on a report on the biology, stock status and management of fish species in southwestern Australia (Smallwood et al., 2013) and on the questions asked as part of documenting the information for each fishery in the MERA application. They contain the following sections:

1. Summary
2. Biology (e.g. taxonomic designation, distinguishing features, growth, reproduction)
3. Fishery (location of interest, fishing effort and regulation)
4. Management regulations (current and future options)
5. Data sources
6. Management planning in MERA
7. References

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Appendix 2.1

Workshop 1: Introduction to Management Strategy Evaluation for Data-Limited Fisheries

17–19 September 2019, IPB Techno Park, Bogor Indonesia

Trainers: Neil Loneragan, Budy Wiryawan, Fayakun Satria, Abdul Halim, Craig Proctor (with guidance from Adrian Hordyk)
Participants: Academics and graduate students, fisheries biologists, modellers and managers with the MinMAF and NGOs

Workshop 1 Agenda
Day 1: 17 September 2019
Welcome & Introductions: Pak Budy, IPB; Pak Fayakun (RCF); Pak Neil **Workshop objectives** **Topic 1**: Fisheries assessment and management *Concepts*: collecting fishery data; using data to inform management; stocks assessment and alternatives for data-limited fisheries; harvest control rules (Key references: Dowling et al., 2018; Hordyk et al., 2015a, 2015b; Prince et al. 2015a, 2015b; Rudd and Thorson and 2017). Examples from Australia (NL) and Indonesia (grouper & snapper, AH; lobster, PC) **Topic 2**: Introduction to management strategy evaluation *Concepts*: a reproducible & defensible method to identify management approaches most likely to meet management objectives; define management objectives. *Problem statement*: Every fishery is different, no general solutions; Management objectives in Indonesia (NL); Introduction to Indonesian stock assessment process (Prof. Indra Jaya) **Topic 3**: Characterizing a fishery: the operating model *Concepts*: information required to characterise knowledge of a fishery system; characterising knowledge (and uncertainty) of entire fishery process (stock dynamics, fishing activity, data collection, management recommendations & implementation) (material from AH) **Activity 1**: Working groups to summarise knowledge of fisheries: • Stock biology: natural mortality; growth; maturity; stock-recruitment relationship; if there are spatial closures – fraction of the habitat in the closed area and movement rates between open and closed areas, current stock status (if known or able to guess a range); description and estimates of parameter values (ranges or distributions) • Fishing fleet: selectivity pattern of fishing gear; history of fishing effort; future changes in fishing efficiency – description and estimates of parameter values (ranges or distributions); sources of fishing mortality – identifying all sources of *F* (i.e. the different fisheries and types of gear that the species is caught in, indicators for the fishery, population, fishers) • Summary of available data sources and potential for collecting new data • Summary of supply and value chains • Role of women in the fishery • Identification of gaps in knowledge [**Possible activity Day 1/Day 2**: use of LB-SPR to estimate selectivity, size at maturity, *F/M* and SPR for the target species] **Activity 1 (cont.)**: Report back on summary of findings from working groups

Workshop 1 Agenda
Day 2: 18 September 2019
Topic 4: Management options for fisheries *Concepts*: range of management approaches – static vs active management; stock assessment & model-free approaches; harvest control rules (material from Adrian Hordyk, examples of management options from Australia) **Activity 2**: Working groups summarise • Current management arrangements for their fisheries (and a history of management changes where applicable) • Potential modifications of existing management arrangements or possible alternative approaches • A list of potentially feasible management approaches to test for each fishery **Topic 5**: Management objectives and quantitative performance metrics. *Concepts*: Why they are important? How do we define what we want? How do we identify methods that perform well (and those that perform poorly)? (material from Adrian) **Activity 3**: Working groups describe management objectives for their fishery, and how these management objectives can be quantified and evaluated within MSE (e.g. must be greater than x% probability that biomass is above 0.4 B_0 after 10 years of active management); definition of target and limit reference points for SPR **Topic 6**: Demonstration of MSE using MERA app (shiny-based app for running MSE without requiring R code). Example: describe fishery, select management approaches (material from Adrian)
Day 3: 19 September 2019
Activity 4: Working groups summarise their findings on the fishery in an extended abstract and develop a brief PowerPoint of their key findings **Activity 5**: Working groups present synthesis of fishery, management objectives, potential management approaches, initial evaluation of MSE results, gaps in knowledge and uncertainties in the data/information. Develop plan for report on their fisheries for input to Workshop 2

Appendix 2.2

Workshop 2: Application of Method Evaluation and Risk Assessment (MERA) to seven data-limited fisheries

22–24 October 2019, Wildlife Conservation Society – Indonesian Program offices, Bogor, Indonesia

Trainers: Adrian Hordyk with Neil Loneragan, Budy Wiryawan, Fayakun Satria, Abdul Halim, Craig Proctor
Participants: 10–15 academics and graduate students, relevant staff from MMAF

Workshop 2 Agenda		
Day 1: Tuesday 22 October 2019		
Time	**Activity/Topic**	**Presenter**
08:00 – 08:30	Registration	
08:30 – 09:20	Welcome and Ceremony	Committee
	Welcome by Pak Budy, Chair of Organising Committee Welcome by Pak Sugeng, Head of Department Introduction to workshop by Prof Neil Loneragan Introductions by participants	
09:20 – 09:30	Break	
09:30 – 10:30	**Topic 1**: Introduction, re-cap of Workshop 1, workshop objectives, introduction to MERA	Neil Loneragan, Adrian Hordyk
10:30 – 11:15	**Topic 2**: Harvest control rules in Indonesia	Dr Azbas Taurusman
11:15 – 12:00	**Topic 3**: MERA questionnaire – fishery questions	Adrian Hordyk
12:00 – 13:00	Lunch Break	
13:00 – 15:00	**Activity 1**: Populate fishery questionnaire	
15:00 – 15:30	Break	
15:30 – 16:30	**Continue Activity 1**: Complete characterising fishery and generate report	

Workshop 2 Agenda		
Day 2: Wednesday 23 October 2019		
Time	**Activity/Topic**	**Presenter**
08:30 – 09:00	Registration	
09:00 – 09:30	**Topic 4**: Introduction to quantitative risk assessment in MERA	Adrian Hordyk
09:30 – 10:00	**Activity 2**: Run risk assessments	
10:00 – 10:15	Break	
10:15 – 12:00	**Continue Activity 2**: Continue risk assessments Create risk assessment reports Report on risk assessment results Presentation of results by groups. Rank stocks by risk	
12:00 – 13:00	Lunch break	
13:00 – 13:30	**Topic 5**: Management planning: Management & data questions	Adrian Hordyk
13:30 – 15:00	**Activity 3**: MERA questionnaire – management & data questions	
15:00 – 15:30	Break	
15:30 – 16:00	**Topic 6**: Management planning in MERA	Adrian Hordyk
16:00 – 17:00	**Activity 4**: Explore management planning in MERA	
Day 3: Thursday 24 October 2019		
Time	**Activity/Topic**	**Presenter**
08:30 – 09:00	Registration	
09:00 – 09:15	**Topic 7:** Preparation for Activity 5	
09:15 – 12:00	**Activity 5**: Management planning in MERA with top 20 MPs	

Workshop 2 Agenda		
Time	**Activity/Topic**	**Presenter**
12:00 – 13:00	Lunch break	
13:00 – 16:00	**Activity 6**: Working groups present synthesis of management planning analysis	
16:00 – 16:30	Break and closing ceremony	Committee

3. Fisheries management for the Blue Swimmer Crab (*Portunus pelagicus*) in the Java Sea, Indonesia

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Male (left) and female (right) *Portunus pelagicus,* the Blue Swimmer Crab (English), or *Rajungan* (Bahasa Indonesia). (Images: Tri Ernawati)

Summary

The Blue Swimmer Crab (BSC) *Portunus pelagicus*, locally known as *Rajungan*, is the third-most economically valuable fisheries resource in Indonesia (after tuna and shrimp). Most BSC is exported, mainly to the United States (~80% of exports), as cooked meat in cans. More than 40% of the national production of BSC comes from the Java Sea, Fisheries Management Area (FMA) 712 in Indonesian waters. In Indonesia, small BSC are found mainly on the east coast of Sumatra, the north coast of Java, and in southern Sulawesi. Recently, monitoring data from the Java Sea from 2016 to 2018 were used to estimate the ratio of small crabs with carapace width (CW) less than the minimum legal size (100 mm) to crabs with CW greater than 100 mm. About 19% of the crabs were smaller than the legal size. The increasing demand for crab products, especially for the export market, has led to an increased intensity of exploitation, mostly as wild catch from capture fisheries. Uncontrolled exploitation and changes in the aquatic environment have likely caused a decline in the wild crab population. Various forms of fishing gear, ranging widely in size, are used to catch crabs. For example, in the Java Sea, the following gears

are used: collapsible traps (*bubu lipat*), set bottom gillnets, mini bottom trawls, dredge nets, guiding barrier and liftnets. The most frequently used fishing gear is the collapsible trap, followed by the set bottom gillnet.

Recent studies on the stock status of BSC using the length-based spawning potential ratio methodology (LBSPR) indicate that the SPR in several areas is about 20% and that overfishing may occur in the waters of northern Java. When the exploitation level *E* (by length converted catch curve method) was estimated in a part of coastal Central Java and eastern Lampung, overfishing was also found. In these studies, more than 80% of crabs had a CW greater than 100 mm. However, previous studies have found the CW of BSC at maturity is about 110 mm; hence, increasing the minimum legal size to 110 mm may help sustain the stocks. In addition to increasing the size at capture, future management options to consider are introducing a closed season (December and January) to conserve breeding stock and juveniles, introducing spatial closures to conserve the nursery grounds, and limiting fishing gear to select larger crabs (i.e. using only collapsible traps for BSC fishing).

The Method Evaluation and Risk Assessment (MERA) simulations identified four main options based on achieving a balance of sustaining stock (biomass >0.5 B_{MSY}) and long-term yield:

1. Setting total allowable effort (TAE) with a 10% annual increase (ITe10).
2. Spatial control with a control marine reserve that prevents fishing in one area without reallocating fishing effort to other areas (MRnoreal).
3. Spatial control with a control marine reserve that prevents fishing in one area and reallocates fishing effort to another area (MRreal).
4. Total Allowable Catch (TAC) with depletion-based stock reduction analysis paired with a 40-10 harvest control rule (DBSRA4010).

Management options based on TAC are unlikely to be feasible in this fishery because of the challenges of tracking the magnitude of the catch during a fishing season. Increasing the size limit combined with a TAE quota and a seasonal closure in December and January, during peak spawning and when the USA market demand is low, has potential. Spatial closure in muddy, mangrove areas to conserve juvenile crabs should also be considered.

Ringkasan

Rajungan (*Portunus pelagicus*) atau yang dikenal sebagai Blue Swimmer Crab adalah salah satu komoditas perikanan yang bernilai ekonomis penting setelah tuna dan udang. Umumnya rajungan adalah produk ekspor terutama ke Amerika Serikat mencapai ~80%, dalam bentuk meat canning. Lebih dari 40% produksi rajungan nasional berasal dari Laut Jawa (WPP NRI 712) di perairan Indonesia.

Di Indonesia, rajungan kecil ditemukan terutama di pantai timur Sumatra, pantai utara Jawa dan Sulawesi Selatan. Baru-baru ini, data pemantauan dari Laut Jawa untuk tahun 2016-2018 digunakan untuk memperkirakan rasio rajungan kecil kurang dari 100 mm lebar karapas (CW) (berdasarkan minimum legal size 100 mm CW), terhadap rajungan yang lebih besar dari 100 mm CW adalah ~19% rajungan lebih kecil dari ukuran legal, yang mengindikasikan bahwa rajungan ukuran legal adalah ~80%. Meningkatnya permintaan akan produk rajungan terutama dari pasar ekspor, telah menyebabkan peningkatan intensitas pemanfaatan, terutama kegiatan penangkapan di alam. Eksploitasi yang tidak terkendali disertai dengan perubahan lingkungan perairan, diduga telah menyebabkan penurunan populasi rajungan di alam. Berbagai alat tangkap digunakan untuk menangkap rajungan dalam berbagai ukuran, sebagai contoh di Laut Jawa digunakan alat tangkap: bubu lipat, jaring insang dasar tetap, jarring arad, garuk, sero dan bagan. Alat tangkap yang dominan adalah bubu lipat diikuti oleh jarring insang dasar tetap atau yang dikenal dengan jaring rajungan.

Studi terbaru tentang status stok rajungan menggunakan rasio potensial pemijahan (*Spawning Potential Ratio*) menunjukkan SPR di beberapa area adalah ~ 20% dan bahwa penangkapan berlebih telah terjadi di perairan utara Jawa. Metode lain dengan pendekatan length converted catch curve di bagian pantai Jawa Tengah dan Lampung timur untuk memperkirakan tingkat eksploitasi E menunjukkan telah terjadi overfishing. Lebih dari 80% rajungan berukuran >100 mm CW pada penelitian ini tetapi berdasarkan penelitian-penelitian sebelumnya, panjang rata-rata matang gonad rajungan di Laut Jawa adalah ~110 mm CW, sehingga meningkatkan minimum legal size hingga 110 mm CW dapat membantu keberlanjutan stok. Sebagai tambahan untuk meningkatkan ukuran tangkap, beberapa pilihan manajemen yang dapat dipertimbangkan untuk masa depan adalah: menetapkan penutupan musim penangkapan (antara Desember dan Januari) untuk melestarikan stok pembiakan dan ikan-ikan kecil, menetapkan penutupan spasial atau wilayah untuk melestarikan area pemijahan, dan membatasi jenis alat tangkap untuk mendapatkan rajungan berukuran besar, antara lain hanya menggunakan bubu lipat untuk perikanan rajungan.

Hasil yang diperoleh dari simulasi *Method Evaluation and Risk Assessment* (MERA), teridentifikasi empat pilihan utama berdasarkan tujuan pencapaian keseimbangan kelestarian stok (biomas >0.5 B_{MSY}) dan hasil tangkapan untuk jangka panjang:

1. Jumlah upaya penangkapan yang diperbolehkan (JUB) dengan peningkatan 10% setiap tahun (ITe10).
2. Pengendalian spasial dengan mengendalikan cagar laut yang mencegah kegiatan penangkapan di suatu area tanpa re-alokasi kegiatan penangkapan ke wilayah lainnya (MRnoreal).
3. Pengendalian spasial dengan pengendalian cagar laut yang mencegah kegiatan penangkapan di suatu area dan re-alokasi kegiatan penangkapan ke wilayah lain (MRreal).
4. Jumlah tangkapan yang diperbolehkan (JTB) dengan analisis pengurangan berbasis penipisan stok yang dipasangkan dengan 40-10 aturan pengendalian penangkapan (DBSRA4010).

Pilihan manajemen dengan basis jumlah tangkapan yang diperbolehkan tidak layak untuk jenis perikanan ini karena tantangan dalam melacak besarnya hasil tangkapan selama musim penangkapan. Meningkatkan batas ukuran tangkap yang dikombinasi dengan kuota upaya penangkapan yang diperbolehkan dan penutupan musim penangkapan antara Desember dan Januari, selama puncak pemijahan dan permintaan pasar AS rendah, memiliki potensi. Penutupan spasial di kawasan bakau berlumpur untuk konservasi rajungan kecil juga sebaiknya dipertimbangkan.

3.1 Biology

3.1.1. Taxonomy

Scientific name: *Portunus pelagicus* (Linnaeus, 1758)

Common names: Blue Swimmer Crab (English), *Rajungan* (Bahasa Indonesia)

3.1.2. Key identifying features

The carapace of the BSC is ovate to transversely hexagonal. The dorsal surface is relatively flat to gently convex. The carapace usually has nine spines on each anterolateral front margin; the last anterolateral spine is enlarged. The posterolateral margins usually distinctly converge. The abdomen of the male consists of three to five segments. The fifth pair of legs are paddle-like. Males have blue or purple markings and females are dull green or drab brown (Ng, 1998).

Portunus pelagicus is one of four morphologically similar species, termed the *P. pelagicus* species complex by Lai et al. (2010). *P. segnis* is confined to the western Indian Ocean from Pakistan to South Africa – it is a Lessepsian migrant into the Mediterranean Sea from the Red Sea. *P. reticulatus* occurs in the eastern Indian Ocean; a zone of hybridisation of these two species may exist in the Bay of Bengal. *P. armatus* occurs around the coastline of most of Australia and east to New Caledonia.

3.1.3. Distribution

Worldwide: The BSC is found in shallow tropical waters and estuarine temperate waters across the Indo-Pacific from the Indian Ocean in the west to the eastern Pacific Ocean (Lai, et al., 2010; Ng, 1998).

Indonesia: The BSC is distributed widely throughout Indonesia in the coastal marine waters of east Sumatra, north Java, south and east Kalimantan, southeast Sulawesi and southwest Papua.

3.1.4. Maximum length, weight and age

The growth of the BSC is normally described by measuring the carapace width (CW). Information on maximum CW derives from several areas in the Java Sea, including Cirebon, Demak, Pati, Sumenep, Sampit, Tanah Laut and eastern Lampung (Figure 3.1). The maximum CW of males is 148–225 mm, with a mean of 175.5 ± 24.78 mm (± SD); for females, 144–195 mm with a mean of 171.2 ± 20.48 mm (BRPL, 2016; Ernawati et al., 2015; Ernawati et al., 2017; Zairion et al., 2014a).

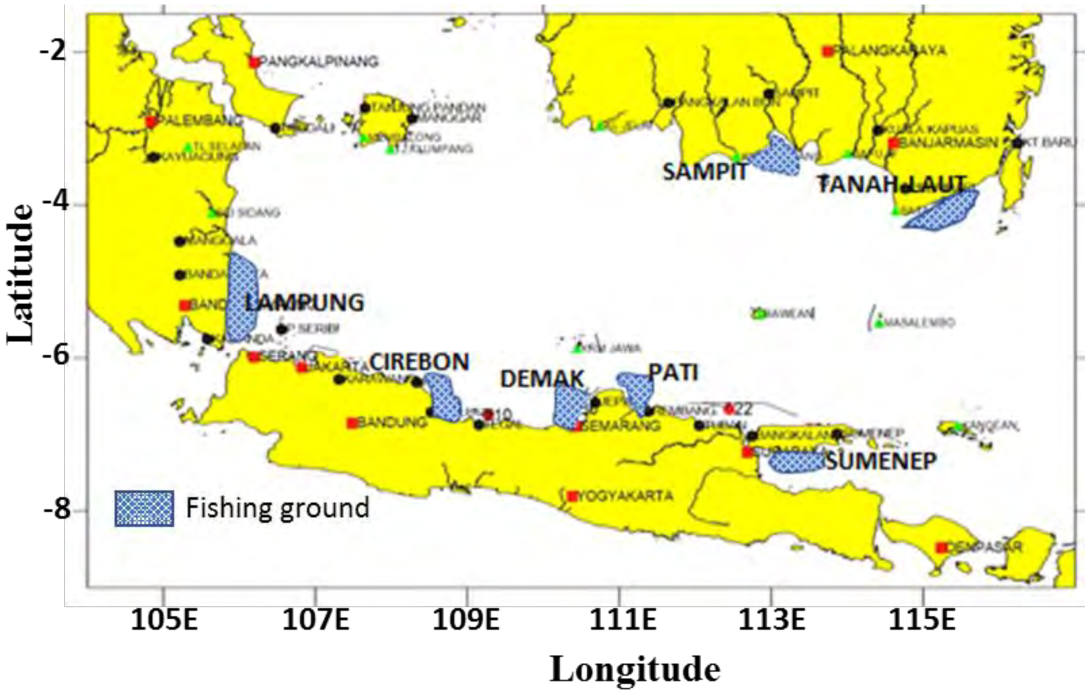


Figure 3.1. The fishing grounds (blue hatched areas) for Blue Swimmer Crabs (*Portunus pelagicus*) in the Java Sea (Fisheries Management Area 712) where information on size composition has been collected.

The maximum weight recorded in east Lampung waters ranges from 0.3 to 0.49 kg for males and from 0.29 to 0.39 kg for females (Zairion et al., 2014a). In Jakarta Bay, the maximum weight reported for *P. pelagicus* is 0.16 kg (Wagiyo et al., 2019).

The maximum age has been reported from several areas of the Java Sea but has been recorded separately for males and females only in Pati; combined records exist for the surrounding areas of Cirebon, Demak and Sumenep (Table 3.1) (Ernawati et al., 2015; Ernawati et al., 2017). Overall, the mean maximum age is 2.61 ± 0.19 years. The maximum age estimated from the length distribution data using von Bertalanffy growth with a version of ELEFAN ranges from 2.38 years (males, Pati) to 2.86 years (both sexes, Cirebon) (Table 3.1).

Table 3.1. The maximum estimated age of Blue Swimmer Crabs in several areas of the Java Sea, Indonesia

No.	Maximum Age (years)	Location	Reference
1	2.38 (males) 2.65 (females)	Pati & surrounding waters	Ernawati et al. (2015)
2	2.86 (combined sexes)	Cirebon	Ernawati et al. (2017)
3	2.70 (combined sexes)	Demak	Ernawati et al. (2017)
4	2.48 (combined sexes)	Sumenep	Ernawati et al. (2017)

3.1.5. Weight–carapace width relationship

The weight–carapace width relationship of BSC has been estimated in a number of locations from the Java Sea, for males and females separately (Table 3.2). The power coefficient of this relationship ranges from 2.95 (females, Jakarta) to 3.56 (males, Tanah Laut) (Table 3.2).

Table 3.2. Weight–carapace width relationships for the Blue Swimmer Crab in several locations in the Java Sea

No	Location	Weight–carapace width relationship	n	Source
1	Cirebon	Male $W = 4.00E\text{-}05L^{3.106}$ Female $W = 6.00E\text{-}05L^{3.023}$	M: 1333 F: 718	Ernawati et al. (2017)
2	Demak	Male $W = 8.00E\text{-}06L^{3.449}$ Female $W = 1.8.0E\text{-}05L^{3.270}$	M: 1536 F: 1433	Ernawati et al. (2017)
3	Pati	Male $W = 1.00E\text{-}05L^{3.342}$ Female $W = 2.00E\text{-}05L^{3.250}$	M: 1817 F: 1813	Ernawati et al. (2014)
4	Sampit	Male $W = 2.00E\text{-}05L^{3.310}$ Female $W = 5.00E\text{-}05L^{3.072}$	M: 302 F: 253	Ernawati et al. (2017)
5	Tanah Laut	Male $W = 5.00E\text{-}06L^{3.558}$ Female $W = 1.00E\text{-}05L^{3.324}$	M: 260 F: 421	BRPL (2016)
6	Eastern Lampung	Male $W = 2.00E\text{-}05L^{3.304}$ Female $W = 3.00E\text{-}05L^{3.173}$	M: 3400 F: 4805	BRPL (2016)
7	Jakarta	Male $W = 3.00E\text{-}05L^{3.203}$ Female $W = 9.00E\text{-}05L^{2.947}$	M: 571 F: 450	Jayawiguna et al. (2017)

W = weight; L = width; M = male; F = female.

3.1.6. Growth

Growth parameters of the BSC in the Java Sea were estimated from regular carapace width (CW) measurements collected at landing sites, using ELEFAN to fit growth curves to the CW distributions. Generally, BSC growth in the Java Sea is fast, with k ranging from 1.05 (Cirebon) to 1.26 (Pati) (Table 3.3). The estimates of L_∞ ranged from 142.5

(Jakarta Bay) to 187 (females in Pati). Except for Pati, estimates of t_0 were from –0.12 to –0.10.

Table 3.3. The growth parameters of the Blue Swimmer Crab in several areas of the Java Sea

Site	n	Growth parameters			Von Bertalannfy growth equation	Source
		L_∞ (mm)	k (per year)	t_0		
Cirebon	2051	168.6	1.05	–0.1040	$L_t = 168.6(1\text{-}e^{-1.05(t + 0.104)})$	Ernawati et al. (2017)
Demak	2969	179.35	1.11	–0.1083	$L_t = 179.35(1\text{-}e^{-1.11(t + 0.1083)})$	Ernawati et al. (2017)
Pati	2118	185 (M)	1.26	–0.0034	$L_t = 185(1\text{-}e^{-1.26(t + 0.0034)})$	Ernawati et al. (2015)
	2105	187 (F)	1.13	–0.0380	$L_t = 187(1\text{-}e^{-1.13(t + 0.038)})$	
Sumenep	4516	161.4	1.21	–0.1219	$L_t = 161(1\text{-}e^{-1.21(t + 0.1219)})$	Ernawati et al. (2017)
Jakarta Bay	2284	142.5	1.08	–0.1120	$L_t = 142.5(1\text{-}e^{-1.08(t +0.112)})$	Wagiyo et al. (2019)

L_∞ = asymptotic carapace width (CW); k = instantious growth rate; t_0 = age at CW0; L_t = CW at age t in years; M = male; F = female.

3.1.7. Age and length at maturity

The age at maturity in the north of the Java Sea has been reported by the *Balai Riset Perikanan Laut* (BRPL; Research Institute for Marine Fisheries); it was estimated at 8–9 months (BRPL 2015a, 2019). The CW at 50% and 95% maturity for female BSCs has been reported in a number of studies (Table 3.4). The CW at 50% maturity ranges from 101.1 mm (Rembang) to 133.2 mm (Tanah Laut) with a mean of 108.0 ± 2.1 mm (Table 3.4).

Table 3.4. Carapace width at 50% and 95% maturity of female Blue Swimmer Crabs in some areas of the Java Sea (FMA 712)

Area	CW_{50}	CW_{95}	Source
Pati	109.8	148	BRPL (2015b)
Cirebon	102	125	BRPL (2015b)
Demak	104.9	121	Ernawati et al. (2017)
Rembang	101.1	118	Ernawati et al. (2017)
Sumenep	101.9	144	Ernawati et al. (2017)
Tanah Laut	133.2	165	BRPL (2017)
East Lampung	103	126	Zairion et al. (2015a)
Mean (SE)	108.0 (2.1)	135.3 (1.7)	

CW_{50} = carapace width at 50% maturity; CW_{95} = carapace width at 95% maturity.

3.1.8. Summary of life history, habitats and movement

The information on the life history of the BSC in the Java Sea is limited. The fecundity of eggs in the coastal waters of northern central Java ranges from 351,214 to 1,347,029 for females between 95.5 and 124.4 mm CW (Ernawati et al., 2014). In the East Lampung coast (western Java Sea), the fecundity is estimated at 229,468 to 2,236,355 (females between 91.58 and 168 mm CW) (Zairion et al., 2015b).

The BSC is found mainly in coastal and shallow waters in Southeast Asia and eastern Asia (Lai et al., 2010). Previous studies in the Java Sea indicate BSCs inhabit areas with sandy, sandy-muddy, muddy-sandy and muddy substrates (Ernawati et al., 2014; Kembaren et al., 2018; Zairion et al., 2014a). The mean temperatures in the northen waters of Central Java is 28.2 ± 0.39 ºC in the eastern monsoon (June–August) and 30 ± 0.39 ºC in the western monsoon (December–February) (Ernawati et al., 2014). Temperatures in the coastal waters of eastern Lampung (western Java Sea) are 28–32 ºC, with a salinity of 27–32 PSU in the dry season (June–August) and 25–30 PSU in the wet season (December–February) (Zairion et al., 2014a). Table 3.5 summarises BSC habitats during the stages of its life history, and their movement patterns.

Table 3.5. Habitats and movement in life history stages of the Blue Swimmer Crab in the Java Sea (FMA 712)

Life history stage	Habitat	Source
Eggs	Assumed similar to spawning females. Females spawn in high salinity (27–32 PSU) at temperatures of 28–32 ºC Substrates: sandy-muddy, muddy-sandy, sandy	Kembaren, et al. (2018), Zairion et al. (2014a)
Larvae	Distributed in water column in depths of 5–15 m around the spawning area	Kembaren et al. (2018)
Juveniles	Muddy substrate around mangroves; depth ~5 m	Ernawati et al. (2015), La-Sara et al. (2016), Zairion et al. (2014a)
Adults	Substrates: sandy, muddy, sandy-muddy	Ernawati et al. (2014), Zairion et al. (2014a)
Movement	Egg-bearing females migrate offshore to areas with high salinity to release their eggs	La-Sara et al. (2016)

3.2. Fishery

3.2.1. Description of the fishery

The BSC is the third-most economically valuable fisheries resource in Indonesia (after tuna and shrimp). The exploitation of BSC in the Java Sea started in the 1970s. Mostly, BSC is exported as canned cooked meat, with more than 80% shipped to the USA. BSC became an export commodity in the early 1990s. In 2016, the national production of BSC reached about 46,965 tons; about 45% (Kementerian Kelautan dan Perikanan [KKP], 2017) came from FMA 712 (the Java Sea) (Figure 3.2).

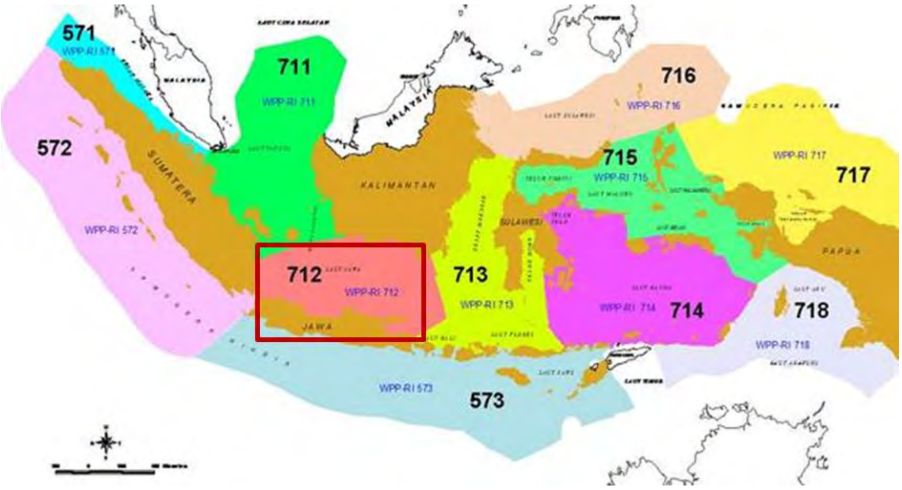
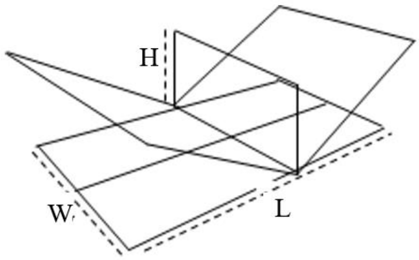


Figure 3.2. The 11 Indonesian Fisheries Management Areas (FMAs). In 2016, ~45% of Blue Swimmer Crabs were landed in FMA 712 (the Java Sea).

BSCs are usually caught by set bottom gillnets, collapsible traps (*bubu lipat*), mini bottom trawls (*jaring arad*), liftnets, guiding barriers (*sero*) and dredge nets (*garuk*). In the Java Sea, BSCs are caught predominantly in collapsible traps and set bottom gillnets.

Collapsible traps (Figures 3.3, 3.4) are operated in waters at depths of 20–40 m. The number of traps operated is 1000–1500 traps/vessel. The collapsible traps are baited, usually with fish ('trash' fish) caught by mini-trawl (*cantrang*) and purse seine. At least three sizes of collapsible traps are commonly operated by fishermen in northern Java coastal areas: small (length 42 cm x width 28 cm x height 20 cm), medium (48 x 28 x 22 cm) and large (52 x 30 x 25 cm) (Figure 3.4). For all sizes, the mesh size of the trap is 1¼ inches (~31.8 mm).

Figure 3.3. Collapsible trap (left) and stacked collapsible traps operated in one trip (right). (Images: Tri W. Budiarti)



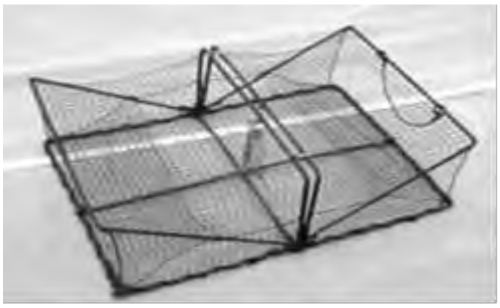


Figure 3.4. Design of collapsible trap. Length (L) = 52 cm, width (W) = 30 cm, and height (H) = 25cm. (Images:Tri W. Budiarti)

Collapsible traps are operated from wooden boats equipped with a line hauler. The boats are typically 11.5 m long, 1.6 m wide and 0.9 m deep (Figure 3.5). The boat is powered by two 30 HP engines and the line hauler uses a 20 HP engine. The fishing vessel has 3 crew members.

Figure 3.5. Boat used for fishing with collapsible traps. (Image: Tri W. Budiarti)

Boats depart at 09:00 from the fishing base. In one day's operation, collapsible traps are set and hauled in up to three times, with soaking times of 4–6 h per day. At a chosen site, first a weighted buoy is dropped. Before being unloaded, the collapsible traps are baited (Figure 3.6). Next, the traps on each line are successively released into the sea, with a buoy marking every 150 traps in the line (Figure 3.7).

Figure 3.6. Collapsible trap with bait circled in red. (Image: Tri W. Budiarti)

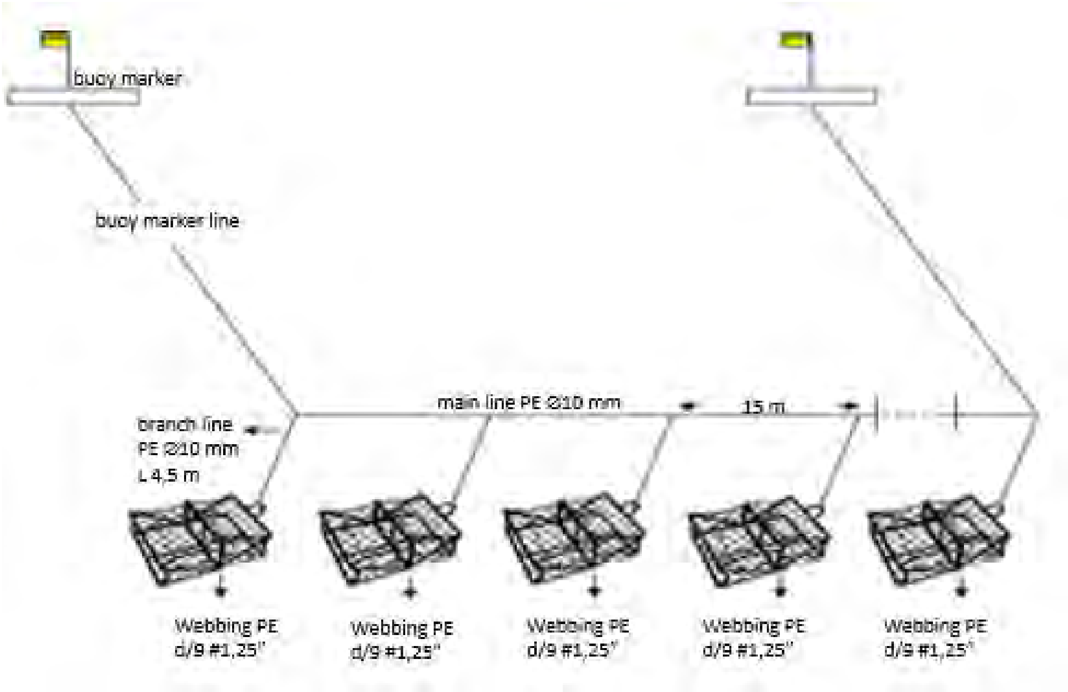


Figure 3.7. Setting a line of collapsible traps. (Illustration: Tri W. Budiarti)

BRPL (2015b) have reported the catch rate for collapsible traps in the Cirebon, Pati and Lampung areas of the Java Sea. In Cirebon, fishers commonly take 5-day trips, with 4 fishing days setting 1000 traps per day. Fishers usually set the traps three times per day. Average catch rate is 15–25 kg per setting, with a total catch per trip of 180–300 kg. In Pati, fishers take 3-day trips and usually set 400–600 traps three times per day. The catch rates per setting are similar to those in Cirebon; total catch per trip is 95–190 kg. In Lampung, fishers generally operate 1000–1500 traps for 8–12 days per trip, with 7–11 fishing days per trip, depending on the distance to the fishing grounds. They set their traps three times per day with an average catch rate of 20–35 kg per setting and a total catch per trip of 420–1160 kg.

3.2.2. Stock depletion and resilience

Prince et al. (2020) summarised the development and current status of the BSC fisheries in Indonesian waters. They state that 'The commercial BSC fisheries in Indonesia, began in the west of the country in the 1970s and have now extended to all but the eastern-most provinces, growing with the expansion into Indonesia's third most valuable fisheries export. An estimated 90,000 artisanal fishers deliver catch to 550 mini-plants which employ 180,000 local women who pick out the crab meat that is sent to 40 processors of pasteurized crab meat (Nugraha, 2019).' They state that the general development of BSC fisheries has been for fishers to initially use bottom-set crab nets to target larger crabs in deeper water. As abundance declines, they use dip nets in shallow waters to catch smaller crabs, and then move to using baited traps across the depth range to target all remaining size classes. In some areas, mini-trawlers are introduced when catch rates become low to catch lower-quality crabs and fish.

Based on statistical data from 2001 to 2016 published by the Directorate General of Capture Fisheries (KKP, 2017), we analysed the trends in total catch for BSCs in the whole of FMA 712. We used trip numbers of collapsible-trap boats as a standard measure of effort to estimate nominal catch per unit effort (CPUE). Both total catch and CPUE fluctuated over these 16 years (Figure 3.8). In 2001, the catch and CPUE were 8832 tons and 1.03 tons/trip, respectively. Total catch tended to increase to 21,720 tons in 2008, then moderately declined to 16,496 tons in 2014. However, by 2016, the total catch had risen markedly to 46,965 tons. CPUE gradually declined to 0.04 ton/trip in 2005 but increased to 0.56 ton/trip by 2010. In the next 4 years, CPUE steadily decreased to 0.31 ton/trip, and then rose sharply to 1.14 tons/trip in 2016 (Figure 3.8).

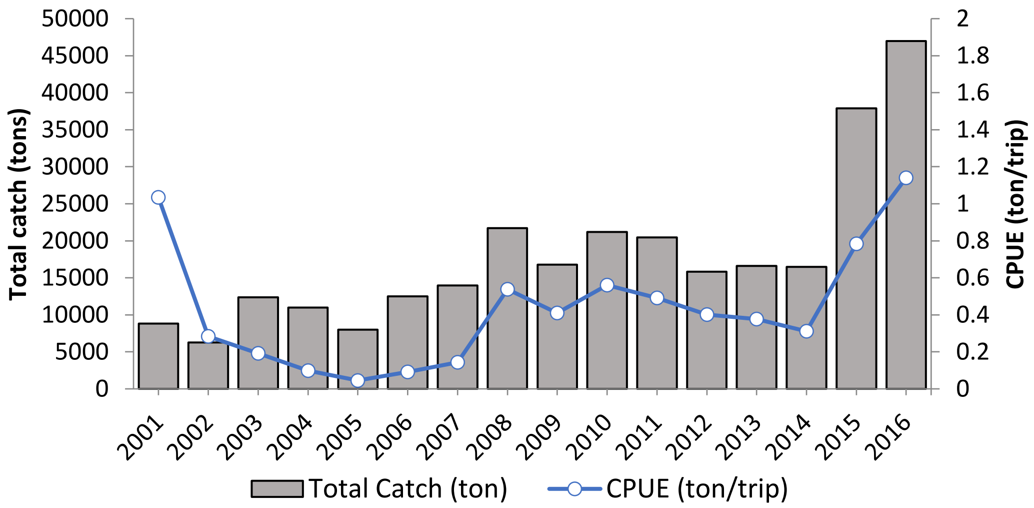


Figure 3.8. Total catch and nominal catch per unit effort (CPUE) of Blue Swimmer Crabs in the Java Sea (FMA 712) from 2001 to 2016 using trip numbers of collapsible-trap boats as effort. Data from KKP (2017).

The estimated spawning potential ratio (SPR) of BSC in the Java Sea is low (0.11–0.24) (Ernawati et al., 2017). SPR estimated by the length-based SPR methodology of Hordyk et al. (2015) produced similar low estimates from seven sites in Indonesia; most estimates fell between 0.10 and 0.17, except that for Kendari (southeast Sulawesi), which was only 0.04 (Prince et al., 2020). The estimated exploitation rate (*E*) in northern central Java coastal waters is high, about 0.80 (Ernawati et al., 2014), which indicates overexploitation. The resilience of BSC in the northern Java Sea is not known. However, the species has a short lifespan and is very fecund, both resilient characteristics (Figure 3.8).

3.2.3. Fishing effort: history, variability and changes in fishing efficiency

Fishing effort measured by the trip number of collapsible-trap units in the Java Sea increased 20-fold from 8832 in 2001 to 175,904 in 2005, but by 2008 it had decreased to 40,404. Effort remained relatively stable over the next 8 years (Figure 3.9). We do not have information on variation in the number of days of fishing effort or fishing efficiency over this time. However, the fishing gear used in the BSC fisheries in FMA 712 has changed very little since BSCs were first exploited in the 1970s. Therefore, the efficiency of the gear is assumed to be stable.

Figure 3.9. Trip numbers of collapsible-trap units as a measure of fishing effort for Blue Swimmer Crabs in the Java Sea (FMA 712) 2001–2016 (KKP, 2017).

3.2.4. Selectivity of fishing methods and discard rates

Selectivity information has been estimated from length data using the LBSPR methodology of (Hordyk et al., 2015) at four locations in the Java Sea (Table 3.6). The estimates of the SL_{50} for the two dominant methods in FMA 712 were 109 and 121 mm CW for collapsible traps and 93.9 and 118 mm CW for set bottom gillnets (Table 3.6). The estimated SL_{50} for gillnets in Jakarta Bay (93.9 mm CW; Wagiyo et al., 2019; Table 3.6) is considerably lower than the minimum and mean size at 50% maturity (99.2 and 102 mm CW) recorded in a number of studies in the Java Sea (Table 3.6).

Table 3.6. The estimated size at 50% and 95% selectivity (SL_{50} and SL_{95}) of collapsible traps and set bottom gillnets for Blue Swimmer Crabs in the Java Sea (FMA 712)

Gear	Locations	SL_{50} (mm CW)	SL_{95} (mm CW)	Source
Collapsible trap	Northern central Java coast	121.0	145	BRPL (2016)
Collapsible trap	Northern east Java coast	109.1	139	Mahiswara et al. (2018)
Set bottom gillnet	Eastern Lampung	118.0	141	BRPL (2016)
Set bottom gillnet	Jakarta Bay	93.87	120	Wagiyo et al. (2019)

SL_{50} = length at 50% selectivity; SL_{95} = length at 95% selectivity; CW = carapace width.

3.3. Management regulations

3.3.1. Current management

The Ministry of Marine Affairs and Fisheries (MMAF) has established a total allowable catch (TAC; *Jumlah Tangkapan yang Diperbolehkan* or *JTB*) as 80% of Maximum Sustainable Yield (MSY) through Regulation 50/2017. For BSCs in the Java Sea, this TAC (*JTB*) has been estimated as 23,508 tons per year for the whole fishery. Besides this regulation on the exploitation level of the fisheries, the Ministry established a minimum size limit for BSCs of 100 mm CW and prohibited the capture of berried females (MMAF Regulation 56/2016). Further, MMAF Regulation 71/2016 prohibits the use of destructive gear, including trawls, in all Indonesian waters; it applies to the capture of BSCs.

The size limit regulation for BSC established in Regulation 56/2016 is being implemented and monitored effectively. Based on monitoring by the BRPL and the Association of Indonesia BSC Producers (APRI) between 2016 and 2018, at some locations in the Java Sea about 80% of landed BSC are legal-sized crabs. Prohibiting the capture of berried females and enforcing the ban on destructive gear (mini-trawls used by small vessels <5 gross tons [GT] until 2016 when small-scale vessels were classified as <10 GT) are still challenging due to the need for strong enforcement and surveillance, and the limited budgets of local government.

3.3.2. Future management options

Several future management options may be feasible for BSC fisheries in the Java Sea. The following options are suggested, while acknowledging that few resources are available for enforcement and monitoring BSC fisheries in Indonesia:

1. ***Size limit***: Because the length at maturity (L50) from several studies is above 100 mm CW, we propose a minimum size of 110 mm CW.
2. ***Closed season***: Seasonal closure to conserve brood stock and juveniles. In the Java Sea (FMA 712), the peak seasons for spawning are the first and last quarters of each year (Ernawati et al., 2017). We propose a month closure in each of these quarters (December and January).

3. ***Spatial closure***: Area closure to conserve the nursery grounds of BSCs. Juveniles are found in highest numbers in muddy substrates around mangroves and spatial closures in these areas may lead to greater recruitment to the fishery.
4. ***Limiting fishing gear***: Regarding gear selectivity, the collapsible trap is the most selective gear for catching BSCs up to 112 mm CW. We recommend using only collapsible traps as fishing gear for BSCs.

3.4. Data sources

The following publications were used as data sources to produce the summary information in this report: Ernawati et al. (2014, 2015, 2017), Jayawiguna et al. (2017), Kembaren et al. (2018), La-Sara et al. (2016), Mahiswara et al. (2018), Wagiyo et al. (2019), Zairion et al. (2014a, 2014b), Zairion et al. (2015a, 2015b). We also used data from technical reports of BRPL assessments in the Java Sea (2015a, 2015b, 2016, 2017, 2019). In 2018, the BRPL began collecting catch data from a sampling program of fishing ports.

3.5. Management Planning in MERA

3.5.1. Performance of management options

In the Method Evaluation and Risk Assessment (MERA) simulations, four broad candidates for management were considered: total allowable catch (TAC), total allowable effort (TAE), size limits and spatial closures. The best options were selected based on a balance of sustaining stock (biomass >0.5 B_{MSY}) and long-term yield:

1. Setting total allowable effort (TAE) with a 10% annual increase (ITe10).
2. Spatial control with a marine reserve (MR) that prevents fishing in one area without reallocating fishing effort to other areas (MRnoreal).
3. Spatial control with a MR that prevents fishing in one area and reallocates fishing effort to another area (MRreal).
4. TAC with depletion-based stock reduction analysis paired with a 40-10 harvest control rule.

Table 3.7 presents the 10 best-performing management options.

Table 3.7. The 10 best-performing management procedures from the Method Evaluation and Risk Assessment (MERA) simulations for Blue Swimmer Crabs in Fisheries Management Area 712 of Indonesia

No.	Mangement procedure	Regulation type	Prob. $B > 0.5\ B_{MSY}$	Prob. $B > B_{MSY}$	Short-term yield	Long-term yield
1	ITe10	TAE	0.77	0.57	0.84	1.07
2	MRnoreal	Spatial	0.84	0.64	0.79	0.94
3	MRreal	Spatial	0.84	0.64	0.79	0.94
4	DBSRA4010	TAC	0.78	0.55	0.60	0.92
5	matlenlim	SL	0.85	0.64	0.48	0.68
6	HDAAC	TAC	0.77	0.57	0.58	0.66
7	matlenlim2	SL	0.85	0.65	0.45	0.63
8	IT5	TAC	0.77	0.60	0.66	0.55
9	IT10	TAC	0.78	0.61	0.65	0.53
10	MCD	TAC	0.82	0.64	0.47	0.51
11	MCD4010	TAC	0.84	0.66	0.31	0.42

Blue shading = four options with highest likelihood of maintaining long-term catches and maintaining yield. ITe10 = setting total allowable effort (TAE) with a 10% annual increase; MRnoreal = spatial control with a marine reserve that prevents fishing in one area without reallocating fishing effort to other areas; MRreal = spatial control with a marine reserve that prevents fishing in one area and reallocates fishing effort to another area; DBSRA4010 = total allowable catch (TAC) with depletion-based stock reduction analysis paired with a 40-10 harvest control rule; matlenlim = size limit based on size at maturity; TAE = total allowable effort; Spacial = spacial closure; TAC= total allowable catch; SL = size limit.

Considering the characteristics of BSC fisheries in the Java Sea and the effectiveness of implementing different regulations, applying effort control, spatial closure and size limit are possible candidates for managing these fisheries. Although MERA showed that a TAC also performed well (DBSRA4010, Table 3.7), the difficulty in implementing an effective TAC precludes its selection – it would require strong monitoring, surveillance and enforcement because of the dominance of small-scale fisheries (vessels <10 GT). These fisheries do not require a permit and are not required to document and record their catch. The current TAC would be replaced by a size limit based on the maturity curves for BSC. Figure 3.10 illustrates the performances of the four best candidates for BSC management plans.

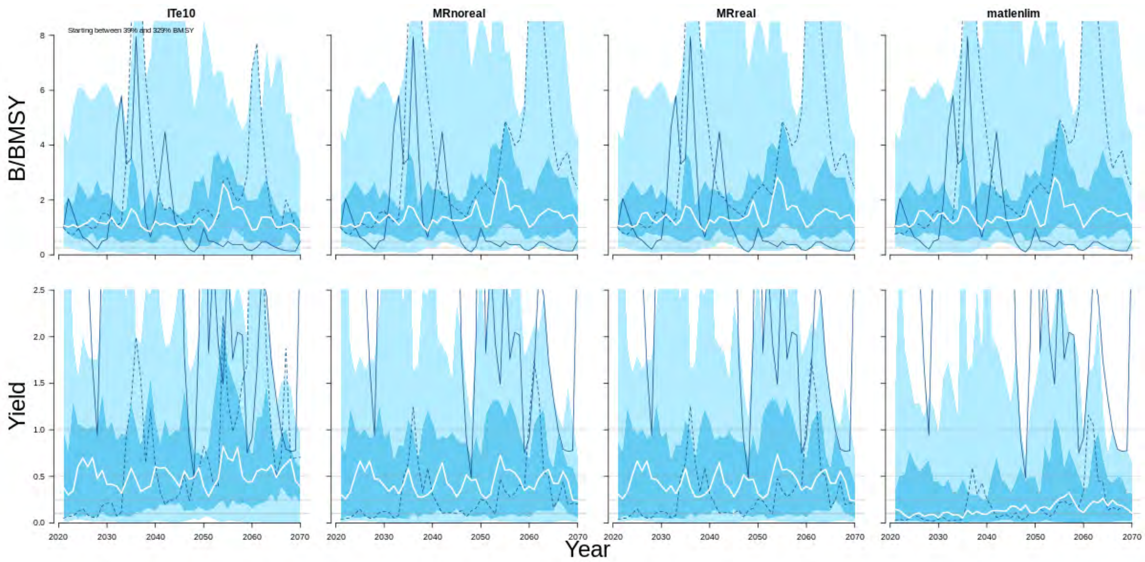


Figure 3.10. Simulated performance of four management planning options for Blue Swimmer Crabs in the Java Sea with probability of $B > B_{MSY}$. The shaded regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5 and 1. ITe10 = setting total allowable effort (TAE) with a 10% annual increase; MRnoreal = spatial control with a marine reserve that prevents fishing in one area without reallocating fishing effort to other areas; MRreal = spatial control with a marine reserve that prevents fishing in one area and reallocates fishing effort to another area; matlenlim = size limit based on the size at maturity.

3.5.2. Future management

A combination of management options (TAE, spatial closure and size limits) could be considered for the BSC fishery in the Java Sea. Those developing the management plan should consider two factors: whether sufficient data are available and the commitment of APRI to monitor the landed catch. The size-limit regulation currently in force is not strong enough to recover the stock, even though compliance is good. In Figure 3.10, the simulated yield for the size-limit option is low, which would be difficult to implement because of the high value of BSC. Other options should be considered in combination with size limits. The TAE, with a seasonal closure in December and January, is one of the best candidates; these months have been identified as the peak spawning season, when many juveniles are caught. In addition, in these months the USA market demand is low (Figure 3.11). Hence, a seasonal closure at this time appears a good option from both biological and economic aspects.

Figure 3.11. The relative monthly sales of Blue Swimmer Crabs from Indonesia to the United States throughout a typical year (Source: Association of BSC Producers in Indonesia). Y axis is a relative measure of sales by APRI.

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4. Fisheries management for the Scalloped Spiny Lobster (*Panulirus homarus*) in the waters of southern Yogyakarta and Pacitan, Indonesia

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Panulirus homarus, the Scalloped Spiny Lobster (English), or *Lobster Pasir* (Bahasa)
(Image: Duranta Kembaren)

Summary

Seven species of spiny lobster are found in Indonesian waters: *Panulirus homarus, P. penicillatus, P. longipes, P. femoristriga, P. polyphagus, P. versicolor and P. ornatus*. Spiny lobster are distributed throughout the coastal waters of Indonesia but the major fisheries production is in the Indian Ocean, from western Sumatra extending east to southern Java and Nusa Tenggara. The Scalloped Spiny Lobster (*P. homarus*) is the dominant species caught off the southern coasts of Java and Bali, where it comprises up to 90% of the spiny lobster catch. In the coastal waters of southern Java, in the region of

Yogyakarta and Pacitan, *P. homarus* comprises 34% of the spiny lobster landings. This species has high economic value for local consumption and is also exported. In southern Java, it is caught using gillnets and traps, with most of the catch coming from gillnets. Fishing is conducted all year round and the length at first capture is smaller than the length at 50% maturity. Length data have been collected since 2010–2012 under a project of the Australian Centre for International Agricultural Research (ACIAR) and through research at the Research Institute for Marine Fisheries in 2013, 2014 and 2016.

The length-data and life-history characteristics of *P. homarus* have been used to estimate the spawning potential ratio (SPR) by the length-based SPR (LBSPR) method. The estimated SPR is 16%, which indicates that the stock is depleted compared with an SPR limit of 20% and target SPR of 40% for many species. The current management for the lobster fishery operates under two regulations: Ministerial Decree 50/2017, which regulates the total allowable catch (TAC) and Ministerial Decree 56/2016, which regulates the minimum legal size for capture of spiny lobster in general. The TAC regulation is difficult to implement because the many private landing sites increase the size of the unreported catch. Further, the regulation for minimum legal size is easy to apply only for the export trade: a certified document is needed for export but local lobster trading is not monitored. For future management, especially for the minimum legal size, species-specific size limits must be determined because of the differences in growth and size at maturity among the species of spiny lobster.

Application of the Method Evaluation and Risk Assessment Tool (MERA) to assess the long-term sustainability and yield of the lobster stocks identified four management procedures that performed well: ITe10 – total allowable effort allocation with a maximum change of 10% per year; MRNoreal – marine reserve, no reallocation of effort; MRreal – marine reserve with effort reallocation; and DD – simple delay-difference stock assessment. The option based on total allowable effort (ITe10) could probably be implemented most effectively. Currently, insufficient information is available to select areas for marine reserves. Assessing the habitat requirements and distribution of the early life stages is needed to make recommendations on spatial closures for this species, which may assist in rebuilding the SPR of the stock. Further work on evaluating performance indicators for this species, and setting appropriate target and limit reference points, would also be useful.

Ringkasan

Di perairan Indonesia terdapat tujuh jenis lobster berduri yaitu *Panulirus homarus*, *P. penicillatus*, *P. longipes*, *P. femoristriga*, *P. polyphagus*, *P. versicolor* dan *P. ornatus*. Lobster berduri tersebar luas di seluruh perairan pesisir Indonesia, namun produksi lobster terbesar berasal dari perairan Samudera Hindia, yang membentang dari barat Sumatera sampai selatan Jawa dan Nusa Tenggara. Lobster pasir (*P. homarus*) merupakan jenis yang dominan tertangkap di pesisir selatan Jawa dan Bali, yang mana produksinya mencapai 90% dari produksi semua jenis lobster yang didaratkan. Di perairan selatan Jawa, khususnya selatan Yogyakarta dan Pacitan, komposisi hasil tangkapan *P. homarus* mencapai 34% dari total pendaratan lobster. Lobster pasir

memiliki nilai ekonomi tinggi baik untuk dikonsumsi lokal maupun sebagai komoditas ekspor. Di perairan selatan Jawa, lobster ini ditangkap menggunakan jaring insang dan perangkap (krendet) yang mana hasil tangkapan jaring lebih dominan daripada perangkap. Penangkapan lobster dilakukan sepanjang tahun dan ukuran rata-rata tertangkap lebih kecil dari ukuran rata-rata mencapai kematangan gonad. Data struktur ukuran panjang karapas telah dikumpulkan sejak tahun 2010–2012 melalui proyek ACIAR dan penelitian di Balai Riset Perikanan Laut pada 2013, 2014 dan 2016.

Data panjang dan karakteristik life-history *P. homarus* digunakan untuk mengestimasi rasio potensi pemijah (SPR) dengan metode berdasarkan ukuran panjang (LB-SPR). Nilai estimasi SPR lobster pasir sebesar 16%, yang mengindikasikan bahwa stok lobster ini telah menurun dibandingkan dengan nilai acuan yang umum digunakan yaitu nilai acuan batas 20% dan nilai acuan target 40%. Peraturan yang mengelola perikanan lobster saat ini ada dua, yaitu Keputusan Menteri Kelautan dan Perikanan Nomor 50/2017 yang mengatur jumlah yang boleh ditangkap (JTB) dan Keputusan Menteri Kelautan dan Perikanan Nomor 56/2016, yang mengatur ukuran minimum yang boleh ditangkap untuk keseluruhan jenis lobster. Pengaturan jumlah yang boleh ditangkap sulit untuk diterapkan karena pendaratan lobster banyak dilakukan di pendaratan pribadi yang menyebabkan tingginya proporsi hasil tangkapan yang tidak tercatat. Lebih lanjut, pengaturan ukuran minimum tertangkap mudah diterapkan pada komoditas yang diekspor karena membutuhkan dokumen sertifikasi namun untuk lobster yang diperdagangkan didalam negeri tidak diawasi. Untuk pengelolaan dimasa yang akan datang, khususnya pengaturan ukuran minimum tertangkap, hendaknya mengatur secara spefisik per jenis karena masing-masing jenis lobster memiliki pertumbuhan dan ukuran mencapai matang gonad yang berbeda.

Analisa menggunakan perangkat MERA (*Method Evaluation and Risk Assessment*) untuk mengkaji keberlanjutan dan produksi stok lobster jangka panjang menghasilkan empat prosedur pengelolaan yang menunjukkan kinerja yang bagus, yaitu: (1) ITe10 – jumlah effort yang diperbolehkan dengan perubahan maksimum 10% per tahun; (2) MRNoreal – perlindungan kawasan tanpa pengalihan upaya; (3) MRreal – perlindungan kawasan dengan pengalihan upaya; dan (4) DD – kajian stok model delay-difference. Namun demikian, menilik dari kemudahan implementasinya di lapangan, pengaturan jumlah upaya yang diperbolehkan (ITe10) merupakan prosedur yang paling mungkin diterapkan secara efektif. Saat ini, tidak tersedia informasi yang memadai untuk memilih opsi pengelolaan dengan penutupan kawasan. Oleh karena itu, dibutuhkan kajian kesesuaian habitat dan distribusi stadia awal lobster untuk mendukung rekomendasi pengelolaan dengan pembatasan daerah penangkapan yang akan menunjang perbaikan stok dengan naiknya nilai SPR. Penelitian lainnya yang dibutuhkan yaitu evaluasi performa indikator pengelolaan untuk lobster pasir dan menetapkan nilai acuan batas dan niali acuan target.

4.1. Biology

4.1.1. Taxonomy

Scientific name: *Panulirus homarus* (Palinuridae; spiny lobsters)

Common names: Scalloped Spiny Lobster (English) and *Lobster Pasir* (Bahasa Indonesia)

4.1.2. Key identifying features

The abdomen of the Scalloped Spiny Lobster has transverse grooves. The anterior margin of the transverse grooves is crenulated, and the grooves are incomplete or disrupted in the middle. The antennular plate bears four well-separated principal spines and some small spinules. The body is greenish to brown (Chan, 1998).

4.1.3. Distribution

Worldwide*:* Scalloped Spiny lobster are widely distributed in the Indo-Pacific from the eastern coast of Africa to Japan, Australia and the Marquesas Archipelago (Chan, 1998)

Indonesia*:* Scalloped Spiny Lobster are widely distributed throughout Indonesia in the coastal waters of western Sumatera, southern Java, Bali and Nusa Tenggara, south Sulawesi, Maluku and Papua (Wahyudin, 2018).

4.1.4. Maximum length, weight and age

The maximum carapace length of Scalloped Spiny Lobster in Indonesian waters is 113 mm, recorded in western Aceh (Kembaren and Nurdin, 2015). The maximum carapace length recorded in the study focus area (southern Yogyakarta and Pacitan) is 96.6 mm; the maximum weight, 0.4 kg; and the maximum age, 10 years (Damora et al., 2018).

4.1.5. Weight-length relationship

Weight (W in g) and carapace length (CL in mm) relationships have been estimated from measurements in southern Yogyakarta (Damora et al., 2018) and southern Bali (Kembaren et al., 2015).

For southern Yogyakarta:

Combined sexes: $W = 0.002\ CL^{2.762}$ ($n = 1067$, $R^2 = 0.93$)

For southern Bali:

Males: $W = 0.002\ CL^{2.768}$ ($n = 1839$, $R^2 = 0.89$)

Females: $W = 0.002\ CL^{2.841}$ ($n = 1947$, $R^2 = 0.93$)

Combined sexes: $W = 0.002\ CL^{2.811}$ ($n = 3786$, $R^2 = 0.91$)

4.1.6. Growth

The growth parameters have been estimated from the analysis of length-frequency distributions of lobster in the waters of southern Yogyakarta and Pacitan (Damora et al., 2018). The estimates of L_∞, k and t_0 for males and females are similar (Table 4.1). Note that the relatively large negative t_0 (~ –0.25 years) shows that the growth curve is not reliable for small lobster.

Table 4.1. Summary of von Bertalannfy growth parameters for *Panulirus homarus* in the waters of southern Yogyakarta and Pacitan

Parameter	Females (n = 692)	Males (n = 375)
L_∞	104.8	101.3
k	0.46	0.49
t_0	–0.25	–0.24

L_∞ = asymptotic length; k = instantaneous growth rate; t_0 = estimated age at 0 length. Source: Damora et al. (2018).

4.1.7. Length and age at maturity:

The estimated size at 50% maturity for female *P. homarus* in the waters of southern Java was 58.5 mm, or about 60% of the estimated asymptotic length (L_∞) (Table 4.2).

Table 4.2. Summary of size-at-maturity parameters for females and both sexes of *Panulirus homarus* in the waters of southern Yogyakarta and Pacitan

Parameter	Females (n = 692)	Both sexes (n = 1067
L_{1st}	nd	53
L_{50}	58.5	nd
L_{95}	74.2	nd

L_{1st} = size at first maturity; L_{50} = size at which 50% of individuals are mature; L_{95} = size at which 95% of individuals are mature; nd = no data. Source: Damora et al. (2018).

4.1.8. Summary of life history, habitats and movement

No specific information of the life history of Scalloped Spiny Lobster is available for this region, but general information on the life history of spiny lobster is known: several planktonic larval stages (phyllosoma) are followed by settlement of the puerulus, and then development into the juvenile and adult stages (Phillips et al., 2013). Spiny lobster hatch as planktonic phyllosoma larvae (1–2 mm long) and develop through a series of moults, increasing in size. After developing in offshore waters, phyllosoma return toward the continental shelf where the final-stage larvae metamorphose into the puerulus, a non-feeding stage (~30 mm long), which then swims towards the coast. When the puerulus stage settles, it moults after a few days to weeks into a benthic juvenile stage. Small juveniles (post-pueruli) are usually found in shallow coastal reefs, and larger juveniles and adults in deeper waters offshore. In these deeper waters they reach maturity and mate. The extruded eggs develop on the female and are released as larvae, completing the life cycle (Phillips et al., 2013).

4.2. Fishery

4.2.1. Description of the fishery

The lobster fishery on the southern coast of Java is characterised by catches of six species of spiny lobster in the genus *Panulirus*: *Panulirus ornatus, P. homarus, P. penicillatus, P. versicolor, P. longipes* and *P. polyphagus.* The primary fishing methods used in this area are gillnets (*jarring lobster*) and hoop-trap nets (*krendet*). Gillnets are constructed of nylon monofilament of mesh size up to 127 mm. They are deployed from an outboard, small-powered vessel with an outrigger (*perahu* or *jukung*; Figure 4.1) and set on the sea floor, generally around coral or rocky reefs in depths of 10–20 m. The gillnets (Figure 4.1) are 40–45 m long and 1.25 m high and are weighted with lead weights on the bottom edge of the net and held vertical by header floats and surface floats.

Krendets are baited hoop-style tangle nets consisting of a circular metal frame 0.8–1.2 m in diameter and monofilament nylon 127 mm mesh (Figure 4.1). The *krendets* are baited with fish or molluscs and deployed either as a single set on ropes from the high cliffs along the coast or from the *perahu*. The *krendets* set from the clifftop are either held away from the cliff face by forked sticks (Figure 4.1) or deployed from fishing platforms built out from the cliff face (Figure 4.1). When deployed from *perahu*, the *krendets* are often deployed as a set of longlines with multiple *krendets* joined by a mainline, or else as individual nets with individual surface floats.

Figure 4.1. Fishing gear and methods used to catch *Panulirus homarus* on the southern coast of Yogyakarta and Pacitan, Java. Top left: gillnet vessels (*perahu*); top right: gillnets; centre left: hoop traps (*krendets*); centre right: *krendets* held out from a cliff face with a forked stick; bottom: a platform from which *krendets* are set. (Source: West et al., 2012)

Spiny lobster are landed at several sites along the southern coast of Yogyakarta and Pacitan: Gesing, Ngerenean, Baron, Drini, Siung, Sadeng and Pacitan (Figure 4.2), which are part of Fisheries Management Area (FMA) 573. The main route for lobsters for export starts with Level 1 collectors (*bakul*) buying lobsters from the boat fishers (caught by gillnet or *krendets*). The *bakul* then sell them to Level 2 collectors (*pengumpul*) who, in turn, sell them to exporters in Surabaya, Jakarta and other places.

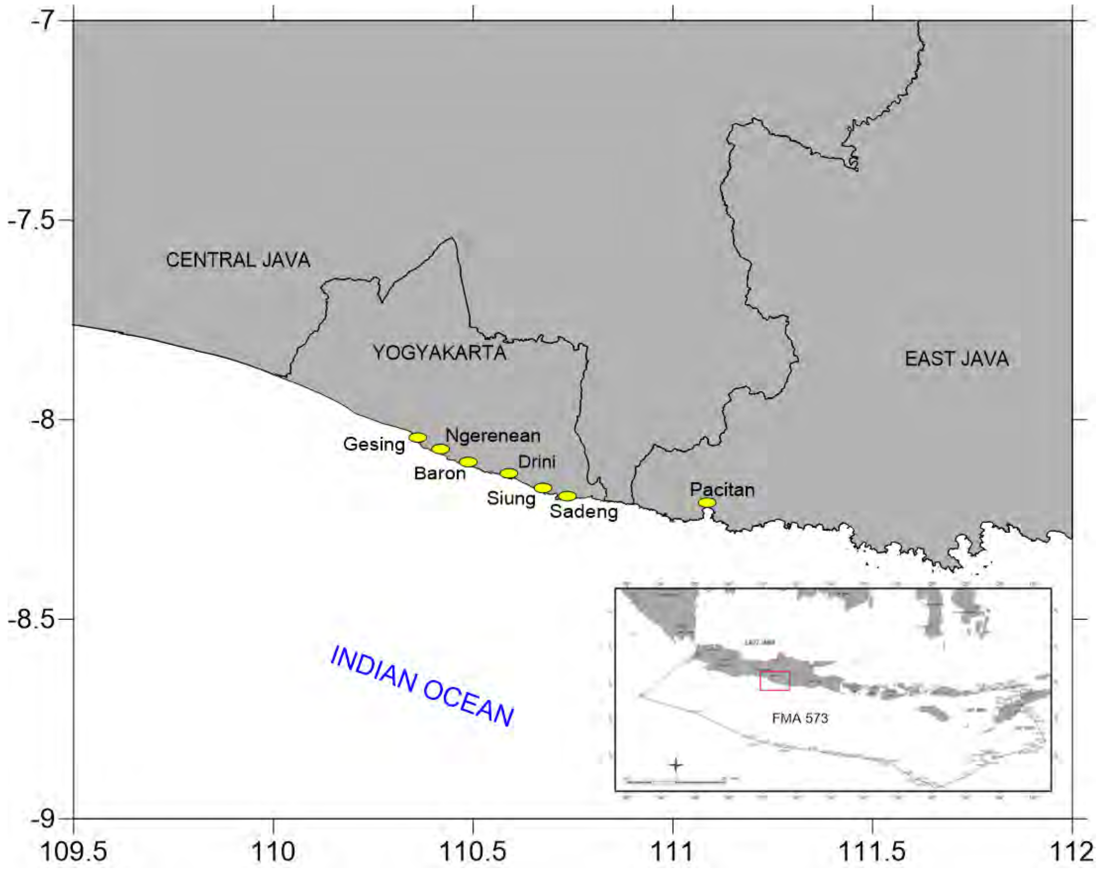

Figure 4.2. Landing sites for the spiny lobster fishery in the southern part of Yogyakarta and Pacitan within Fisheries Management Area 573 (shown on inset). Latitudes and longitudes are shown on the left hand and bottom borders, respectively.

4.2.2. Stock depletion and resilience

The current spawning stock biomass is probably heavily depleted compared to the unfished spawning stock biomass due to the high value of lobster, the number of fishers in the fishery and the intense fishing effort over a number of decades. Damora et al. (2018) reported that the SPR of Scalloped Spiny Lobster in southern Yogyakarta was 16%, which is below the general SPR limit of 20% and indicates that the Scalloped Spiny Lobster stock is depleted.

Typically, spiny lobster stocks are considered resilient because of their relatively short life cycle (<10 years), early maturity and high fecundity.

4.2.3. Fishing effort: history, variability and changes in fishing efficiency

The analysis of catch per unit effort (CPUE) based on the landing data of one collector on the southern coast of Yogyakarta from August 2009 to May 2013 (Damora et al., 2018) shows that the monthly CPUE (per trip) was higher from October to February than in the other months of the year (Figure 4.3a); rainfall is highest during this period. High rainfall affects the turbidity of the waters and increases the activity of the lobster.

Longer-term historical data collected by the Directorate General of Capture Fisheries (DGCF), Republic of Indonesia, shows that the total catch of spiny lobsters in FMA 573 between 2001 and 2014 decreased gradually from about 850 t in 2003–2005 to 200–400 t from 2012 to 2014 (Figure 4.3b). The fishing effort per gillnet unit (~40–50 m length ×1.25 m height) varied from 15,000 to 25,000 units, except for 2008–2009 when it was 40,000–50,000 units. Gillnet effort was also high in 2013–2015 (18,000–30,000 units), when the lowest catches were recorded (240–380 t; Figure 4.3b).

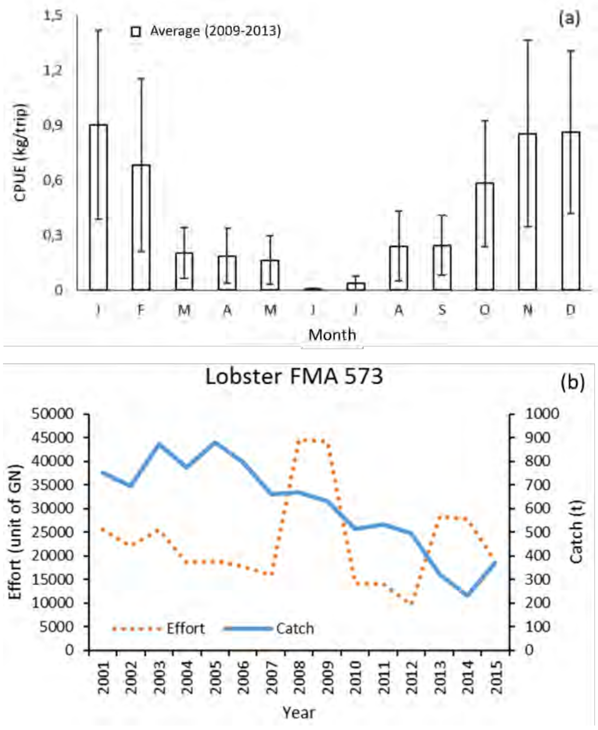

Figure 4.3. (a) Monthly catch per unit effort (CPUE in kg per trip ± 1 SE?) for spiny lobster on the southern coast of Yogyakarta (Source: Damora et al., 2018), and (b) catch (tonnes) and effort (gill net units) for spiny lobster in FMA 573 (Southern Java and Nusa Tenggara) from 2001 to 2015 (data from the Directorate General of Capture Fisheries, Indonesia).

4.2.4. Selectivity of fishing methods

According to West et al. (2012), Scalloped Spiny Lobster caught in gillnets ranged from 32.2 to 96.6 mm carapace length (CL), with 50% selectivity estimated at 53.9 mm CL, about 5 mm below the estimated L_{mat} (Table 4.2). Lobster caught in *krendets* ranged from 28.2 to 93.4 mm CL, with an estimated 50% selectivity of 51.3 mm CL (~7 mm < L_{mat}). The selectivities of gillnets and *krendets* were asymptotic. The proportions of Scalloped Spiny Lobster caught by gillnets and *krendets* were estimated at 70% and 30%, respectively.

4.3. Management regulations

4.3.1. Current management

Spiny lobster are regulated at the national level under Ministerial Decree No. 56/2016. This decree regulates the catching and exporting of spiny lobster (*Panulirus* spp.), with harmonised system code 0306.21.10.00 or 0306.21.20.00, from the territory of Indonesia. Lobster can only be caught and exported under the following provisions: (a) not in egg-bearing condition, and (b) carapace length is above 80 mm or weight is above 200 g. The

Directorate General of Surveillance and the Agency of Fish Quarantine are mandated to monitor the catch size limit of spiny lobsters. This regulation is relatively easy to apply for exported lobster because exporters need a certified document; however, it is difficult to enforce for local trading and markets because they are not monitored. In addition, the total allowable catch (TAC) of spiny lobster is regulated under Ministerial Decree No. 50/2017. This decree is updated by the National Commission for Stock Assessment every two years; the most recent TAC (2017) is 776 t. The DGCF is mandated to monitor the TAC but monitoring the total landings is difficult because catches can be landed at many private landing sites, which increases the unreported catch.

4.3.2. Future management options

For future management of Scalloped Spiny Lobster, the following should be considered:

- Assess the minimum size limits for all species of spiny lobster because they have different life histories (e.g. should the minimum legal size for *P. homarus* and *P. ornatus* be different).
- Assess the habitat and distribution of early life stages to make recommendations on the location of potential spatial closures for this species.
- Investigate the use of limit reference points for spiny lobster based on the spawning potential ratio or catch per unit effort.

4.4. Data sources

The following data sources were used to summarise information on the Scalloped Spiny Lobster:

- ACIAR Project FIS/2006/142 for data from 2010 to 2012
- BRPL/RIMF for data from 2013 to 2014 and 2016
- Statistical Capture Fisheries data for the years 2001 to 2015 (DGCF: Ministry of Marine Affairs and Fisheries).

4.5. Management planning in MERA

The Method Evaluation and Risk Assessment application (MERA) provides the manager with an accessible and powerful tool for identifying species at risk, selecting management procedures that can achieve performance objectives, and calculating stock status. MERA is intended to better account for uncertainty in the fishery system. It prioritises robust management options and identifies the value in collection of alternative data and possible research programs. It has four sections: risk assessment for quantifying future biological risk of status quo management; management planning for determining a suitable management mode; management performance for evaluating current management mode; and status determination for calculating status stock.

Here we present the analysis of management planning for Scalloped Spiny Lobster in the waters of southern Java in MERA. We highlight the management procedures with the highest scores for long-term yield, considering only those procedures with a probability of >0.75 that the biomass is >0.5 B_{MSY} (B_{MSY} = biomass at maximum sustainable yield; Table 4.3). In general, the performance of management options based on total allowable effort (TAE; ITE10) and spatial management (MRNoreal, MRreal) was better than that of options based on TAC; these options had higher long-term yields than TAC. However, we also need to consider the score for the probability of biomass greater than MSY (probability B >0.5 B_{MSY} & probability $B > B_{MSY}$); that is, a measure of the yield of the fishery. After adding these considerations, the TAE and TAC have higher scores than the spatial management options. Thus, the TAE and TAC options had the best theoretical performance for managing Scalloped Spiny Lobster.

Table 4.3. Performance of management procedures from the Method Evaluation and Risk Assessment (MERA) simulations for Scalloped Spiny Lobster in the waters of southern Yogyakarta and Pacitan, Indonesia

Management procedure	Regulation type	Prob. B > 0.5 B_{MSY}	Prob. $B > B_{MSY}$	Short-term yield	Long-term yield
ITe10	TAE	0.85	0.53	1.06	1.09
MRnoreal	Spatial	0.77	0.38	1.07	1.09
MRreal	Spatial	0.77	0.37	1.07	1.09
DD	TAC	0.85	0.53	0.86	1.04
DD4010	TAC	0.86	0.57	0.76	1.02
matlenlim	SL	0.77	0.38	0.99	1.01
DCAC	TAC	0..86	0.61	0.85	1.00
DBSRA	TAC	0.84	0.54	0.79	1.00
DBSRA_40	TAC	0.66	0.29	1.07	0.95
Fratio	TAC	0.76	0.49	0.87	0.94
HDAAC	TAC	0.91	0.71	0.58	0.93
matlenlim2	SL	0.77	0.38	0.94	0.93
DBSRA4010	TAC	0.9	0.66	0.57	0.87
DCAC_40	TAC	0.89	0.71	0.86	0.84
DDe	TAE	0.74	0.53	0.98	0.83
IT10	TAC	0.81	0.65	0.86	0.82
IT5	TAC	0.82	0.61	0.88	0.81
DDe75	TAE	0.88	0.62	0.92	0.77
MCD	TAC	0.96	0.83	0.45	0.72
MCD4010	TAC	0.97	0.84	0.33	0.66

Blue shading = the four options with highest likelihood of maintaining long-term catches and yield. TAE = total allowable effort; SL = size limit; TAC = total allowable catch; ITe10 = setting total allowable effort (TAE) with a 10% annual increase; MRnoreal = marine reserve, no reallocation of effort; MRreal = marine reserve with reallocation of effort; DD = delay-difference stock assessment.

Based on the quantitative performance of the candidate management procedures, the four management procedures with the highest scores for long-term yield were ITe10, MRnoreal, MReal, and DD. The ITe is the index target effort-based control where the effort is modified according to current levels (mean index over past 5 years) relative to a target level. The number 10 refers to the maximum allowable annual change in effort of 10 %. The MRnoreal and MReal options are the spatial closure and allocation management options closing an area in one location to fishing and either spatially reallocating fishing effort (MReal) or not reallocating effort (MRnoreal). The DD option is a simple delay-difference stock assessment with k, Y and MSY as leading parameters used to estimate the TAC using a time-series of catches and a relative index of abundance. This DD model includes observation error only and does not estimate process error (e.g. recruitment deviations).

The objective of this management is to maintain the level of biomass (B/B_{MSY}) at 0.9 to 1.1 in the long term. To meet this objective, the best candidate management option for managing the Scalloped Spiny Lobster was ITe10 (Figure 4.4). The projection for this management procedure showed that the level of biomass fluctuates but tends to increase over the period of projections, and the yield projection fluctuates but tends to be relatively stable (Figure 4.4).

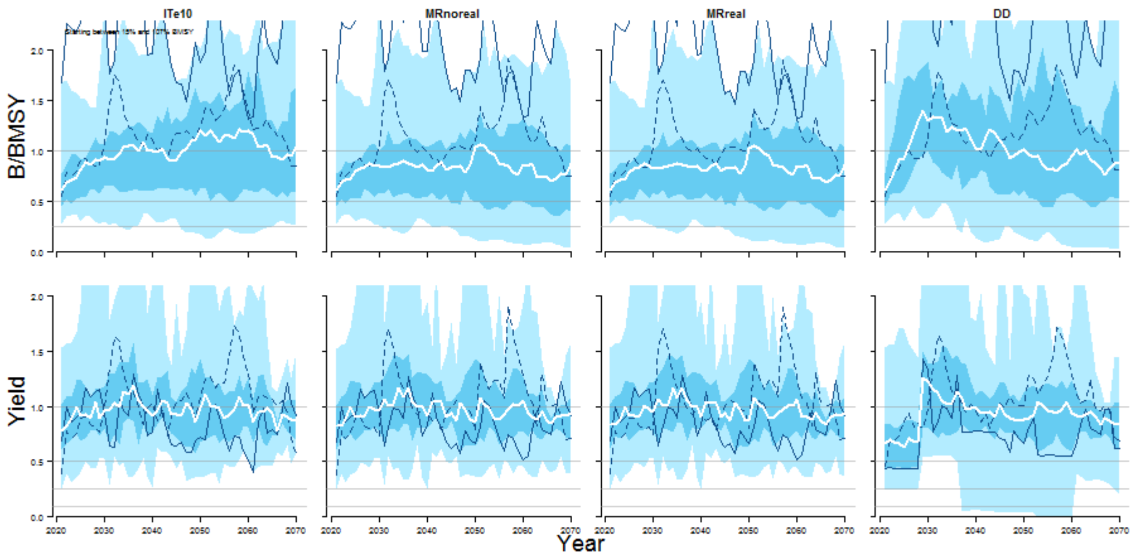

Figure 4.4. Simulated performance of four management planning options for Scalloped Spiny Lobster in southern Yogyakarta and Pacitan with probability of $B > B_{MSY}$. The shaded regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5 and 1. ITe10 = setting total allowable effort (TAE) with a 10% annual increase; MRnoreal = marine reserve, no reallocation of effort; MRreal = marine reserve with reallocation of effort; DD = delay-difference stock assessment.

The MRnoreal, MReal and DD management options tended to have lower levels of biomass than the Ite10 option in the long term, although the yields were similar to that of the ITe10 procedure (Figure 4.4). For the Scalloped Spiny Lobster fishery, we consider these management procedures would be difficult to implement since the time-series data for effort (vessels, gears) which operate in southern Yogyakarta and Pacitan are not available. To implement these management procedures, a time series of effort data for the past five years is required.

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5. Fisheries management for the Scalloped Hammerhead Shark (*Sphyrna lewini*) in the eastern Indian Ocean

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Sphyrna lewini, the Scalloped Hammerhead Shark (English), or *Hiu Martil* (Bahasa Indonesia). (Image: Benaya M. Simeon)

Summary

Hammerhead sharks are valuable fish because their fins have high value, which has led to an increase in targeting of this species in some areas. This genus comprises four morphologically similar species: *Sphyrna lewini, Sphyrna mokarran, Sphyrna zygaena* and the Winghead Shark, *Eusphyra blochii.* All of these species are caught globally and throughout the waters of the Indonesian archipelago both in targeted fisheries and as bycatch in other fisheries, such as longline and gillnet fisheries. The Scalloped Hammerhead Shark, *Sphyrna lewini,* is captured in various other fisheries throughout the rest of its range in the Indian Ocean. Few species-specific data are available from other areas; however, numbers are likely to have declined in other areas where this species is

heavily fished. Other countries with major fisheries for sharks include the Maldives, Kenya, Mauritius, the Seychelles and Tanzania. Sharks are considered heavily over-exploited in these waters.

Fishing pressure is also high in the Indian Ocean and Western Pacific, with many countries in this region among the largest shark-fishing nations in terms of global catch. Indonesia has the largest chondrichthyan fishery in the world: 105,000 tonnes and 118,000 tonnes of sharks were landed and reported in 2002 and 2003, respectively. The Scalloped Hammerhead is a target and bycatch of shark longline and tuna gillnet fisheries and trawls in several areas in this region. The species is used for its fins (high value in adults), meat, skin and cartilage.

Hammerhead Sharks are caught globally as a commodity in both industrial and artisanal fisheries, including those in the eastern Indian Ocean. Illegal, unregulated and unreported fishing has increased markedly in northern Australia recently. Hammerheads are known to feature in the catches, and are suspected to be targeted for their large valuable fins, although no specific data are available. Determining the status of *S. lewini* in this region is an urgent priority.

Sphyrna lewini is one of the most common shark species found in Indonesian waters; it is landed in numbers at Tanjung Luar in east Lombok from catches in Fisheries Management Area (FMA) 573 in the eastern Indian Ocean. Recently, *S. lewini* was reported to be caught by 46 targeted fishing fleets in Indonesia, worked by about 132 fishers. Between 2014 and 2019, the mean size at capture was 202 cm, with 32% of the catch below this size, that is, immature. The exploitation rate (E) increased from 0.51 in 2018 to 0.76 in 2019. The local community at Tanjung Luar is highly dependent on shark resources, both from the sale of fins and because shark flesh is a cheap source of protein. Considering these pressures, some recommendations for conserving *S. lewini* in the region have been made. At Tanjung Luar, the provincial government and shark fishers have developed a local agreement on shark fishing rules, which has been established in Governor Decree No 55 / 2020 with agreements to limit fishing effort (number of hooks on shark longlines and number of days fishing).

The Method Evaluation and Risk Assessment (MERA) analyses indicate that several types of management procedures could improve the stock status of *S. lewini*: total allowable catch (TAC), total allowable effort (TAE), and spatial management (MRreal, MRnoreal). The results from two models that used TAC differed from those of the other management procedures and indicated a decrease in population. In contrast, the TAE and spatial management models showed promise for improving the population if management measures were enforced. If these management procedures were used, the population is predicted to improve significantly in 20–40 years, which means the population would be restored in one or two generations. The modelling showed that, with strict management implementation and use of precise management tools, there is hope for the hammerhead population in the eastern Indian Ocean. Based on the MERA analyses and the likelihood of effectively implementing the management procedures, we recommend the ITe10 management procedure (individually transferrable effort quota, with a maximum change in effort of 10% annually) as the best candidate for managing the *S. lewini* fishery. This option has the highest probability of effective implementation and meeting management objectives. It also has a low risk of the stock declining to low levels. To be implemented in the fishery, this management approach requires establishing an accurate database for the number of operational boats, agreements on fishing rules to limit effort, and mechanisms such as good enforcement and education programs to ensure compliance.

Ringkasan

Hiu kepala martil adalah ikan yang bernilai karena harga siripnya yang tinggi, dimana hiu ini bahkan menjadi target penangkapan di beberapa lokasi. Genus ini di secara morfologikal memiliki kemiripan antara 4 spesies yaitu: *Sphyrna lewini*, *Sphyrna zygaena*, *Sphyrna mokarran*, dan *Eusphyra blochii*. Jenis hiu ini tertangkap secara global termasuk di perairan kepulauan Indonesia, dimana hiu martil tertangkap sebagai tangkapan target dan sampingan pada perikanan rawai dan jaring insang. Hiu kepala martil jenis *Sphyrna lewini* ditangkap pada berbagai perikanan di wilayah Samudera Hindia. Ketersediaan data yang spesifik pada tingkat spesies cukup terbatas, namun di sisi lain penangkapan yang berlebih terus terjadi hingga jumlah populasi hiu ini diketahui menurun di perairan ini. Negara lain yang diketahui sebagai memanfaatkan hiu melalui perikanan di perairan ini termasuk Maladewa, Kenya, Mauritius, Negara Kepulauan Seiselensa, dan Tanzania.

Tekanan perikanan yang tinggi juga terjadi di Samudera Hindia dan Samudera Pasifik bagian Barat, dengan banyak negara perikanan besar yang berkontribusi pada tangkapan global. Indonesia telah menjadi negara penangkap hiu terbesar di dunia. Indonesia memiliki perikanan ikan bertulang rawan setidaknya 105,000 hingga 118,000 ton hiu didaratkan dan dilaporkan pada tahun 2002 dan 2003. Hiu martil diketahui menjadi target dan tangkapan sampingan untuk rawai hiu dan tuna, perikanan jaring insang, dan jaring pukat di beberapa perairan di area ini. Ikan ini dimanfaatkan baik sirip (bernilai tinggi pada individu dewasa), daging, kulit, dan tulang.

Hiu martil ditangkap secara global sebagai komoditas perikanan komersial dan perikanan artisanal termasuk di perairan Samudera bagian Timur. Penangkapan illegal, yang tidak diregulasikan, dan tidak terlaporkan (IUU Fishing) tercatat bertambah di perairan Utara Australia akhir-akhir ini. Hiu marti diketahui sebagai salah satu tangkapan dan dicurigai sebagai target penangkapan karena sirip dari individu dewasanya memiliki nilai jual yang tinggi, walaupun tidak ada data spesifik yang tersedia. Penelitian lebih lanjut perlu dilakukan untuk menentukan status hiu martil di area ini menjadi prioritas penting yang harus dilakukan.

Hiu martil (*S.lewini*) adalah jenis hiu yang banyak tertangkap di perairan Indonesia, hiu ini didaratkan dalam jumlah besar di Tanjung Luar - Lombok Timur, yang tertangkap di WPP (Wilayan Pengelolaan Perikanan) 573 di perairan Samudera Hindia bagian Timur. Saat ini, *S.lewini* dilaporkan ditangkap oleh 46 armada perikanan Indonesia yang terdiri dari 132 nelayan. Antara tahun 2014 hingga 2019, panjang total rata-rata tercatat 202 cm, dengan 32% adalah individu yang belum dewasa. Nilai eksploitasi (*E*) bertambah dari 0.51 pada tahun 2018 ke nilai 0.75 pada tahun 2019. Masyarakat lokal di Tanjung Luar memiliki ketergantungan yang tinggi pada sumberdaya hiu, baik dari penjualan sirip dan daging sebagai sumber protein murah. Di Tanjung Luar, pemerintah provinsi telah menetapkan regulasi penangkapan hiu yang disepakati bersama nelayan hiu. Regulasi tersebut berupa pembatasan jumlah mata pancing dari rawai hiu, pembatasan jumlah hari melaut (pembatasan upaya penangkapan), dan pembatasan jumlah armada yang bisa beroperasi setiap tahunnya.

Analisis MERA (*Method Evaluation and Risk Assessment*) mengidikasikan beberapa prosedur pengelolaan yang bisa memperbaiki status stok dari *S.lewini*, seperti: jumlah tangkapan yang diperbolehkan (TAC), jumlah upaya yang diperbolehkan (TAE), dan pengelolaan spasial (MRreal, MRnoreal). Dua model yang digunakan adalah TAC yang menunjukkan hasil yang berbeda dari prosedur pengelolaan lainnya dan mengindikasikan penurunan populasi Namun hasil yang sangat berbeda ditunjukkan oleh model TAE dan pengelolaan spasial yang menunjukkan hasil yang menjanjikan dimana perbaikan populasi mungkin terjadi jika pengelolaan dilakukan secara ketat. Jika prosedur-prosedur pengelolaan ni dilakukan, populasi diprediksi akan membaik dalam 20–40 tahun, artinya populasi akan kembali membaik dalah satu atau dua generasi. Model menunjukkan bahwa melalui implementasi pengelolaan yang ketat dan penggunaan perangkat pengelolan yang presisi, ada sebuah harapan untuk populasi hiu martil di perairan Samudera Hindia bagian Timur. Berdasarkan analisis MERA dan pertimbangan efektivitas implementasi prosedur pengelolaan, kamu merekomendasikan prosedur pengelolaan ITe10 (TAE dengan perubahan upaya maksimal 10% per tahun) sebagai kandidat terbaik untuk mengelola perikanan *S.lewini*. Model ini memiliki probabilitas terbesar dan implementasi yang efektif dan sesuai dengan tujuan pengelolaan. Model ini juga memiliki resiko yang rendah dari penurunan stok hingga tingkat terendah. Bertujuan untuk mengimplementasikannya dalam perikanan, pendekatan pengelolaan perlu dilakukan seperti memperkuat akurasi database armada yang beroperasi, kesepakatan penangkapan ikan melalui pembatasan upaya tangkap, dan mekanisme seperti penegakan hukum dan edukasi untuk memastikan kepatuhan nelayan.

5.1. Biology

5.1.1. Taxonomy

Scientific name: *Sphyrna lewini* (Griffith and Smith, 1834; Sphyrnidae)

Common names: Scalloped Hammerhead (English), *Hiu Martil* (Bahasa Indonesia), *Hiu Bingkoh, Hiu Capil* (Balinese), *Cucut Capingan* (Javanese) and *Yee Rimbah* (Acehnese)

5.1.2. Key identifying features

Sphyrna lewini is a large species that reaches lengths of at least 370–420 cm (White et al., 2006). The broad head has a scalloped form, with the anterior margin well arched and shallowly indented at the midline. The width of the head is less than one-third of the total length. The first dorsal fin is tall and moderately falcate. The second dorsal fin is short with a long rear tip and a weakly concave posterior margin. The posterior margin of the anal fin is deeply notched. The upper pre-caudal pit is crescentic.

5.1.3. Distribution

Worldwide: The Scalloped Hammerhead is a coastal and semi-oceanic shark that is circum-globally distributed in coastal warm temperate and tropical seas, from the surface and intertidal zones to a depth of at least 275 m (Compagno, 1999). Although it is wide ranging, genetic evidence suggests multiple subpopulations of this species.

Indonesia: The Scalloped Hammerhead is found in the Indian Ocean, Sunda Strait, Java Sea, South China Sea and waters around the islands of Sumatra, Kalimantan, Sulawesi, Molluccas and Papua (White et al., 2006). This study, and previous research by White et al. (2006), focuses on *S. lewini* landed at the Tanjung Luar site in eastern Lombok; the sharks were likely caught in FMA 573 (Figure 5.1).

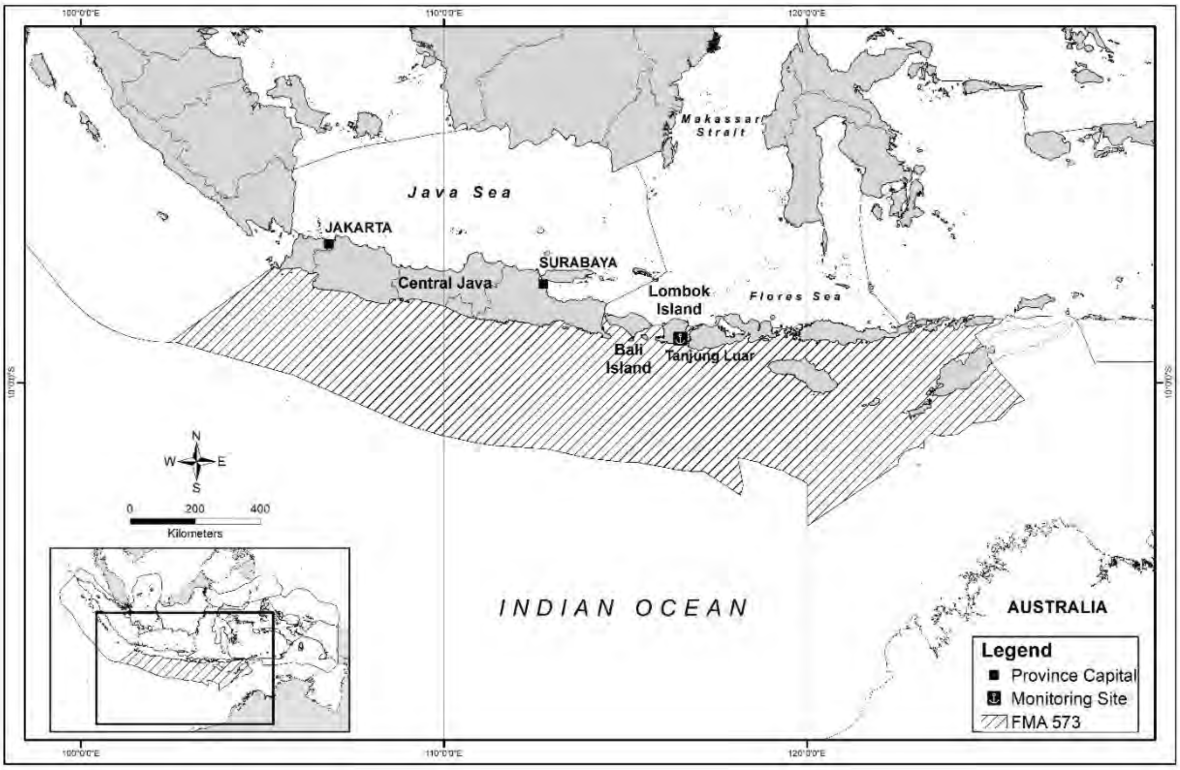

Figure 5.1. Landing sites and fishing grounds for Scalloped Hammerhead Shark (*Sphyrna lewini*) in Indonesia. Shaded area shows Indonesian Fisheries Management Area 573.

5.1.4. Maximum length, weight and age

White et al. (2006) recorded the maximum total length of *S. lewini* as 3700 mm. The maximum age recorded for this species is 30.5 years for both males and females (Piercy et al., 2007 and the maximum weight is 1524 kg. The maximum length of a male recorded at the Tanjung Luar landing site was 3400 mm. More recently, the maximum length recorded between 2015 and 2019 during a measuring program by the Wildlife Conservation Society – Indonesia Program (WCP-IP) at Tanjung Luar was 3620 mm, and a maximum age of 26 years (Simeon et al., 2020).

5.1.5. Growth

The growth parameters of *S. lewini* landed at Tanjung Luar were estimated from landing monitoring data and were also drawn from publications. We analysed length data recorded from 2014 to 2019 and separated the growth parameters based on sex (Table 5.1); the published parameters are significantly higher than those from our study. We have taken a precautionary approach toward the modelling in MERA and used growth parameters from our analysis of 6 years of data.

Table 5.1. Summary of the von Bertalanffy growth parameters for *Sphyrna lewini* landed at Tanjung Luar, eastern Lombok, Indonesia

Parameter	Females (n = 2245)	Males (n = 718)	Both sexes (n = 634)
L_∞ (mm)	3790	3590	3990
k (growth.year^{-1})	0.05–0.15	0.08–0.13	0.24–0.29
t_0 (years)	–0.56	–0.66	–0.34 to –0.28

Size range = 420–3400 mm total length (Jaliadi et al., 2017; Sentosa et al., 2016; Simeon et al., 2020). L_∞ = asymptotic length; k = instantaneous growth rate; t_0 = theoretical age at 0 length.

5.1.6. Length and age at maturity

Scalloped Hammerhead can give birth to 40–50 pups (Simeon et al., 2020; White et al., 2006). This shark reaches 50% maturity (A_{50}) at age 4.1 years (females) and 3.8 years (males) (Baum et al., 2007; Rigby et al., 2019). Total length at 50% maturity (L_{50}) is 1554 mm (females) and 1404 mm (males) (Table 5.2). The gestation period is 9–12 months (Chen et al., 1990); they reproduce every 2–3 years.

Table 5.2. Length and maturity parameters of *Sphyrna lewini* landed at Tanjung Luar, eastern Lombok, Indonesia

Parameter	Females (n = 2245)	Males (n = 718)
L_{50}	1554 mm	1404 mm
L_{95}	1995 mm	1533 mm

L_{50} = total length at 50% maturity, L_{95} = total length at 95% maturity. Source: Simeon et al. (2020).

5.1.7. Summary of life history, habitats and movement

Juvenile and adult Hammerhead Sharks occupy different habitats. Juveniles are demersal, gregarious and primarily found in coastal areas, estuaries and embayments; adults are mainly solitary and inhabit pelagic waters (Clarke, 1971; Compagno, 1984). Juveniles have relatively high metabolic rates and commensurately high daily food requirements (Lowe, 2001, 2002). Newborn pups and juveniles have been found gathering in coastal spawning grounds for two years before they moved to adult shark habitats (Holland et al., 1993). They have been observed to stay in several core areas during the day (Holland et al., 1993), and often form large swarms (Stevens and Lyle, 1989). Scalloped Hammerheads are likely to form aggregations based on sex.

Many shark species have a complex life history, with high mobility and broad spatial ranges (Michael, 1993). Chapman et al. (2015) proposed a scheme of shark movement called 'triangle migrations' that describes the spatial structure of coastal shark populations based on movement of individuals between nursery areas and habitats occupied by adults of both sexes. Scalloped Hammerheads mate with multiple partners as an inbreeding avoidance mechanism, rather than competing for mates (Marie et al., 2019).

5.2. Fishery

5.2.1. Description of the fishery

In Indonesian waters, hammerhead sharks (*S. lewini, S. mokarran, S. zygaena*) are caught by several fishing methods in targeted fisheries and as bycatch in fisheries such as tuna fisheries. These methods include: shark bottom longline, shark drift/surface longline, drift gillnet, and tuna longline (Jaiteh et al., 2017b).

Bottom longline: Fishing gear consisting of many hooks set on the sea floor at depths between 50 and 100 m; bottom longlines are used to catch demersal sharks.

Drift/surface longline: This type of fishing gear is specifically intended to capture various shark species whose habitat is the high seas or oceans. Mature adults of the three hammerhead species (*S. lewini, S. mokarran* and *S. zygaena*) are often caught with this gear. Because this gear is generally set at the surface layer, fishers often call it the surface shark line or *ngambangan* (floating line).

Drift gillnet: This type of fishing net is used to catch tuna, most commonly Skipjack Tuna, but some species of sharks are often caught as well. With a relatively large mesh size, it is considered more selective than other types of fishing net, and catches relatively large, mature fish. However, several hammerhead species (*S. lewini, S mokarran* and *S. zygaena*) are also caught with this gear.

Tuna longline: Tuna longline fishing gear is used by fishers mostly based in ports of Java (Palabuhanratu, Cilacap), Bali (Benoa) and northern Sulawesi (Bitung) to catch the larger species of tuna, including Yellowfin Tuna, Bigeye Tuna, Albacore and Southern Bluefin Tuna. Some adult and mature oceanic sharks such as *S. lewini, S. mokarran* and *S. zygaena* are caught occasionally with this gear.

In general, hammerhead sharks are fished and landed throughout the year without being restricted by season. However, the months from April to October and from November to February, when catches are highest, are usually considered as defining the shark fishing seasons for the Indian Ocean.

Indonesian Government data on landings of hammerhead sharks between 2005 and 2015 show that the fishing areas for *Sphyrna* spp. are in the Indian Ocean (FMA 573 and FMA 572), from the Malacca Strait to the Karimata Strait (FMA 711), the Java Sea (FMA 712), and from the Makassar Strait to the Flores Sea (FMA 713) (Figure 5.2). The largest landings of hammerheads were in FMA 713, from Makassar Strait to the Flores Sea, where sharks were captured using surface and bottom longlines.

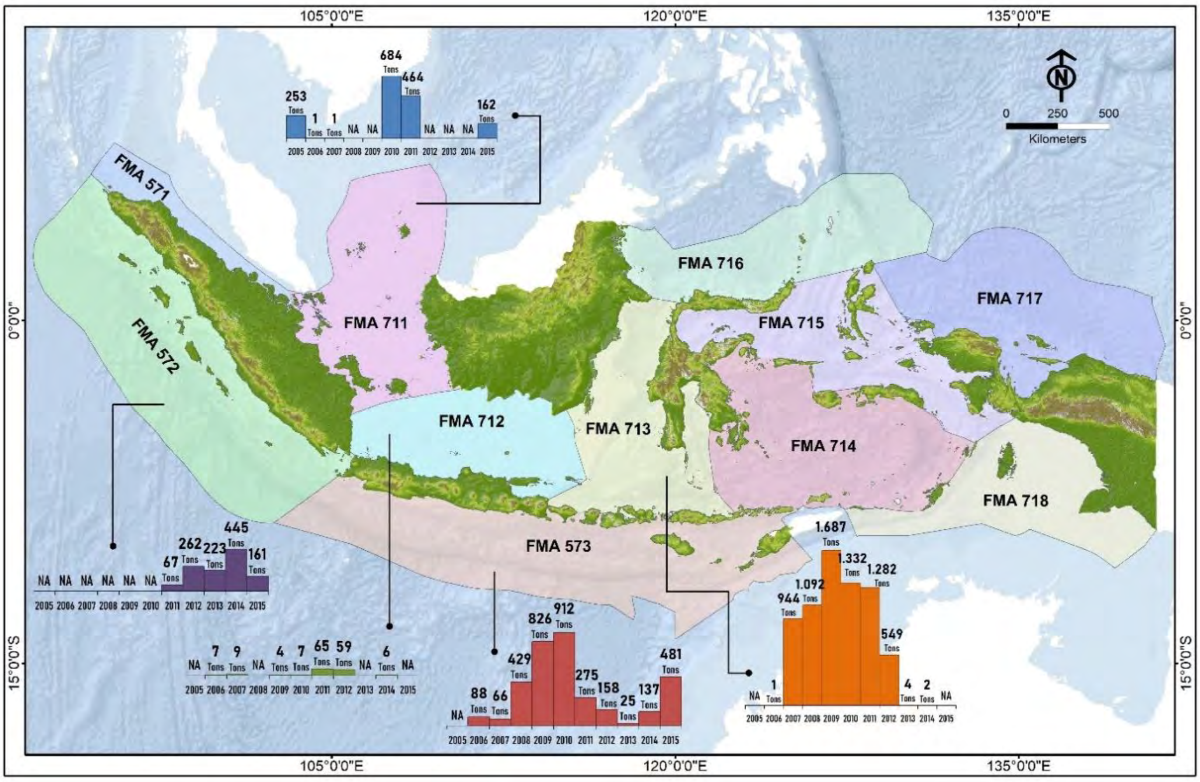

Figure 5.2. Landings of hammerhead sharks (*Sphyrna lewini, S. mokarran* and *S. zygaena*) in five Indonesian Fisheries Management Areas (FMAs 572, 573, 711, 712, 713) between 2005 and 2015 (Source: Ministry of Marine Affairs and Fisheries [MMAF], 2016).

As a resource, hammerhead sharks are the main source of income for certain community groups, including fishers, middlemen, sellers and fish processors. Some people in the regions where sharks are targeted depend highly on their catches (Jaiteh et al., 2017a, 2017b). One example is local fish traders, such as those in Indramayu, West Java, who are involved only in the salted shark meat trade; they started collecting and selling shark fins in 1986 (Suzuki, 2002). In the past few decades, shark fishing has grown from a small-scale longline fishery to a commercial fishery both targeting Sphyrnidae and also harvesting them as bycatch. Shark fin exporters, motivated by the hammerhead shark's large fin size of high value in the shark fin trade, provide loans and capital to local fishers to increase their catches. Hence, the hammerhead shark fishery is an important industry for particular communities, which have gradually shifted their original view of these sharks as an incidental bycatch to one of an expected bycatch – although hammerhead sharks are not the target, they are an important component of the catch because of their value.

5.2.2. Stock depletion and resilience

Statistical data on Indonesian fisheries shows that catches of hammerhead sharks increased sharply from 100 t in 2006 to 3400 t in 2010 and 2011 before declining sharply to about 530 t in 2013 (Figure 5.3). Landings increased to 894 t in 2015 (Figure 5.3).

Stock depletion has been recorded in other regions outside Indonesian waters. For example, both species-specific estimates for *S. lewini* and grouped estimates for *Sphyrna* spp. suggest declines in abundance of 50–90% over the past 32 years in several areas of their range, including South Africa, the northwest and western central Atlantic, and Brazil (Baum et al., 2007; Rigby et al., 2019). Given continued high fishing pressure and the observed and inferred declines, the species was classified by the International Union for Conservation of Nature as Critically Endangered in the Indian Ocean, including in Indonesian waters (Rigby et al., 2019).

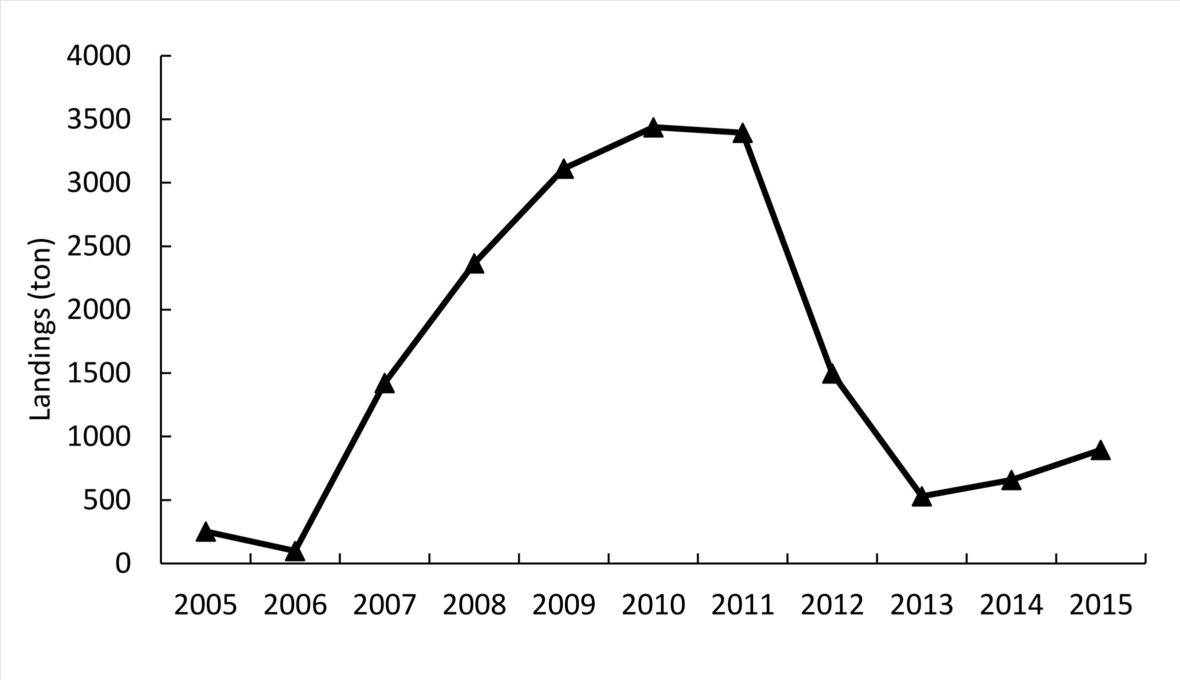

Figure 5.3. National landings of hammerhead sharks (*Sphyrna lewini, S. mokarran,* and *S. zygaena*) in Indonesian waters from 2005 to 2015 (Source: MMAF, 2016).

5.2.3. Fishing effort: history, variability and changes in fishing efficiency

The Indonesian shark fishery started in the 1970s; Scalloped Hammerhead Shark were a target species then (Simeon et al., 2017; Tull, 2014). The efficiency of shark fishers developed along with other fishery developments in the 1980s (Table 5.3), when shark began to be targeted in several places. This included Tanjung Luar in eastern Lombok, which is now the biggest landing site for shark-targeted fisheries in Indonesia. The number of shark fishing boats increased significantly toward the end of the 1990s (Table 5.3) due to the Asian economic crisis and its effect on Indonesia. Shark as an export commodity was sold in US dollars, which was very attractive when the Indonesian Rupiah declined sharply in value during this crisis.

Research in three Indonesian fishing communities (Pulau Osi, Cerum; Dobo, Aru Islands; and Pepela, Roti Island) indicated that the number of shark caught in 2010 that were smaller than the size at maturity was greater for many species than the number in caught 2005 and in the 2000s. In addition, fishers perceived that catches had declined and fishing locations had changed for many species, including hammerheads (Jaiteh et al., 2017a, 2017b).

Table 5.3. Changes in boats, engines and technology used in Indonesian shark fisheries since the 1980s

Decade	No. boats	Engine	Technology
1980s	<10	Manual diesel engine (no electronics)	No GPS
1990s	~100	Electric-start diesel engine Diesel engines up to 16 HP	Few boats with GPS
2000s	~60	Battery for electricity supply on boats Diesel engines up to 24 HP	All boats with GPS and solar panels

GPS = global positioning system. Source: Haking, elder of Tanjang Luar, pers. comm., 2018.

5.2.4. Selectivity of fishing methods and discard rates

All hammerhead shark species, including the Scalloped Hammerhead, have much lower survival rates after capture than rays. These observations come from attempts to tag hammerheads; most sharks died in the fishing gear (Gulak et al., 2015). Larger, mature Scalloped Hammerheads are caught mostly by longline and offshore fishing gear. Based on critical habitat surveys, juvenile hammerheads (mean total length = 58.5 cm) were caught mostly in coastal areas and died about three hours after being hauled from the net (Simeon et al., 2018). Most Scalloped Hammerheads, including very small juveniles, are landed and sold. In other sites, monitoring data from landings show that, in the past six years, the median size of catches was 210 cm and the size at 50% selectivity (L_{50}) was 155.5 cm. Earlier research (White et al., 2008) estimated the L_{50} at 175 cm, 20 cm longer than the most recent measurement. Estimated fishing mortality (F) of *S. lewini* increased from 1.13 (White et al., 2012) to 2.0 (Simeon et al., 2020) during this time. Fishing mortality in 2019 reached an estimated F_{MAX} of 0.2 (White et al., 2012).

5.3. Management regulations

5.3.1. Current management

National Plan of Action for the Conservation and Management of Sharks

In 1999, the Food and Agriculture Organization (FAO) established the International Plan of Action for the Conservation and Management of Sharks. Indonesia initiated a plan to set up a National Plan of Action (NPOA) for the Conservation and Management of Sharks. In 2010, Indonesia established the NPOA for Sharks and Rays 2010–2014, with the following main programs: (1) review of status of shark fisheries, (2) development of data-collection methods and processes, (3) development of shark and ray research, (4) management improvements, (5) raising awareness of sharks and rays, and (6) institutional strengthening.

Many activities were conducted over this time within the framework of the NPOA, including improving the collection of data on sharks at shark landing sites in Indonesia, research on elasmobranch diversity in Indonesia, research on biological and fisheries aspects of sharks, stationing observers on tuna fishing vessels, protecting sharks and rays (whale shark, *Rhincodon typhus*; manta rays, *Mobula birostris, M. alfredi*) that are vulnerable to extinction, disseminating information, and public awareness-raising activities.

Prohibiting the retention of juvenile and pregnant sharks maintains resource sustainability because sharks are given the opportunity to regenerate. One of the major issues in shark fisheries is shark finning; the proposed regulation prohibiting shark finning seeks to ensure that sharks are not caught solely for their fins. This proposed regulation, if effectively implemented, would reduce shark bycatch. However, the regulation might be ineffective because of the difficulty of enforcing it across the large area of the Indonesian archipelago.

Ministry of Marine Affairs and Fisheries Regulation No. PER.18/MEN/2010 on Fishing Log Books

This regulation obliges every fishing vessel which has a *SIPI* (fishing licence) to fill out a fishery log book, which reports on the fish species caught, including hammerheads. Pictures of sharks are provided with this log book as a guide to help fishers record data on the sharks they catch.

Ministry of Marine Affairs and Fisheries Regulation No. 1/PERMEN-KP/2013 on the Fishing Vessel and Fish Transportation Vessel Observers

Because the personnel assigned to monitor fishing vessels are better known as observers, this regulation is also known as the 'Ministerial Regulation on Observers Monitoring Activities'. The aim of this regulation is to obtain objective, accurate data on fishing and fish transport from directly on board both fishing and fish-carrying vessels.

Ministry of Marine Affairs and Fisheries Regulation numbers 59/PERMEN-KP/2014, 34/PERMEN-KP/2015, 48/PERMEN-KP/2016 on the Prohibition on the Issuance of Oceanic White Tip Sharks and Hammerhead Sharks from the Territory of the Republic of Indonesia out of Indonesian Territory

In 2014, three species of hammerhead shark were included in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). In response, the Indonesian Government, through the Ministry of Marine Affairs and Fisheries (MMAF), issued a regulation prohibiting the export of all forms of hammerhead shark products and derivatives. However, the fishing of hammerheads for domestic trade and use is still allowed.

Critical habitat protection

Coral reefs, seagrass beds and mangrove forests are spawning areas for many species of fish. Currently, Indonesia has established more than 20 million hectares of marine protected areas; one of their functions is to protect spawning and nursery grounds for various types of fish, including sharks. Such habitats are considered an important part of fish resources.

Specifically, efforts have been made to protect hammerhead sharks' critical habitat (i.e. the pupping and nursery grounds). Indonesia has identified two critical habitats in Aceh and Sumbawa where juvenile hammerheads are frequently caught (Simeon et al., 2018). Protection for juveniles is currently being developed by stakeholders in these areas.

In addition to the development of marine conservation areas, several local governments in Indonesia, including the Raja Ampat Regency in West Papua Province and the West Manggarai Regency in East Nusa Tenggara Province, have issued local regulations prohibiting shark fishing in the waters under their jurisdiction. The decision by these local governments to ban shark fishing is influenced by marine tourism – sharks are one of the attractions to divers in these regions.

Public consultation

CITES CoP16 (16th meeting of the Conference of the Parties), held in Thailand in 2013, listed five shark species in CITES Appendix II; four of these species are found in Indonesian waters. The MMAF, as the authorised party in fishery management, is responsible for providing information on the management of these listed sharks to relevant stakeholders such as fishers, traders, quarantine officers, supervisory officers and regional governments. In 2013, public consultations involving fishers were conducted in several locations (Aceh, Sibolga, Tanjung Luar, Jakarta) on the provisions of CITES Appendix II concerning international trade in hammerhead sharks and the issue of look-alike species. Public consultations specifically aimed at exporters were conducted only in Surabaya, East Java. Following CITES CoP17 in 2016, public consultations on policies for management of the development of sharks and rays were held in 2017 in Aceh, Jakarta, Cilacap, Banyuwangi, Surabaya, Denpasar, Nusa Tenggara Barat (NTB), Pontianak, Makassar and Sorong.

Catch quota (total allowable catch)

Defining a catch quota (total allowable catch, TAC) was one of the mandatory regulations recommended by CITES non-detriment findings in 2018, when the quota was released by the National Management Authority of CITES. The catch quota is specified by size and applies only to adult Scalloped Hammerhead Shark.

Total allowable effort

Tanjung Luar is one of the biggest traditional fishing villages in Indonesia. Fishers depend greatly on sharks, which they have been catching since before the 1940s (Lestari et al., 2017). However, following decades of high fishing pressure, some sharks, including hammerheads, are being over-exploited (Simeon et al., 2017; White et al., 2012). To decrease fishing pressure on sharks, the provincial government and shark fishers developed a local agreement on shark fishing rules. They agreed to limit the number of hooks on shark longlines, the number of fishing days each year, and the number of boats in operation each year (Shark Working Group, pers. comm., July 2019).

5.3.2. Future management options

The current management practices and codes of conduct are comprehensive, but not all measures have been implemented, and not all practices are followed. Compliance of fishers with these management measures needs to be better, and more effectively monitored.

5.4. Data sources

Data for this study were supplied by:

- Ministry of Marine Affairs and Fisheries
- West Nusa Tenggara Provincial Working Group for Shark and Ray
- Indonesia hammerhead non-detriments findings (S. Oktaviyani, pers. comm., 2020)
- Australian Centre for International Agricultural Research project on illegal, unregulated and unreported fishing (White et al., 2012)

5.5. Management planning for *Sphyrna lewini* in MERA

The Method Evaluation and Risk Assessment (MERA) application (available at https://www.merafish.org) was used to evaluate the potential effectiveness of different management approaches for *S. lewini* fisheries in Indonesia. An operating model of *S. lewini* fisheries was developed by populating the MERA questionnaire based on the information presented previously in this section.

The management planning mode was used to evaluate the effectiveness of 20 management options, including an annual total allowable catch (TAC), an annual total allowable effort (TAE) limit, spatial closures (spatial), and regulations defining the size of sharks that could be retained (SL) (Table 5.4; full details for each of the management procedures are available at https://dlmtool.github.io/DLMtool/reference/index.html).

Table 5.4 shows the results of the management planning evaluation in MERA, including four performance metrics:

- a limit reference point: probability that the spawning biomass is greater than 0.5 B_{MSY}*
- a target reference point: probability that the spawning biomass is greater than B_{MSY}
- the average yield (relative to MSY) in the first 10 years of the projection period
- the average yield (relative to MSY) in the last 10 years of the projection period

A two-step process was used to filter the 20 candidate management procedures and to identify the management approach best suited to the fishery. First, management procedures that had at least a 70% probability of meeting the limit reference point of biomass B >0.5 B_{MSY} were identified. Those management procedures returning values below this probability were considered unacceptable; the risk of stock biomass declining to unacceptably low levels was greater than the acceptable risk threshold.

Four procedures had a higher probability than B >50% B_{MSY} and yielded relatively high values for long-term yield: (1) *F*-ratio (F_{MSY}/M = ratio of fishing mortality at MSY to natural mortality), (2) depletion-based stock reduction analysis (DBSRA), (3) DBSRA_40 (DBSRA that assumes the current stock biomass is 40% of unfished levels), and (4) depletion corrected average catch (DCAC) (Table 5.4). All these management procedures are based on TAC as the preferred management approach.

The second step was to evaluate management procedures that had a high probability for long-term yield; two of these were identified: (1) size limit management procedures, in which fishing retention-at-length is set 10% higher than the length-at-maturity (matlenlim2), with a probability of 89%, and (2) spatial control that prevents fishing in area 1 and does not reallocate this fishing effort to area 2 (MRnoreal), with a probability of 87%. However, the values for probability of B >50% B_{MSY} were relatively low: 58% and 60%, respectively. The remaining 14 management procedures were then ordered by the average short-term and long-term yield; the four management procedures with highest yield from each of the management classes were identified: (1) mean catch depletion (MCD – a TAC), (2) *F*-ratio (ratio of F_{MSY}/M), (3) ITe10 (effort control with maximum of 10% annual change in effort – a TAE), and (4) MRreal (spatial – marine reserve with reallocation of effort to areas outside the reserve). MRreal had the highest probability value for long-term yield (Figure 5.4).

Some of the models predicted significantly increased abundance in the short term, but decreased abundance in the long term. The worst management models were DBSRA_40 and matlenlim2. MERA also showed biomass projections for the next 50 years, assuming that management is implemented effectively. The four best models predicted increased probabilities of higher biomass (Figure 5.4).

Two models that did not use total allowable catch as a management procedure, *F*-ratio and the mean catch depletion (MCD), gave different projections for biomass. MCD had a higher value for short-term yield and would be chosen over *F*-ratio. The results from the *F*-ratio management procedure predicted decreased probabilities of higher biomass in the first decade of management, which continued until the fifth decade. The other three management models – MRreal, ITe10 and MCD – had better biomass projections, with nil probability of stock depletion. Hence, the recommended management procedures from the analysis are (1) total allowable catch based on MCD, (2) spatial management of fishery based on MRreal, and (3) total allowable effort based on ITe10. The recommended TAC is known as 'catch quota' in Indonesia. The spatial fishery procedure recommended is protection of several critical habitats for Scalloped Hammerhead (e.g. nursery grounds, mating grounds and pupping grounds). The TAE recommended is effort limitation in Tanjung Luar, the largest targeted shark fishing village in Indonesia.

The three management procedures recommended above may be feasible to implement in Indonesia. A catch quota is possible for hammerhead sharks because they are listed in CITES Appendix II and the Indonesian Government is considering implementing quotas for them. However, if catches exceed quotas, enforcement would likely be challenging. Spatial management can be applied only in marine protected areas or certain marine management areas. However, hammerhead sharks also use areas outside these protected/managed areas, where they are vulnerable to fishing. The third option, TAE –

limiting fishing pressure by limiting the number of hooks on shark longlines, the number of days each boat spends fishing each year, and the number of fishing boats that operate in a year – could be implemented with support from the fishing port authority and is already being used to some extent in Tanjung Luar.

Based on this analysis, we recommend the ITe10 management procedure of TAE as the best candidate for managing the *S. lewini* fishery; it has the highest probability of being implemented effectively and meeting management objectives. It also has a low risk of stock declining to low levels. For implementation in the fishery, this management approach requires establishing (i) an accurate database for number of existing boats, (ii) agreeing on fishing rules to limit effort, and (iii) implementing mechanisms such as good enforcement and education programs to ensure compliance.

Note that these measures need to be implemented in all Indonesian waters because of the wide geographic distribution of *S. lewini* and their capture in a number of fisheries areas. The current management of shark fishing at Tanjung Luar and the ITe10 management procedure share some similarities. Currently, however, implementation is weak in several areas outside Tanjung Luar. Scalloped Hammerhead Sharks are caught and landed in many areas in Indonesia and are a valuable fishery commodity in many fisher communities. We believe that these fisheries management procedures can be implemented with the support of stakeholders, including local government, fishers and the local community.

Table 5.4. Summary of results from the Method Evaluation and Risk Assessment (MERA) analysis of Scalloped Hammerhead Shark populations in eastern Indonesia

Management procedure	Regulation type	Prob. $B > 0.5\,B_{MSY}$	Prob. $B > B_{MSY}$	Short-term Yield	Long-term yield
MCD	TAC	0.85	0.47	0.39	0.61
*F*ratio	TAC	0.76	0.45	0.35	0.43
DBSRA	TAC	0.79	0.38	0.33	0.68
MRreal	Spatial	0.88	0.48	0.31	0.79
ITe10	TAE	0.92	0.6	0.26	0.62
HDAAC	TAC	0.88	0.49	0.24	0.69
MRnoreal	TAC	0.93	0.61	0.21	0.62
DCAC_40	TAC	0.34	0.2	0.9	0.47
DCAC	TAC	0.38	0.19	0.77	0.6
matlenlim	SL	0.88	0.48	0.19	0.51
DD4010	TAC	0.52	0.18	0.88	0.55
matlenlim2	SL	0.88	0.48	0.17	0.46
IT5	TAC	0.94	0.7	0.17	0.16
IT10	TAC	0.94	0.7	0.16	0.15
DBSRA_40	TAC	0.22	0.13	1	0.38
DBSRA4010	TAC	0.91	0.49	0.13	0.67
DD	TAC	0.37	0.13	1	0.52
MCD4010	TAC	0.97	0.56	0.09	0.58
DDe75	TAE	0.11	0.02	0.96	0.44
DDe	TAE	0.05	0	1.1	0.35

Blue shading = four options with highest likelihood of maintaining long-term catches and maintaining yield. MCD = mean catch depletion; *F*-ratio = ratio of F_{MSY}/M; MRreal = marine reserves with reallocation of fishing effort outside the reserve; ITe10 = total allowable effort with a maximum change in effort of 10% annually. TAC = total allowable catch; Spacial = spacial closure; TAE = total allowable effort; SL = size limit.

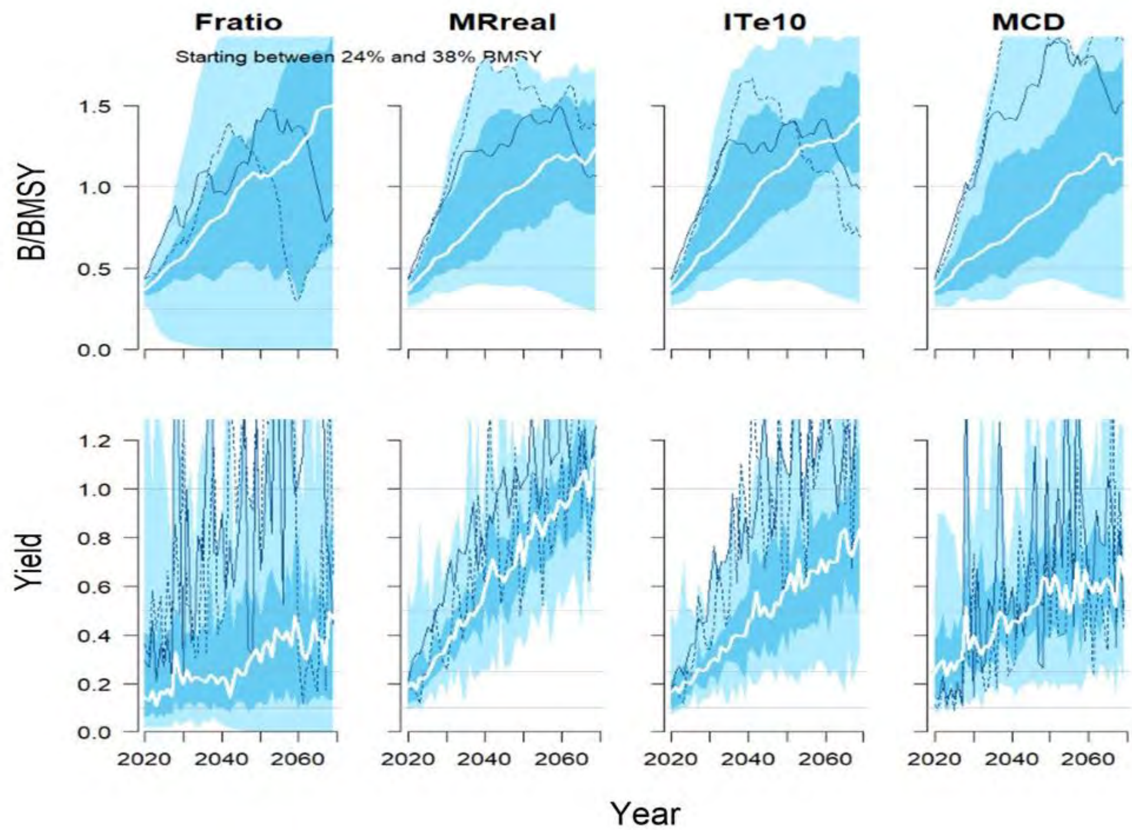

Figure 5.4. Simulated performance of four management planning options with probability of $B > B_{MSY}$ for Scalloped Hammerhead Shark (*Sphyrna lewini*) in eastern Indonesia. The shaded regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5 and 1. *F*-ratio = F_{MSY}/M; MRreal = marine reserves with reallocation of fishing effort outside the reserve; ITe10 = total allowable effort with a maximum change in effort of 10% annually; MCD = mean catch depletion.

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6. Fisheries management for the Redbelly Yellowtail Fusilier (*Caesio cuning*) in the waters of the Karimunjawa Islands, central Java Sea, Indonesia

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Caesio cuning, the Redbelly Yellowtail Fusilier (English), or *Ekor Kuning* (Bahasa Indonesia) (Image: australianmuseum.net.au)

Summary

The Redbelly Yellowtail Fusilier (*Caesio cuning*) is a member of the Caesionidae and is one of the main species targeted by fishers in the Karimunjawa Islands in the central Java Sea. Redbelly Yellowtail Fusilier (RBYF) form schools in the water column and are often found in areas with coral reefs. In Karimunjawa today, this species is fished mainly using spearguns, although, in the early 2000s, *muroami* – a destructive circular netting and

scaring technique – was the main fishing method. Spearguns are used with and without surface-supplied air via a hookah compressor. The hookah compressor allows fishers to dive deeper and for longer. It also allows fishers to catch a diverse range of species to meet their targeted yield and selling price. Consequently, fish are caught in large numbers and without regard to size.

In terms of species composition, an evaluation of extensive data from landings surveys from 2009 to 2017 suggested that RBYF comprise 46% of total fish caught in the waters of the Karimunjawa Islands. However, 43% of the landed RBYF were below the size at 50% maturity and the estimated spawning potential ratio (SPR) of 19% is low (SPR <20%). This indicates that the exploitation rate of RBYF in Karimunjawa is high and is an example of growth overfishing, when the catch is dominated by immature fish. Currently, there is no defined fisheries management policy or harvest strategy for RBYF in the Karimunjawa region, at either local or central government level. Thus, management is needed to overcome existing problems and to sustain the fishery into the future.

The Method Evaluation and Risk Assessment (MERA) tool was used to evaluate management options for the fishery. This approach synthesises all current information on the biology, fishery and management of a fishery to evaluate policy strategies for the fishery, building in uncertainty in the projections. The five best management procedures selected, based on their probability score and feasibility of implementation, were two size-based measures (Matlenlim and Matlenlim2 – setting a size limit equivalent to the size at 50% maturity, or a limit 10% greater than this size, respectively), total allowable effort (ITe10 – setting total allowable effort [TAE] with a maximum change of 10% annually), and two spatial closures (MRnoreal and MRreal – spatial closure with either no reallocation or reallocation of fishing effort outside the closure). The management procedures with the highest yield for the short and long term were total allowable effort (ITe10), size limit (Matlenlim and Matlenlim2), and spatial management (MRreal and MRnoreal). These three procedures also had a high probability of maintaining the biomass in the population above 0.5 of the biomass at maximum sustainable yield. These management procedures (size limit, TAE, and spatial closure) could be effective in the Karimunjawa islands because of (a) sufficient available data, including a commitment from the WCS-IP (Wildlife Conservation Society – Indonesia Program) to continue monitoring catches (species composition and size distribution); (b) strong compliance from local fishers; and (c) strong enforcement by the national park authority of the zoning regulations. Nevertheless, the WCS-IP should work with both local government (provincial fisheries authority) and the national park authority to encourage the allocation of funding and human resources for catch monitoring.

Ringkasan

Ikan ekor kuning (*Caesio cuning*) termasuk salah satu spesies dari family Caesionodae dan merupakan salah satu spesies target utama tangkapan nelauan di Karimunjawa, Laut Jawa, Jawa Tengah. Gerombolan ikan ekor kuning sering ditemukan di terumbu karang. Di KArimunjawa, ikan ekor kuning dominan ditangkap menggunakan panah, meskipun pada awal tahun 2000an penangkapan ikan ekor kuning dominan menggunakan alat

tangkap muroami. Panah dioperasikan dengan dan tanpa kompresor atau hookah. Penggunaan hookah memungkinkan nelayan menyelam lebih lama dan dalam dari biasanya. Keuntungan lainnya adalah memungkinkan nelayan menangkap beragan jenis untuk meningkatan hasil tangkapan dan harga jual ikan target. Sehingga hasil tangkapan lebih banyak tanpa memperhatikan ukuran ikan yang ditangkap.

Komposisi hasil tangkapan berdasarkan evaluasi pendaratan ikan di Karimunjawa pada tahun 2009–2017, ikan ekor kuning menyimbang 46% dari total tangkapan ikan di Kepulauan Karimunjawa. Namun, 43% dari hasil tangkapan ikan ekor kuning merupakan ikan kecil dan diduga belum mengalami matang gonad dengan nilai SPR sebesar 19% (SPR<20%). Hal ini menunjukkan tingkat eksploitasi ekor kuning di Karimunjawa cukup tinggi sehingga terindikasi mengalami overfishing pertumbuhan, dengan hasil tangkapan didominasi oleh ikan ukuran kecil atau immature. Saat ini, belum ada strategi pengelolaan atau penangkapan ikan untuk perikanan ekor kuning di Karimunjawa oleh pemerintah daerah maupun pusat. Oleh karena itu, pengelolaan perikanan ekor kuning diperlukan untuk mengatasi permasalahan perikanan di masa depan.

Method Evaluation and Risk Assessment (MERA) merupakan metode untuk evaluasi berbagai pilihan pengelolaan perikanan. Metode ini mencakup informasi biologi, perikanan dan pengelolaan untuk mengevaluasi berbagai strategi kebijakan perikanan dan membangun model proyeksi ketidakpastiannya. Prosedur pengelolaan perikanan dalam urutan lima teratas berdasarkan skor dari pobabilitas dan kelayakan adalah pengaturan ukuran penangkapan (Matlenlim dan Matlenlim2 – ukuran penangkapan pada panjang 50% ikan matang gonad (L_M) dan sedikit lebih besar dari ukuran Lm); pengaturan upaya penangkapan (ITe10 – menetapkan upaya penangkapan yang diperbolehkan atau TAE dengan perubahan maksimum 10% per tahun); dan penutupan area penangkapan secara spatial (MRnoreal dan MRreal – penutupan dengan relokasi daerah penangkapan dan penutupan dengan relokasi daerah pennagkapan diluar kawasan konservasi). Pilihan prosedur pengelolaan dengan probabilitas tertinggi untuk jangka pendek dan jangka panjang adalah upaya penangkapan yang diperbolehkan (ITe10), pengaturan ukuran penangkapan (Malenlim dan Matlenlim2), dan penutupan spasial (MRreal dan MRnoreal). Ketiga prosedur pengelolaan ini memiliki probablilitas atau peluang keberhasilan tertinggi untuk mempetahankan biomassa pada level 0.5 MSY. Prosedur pengellaan ni (ukuran tangkap, TAE, dan penutupan spasial) efektif dilakukan di Karimunjawa dikarenakan: (a) tersedia data dan informasi perikanan salah satunya adalah komitmen WCS-IP dalam pendataan hasil tangkapan ikan (komposisi spesies dan distribusi ukuran); (b) kepatuhan nelayan local yang kuat, dan (c) penegakan aturan yang kuat dari otoritas Taman Nasional berkaitan dengan pengaturan zonasi. Namun demikian, WCS-IP juga bekerja sama dengan pemeritan daerah (otoritas perikanan di tingkat provinsi) dan otoritas taman nasional untuk mendorong alokasi dana dan sumberdaya manusia dalam pendataan perikanan.

6.1. Biology

6.1.1. Taxonomy

Scientific name: *Caesio cuning* (Caesionidae)

Common names: Redbelly Yellowtail Fusilier (English) and *Ekor Kuning* (Bahasa Indonesia)

6.1.2. Key identifying features

The body of the Redbelly Yellowtail Fusilier (RBYF) is deep and is a greyish-blue; the undersides of the body and head are pinkish with yellow markings. The caudal fin and fin on the upper back are yellow (White at al., 2013). The caudal fin is forked. Pectoral, pelvic, and anal fins are coloured white to pink. The dorsal fin is yellow posteriorly and greyish-blue anteriorly (Carpenter, 1988). Scales are lighter in the centre than at the margins; those on the lower one-third are white, sometimes suffused with pink. There are no prominent black markings on the caudal fin. *C. cuning* is distinguished from *C. teres* by a continuous supra-temporal band of scales across the dorsal midline. The maximum recorded length of RBYF is 600 mm standard length (FishBase, 2020), but mostly the maximum length seen is 350 mm (Kuiter and Tonozuka, 2001).

6.1.3. Distribution

Worldwide: RBYF inhabit tropical marine waters of the Indo-West Pacific from Sri Lanka, throughout Southeast Asia and Micronesia, north to Japan, south to Australia and east to Vanuatu (Carpenter, 1988). The species is widely distributed throughout tropical waters from the Red Sea into the Indian Ocean (excluding the Persian Gulf) and into the western Pacific Ocean.

Indonesia: RBYF are distributed throughout Indonesian waters from southwest Sumatra to the Timor Sea and the Mentawai Islands. The species is also recorded from the Raja Ampat Islands, Manado and surrounding areas, Sangalaki Island in East Kalimantan, the Togean Islands and Banggai.

6.1.4. Maximum length, weight and age

The maximum total length reported globally is 600 mm unsexed (FishBase, 2020). In Karimunjawa waters, the maximum total length recorded is 590 mm (Agustina et al., 2018), with a maximum weight of 2.4 kg. The maximum age in these waters is not known but is probably about 10 years.

6.1.5. Weight-length relationship

The power exponent of the weight-length relationship of RBYF from four regions of Indonesia ranges from 3.03 (Papua New Guinea) to 3.13 (Natuna); for fish from Karimunjawa, it is 3.11 (Table 6.1).

Table 6.1. Summary of weight-length relationships (combined sexes) of Redbelly Yellowtail Fusilier (*Caesio cuning*) in four regions of Indonesia

W-L equation	R^2	No.	Location	Reference
$W = 0.0087TL^{3.1083}$	NA	1781	Karimunjawa	Ningrum (2019)
$W = 0.008L^{3.129}$	0.204	2627	Natuna	Prihatiningsih et al. (2018)
$W = 0.0208FL^{3.0322}$	0.954	137	Papua New Guinea	Longenecker et al. (2014)
$W = 0.005L^{3.123}$	0.916	535	Seribu Islands	Zamani et al. (2011)

W = weight; TL = total length; FL = fork length; R^2 = coefficient of determination; NA = not available.

6.1.6. Growth

The growth parameters (combined sexes) of RBYF in the Karimunjawa Islands have been estimated from length-frequency analysis and ELEFAN for 1781 fish collected as part of the monitoring program of the WCS-IP (Wildlife Conservation Society – Indonesia Program) in the region (Ningrum, 2019): asymptotic length (L_∞), 407 mm; instantaneous growth rate (k), 0.32 year^{-1}; and estimated age at 0 length (t_0), –0.48. The large estimated t_0 *of* –0.48 indicates that this growth curve does not provide reliable estimates for small fish; smaller, younger fish should be incorporated in the growth analysis.

6.1.7. Length and age at maturity

The estimated sizes at 50% and 95% maturity from 12 months of length data collected in 2018–19 in the Karimunjawa Islands (1149 fish, combined sexes) were 233 mm and 283 mm, respectively (Ningrum, 2019).

6.1.8. Summary of life history, habitats and movement

The species of this genus inhabit coastal areas of the Indo-West Pacific, primarily on coral reefs. They are schooling fish, often found in mixed schools with other *Caesio* species. They feed on zooplankton in midwater aggregations (Carpenter, 1988). *C. cuning* is the most ancestral of the living caesionid species (Allen and Erdmann, 2012).

RBYF inhabit coastal areas, usually associated with coral reefs, mid-water in deep lagoons and close to external reefs in depths from the surface to 50 m. The species is often found in silty, shallow waters (<30 m) with low visibility, which it tolerates more than other species of caesionids, and is the most abundant caesionid in reef areas characterised by turbid, low-visibility waters. RBYF are not known to migrate but also live in rocky areas and sandy areas with mangroves (Barnes et al., 2012).

Juveniles and adults feed on unspecified zooplankton and invertebrates (Fishbase, 2020), but there is little information on their feeding and diet. FishBase categorises them as planktivores.

From what is known of the few *Caesio* species studied, reproduction is characterised by early sexual maturity, high fecundity, small pelagic eggs, spawning prolonged throughout most of the year, and mass spawning on a lunar cycle (Carpenter, 1988). *C. cuning* has two sexes and external broadcast fertilisation. The numerous eggs are small, spherical and buoyant (i.e. they are found in the surface waters) (Carpenter, 1988).

In Karimunjawa waters, the female gonads of *C. cuning* have been staged macroscopically: Stage I – gonads are clear, fork length 150–170 mm; Stage II – gonads are yellowish-orange, egg grains not visible, fork length 175–195 mm; Stage III – gonads are yellowish-white, eggs visible, fork length 196–216 mm; Stage IV – gonads are clear yellow, eggs expelled with little pressure, fork length 225–235 mm. In January and February, most fish are at stages I and II (immature fish) (Pratiwi, 2017); in March and April most fish are maturing or mature (stages III and IV) (Darmawan, 2018).

RBYF eggs are scattered in the water column. The larvae are found near coral reefs, juvenile fish form schools in the neritic waters, and adult fish school in deeper waters (Ackiss et al., 2013). The species forms schooling, spawning aggregations outside the reefs; as adults they are very active (Ackiss et al., 2013). The growth of RBYF is isometric (Indarsyah et al., 2010). The RBYF in Karimunjawa mainly spawn at three times of the year: June–July, October–November, and February–March (Susilo et al., 2008). Reproduction is thought to be influenced by several factors, one of which is the change in season from the rainy to the dry season of the eastern monsoon (Susilo et al., 2008).

6.2. Fishery

6.2.1. Description of the fishery

The Karimunjawa Islands are located 45 nautical miles (~83 km) northwest of Jepara City, central Java. Administratively, this area is one of the subdistricts in the Jepara Regency, Central Java Province (National Park Management Body of Karimunjawa). Of the 27 islands, five are inhabited: Karimunjawa Island, Kemujan Island, Parang Island, Nyamuk Island and Genting Island (Figure 6.1). Karimunjawa is a district with 3 villages: Karimunjawa Village, Kemujan Village and Parang Village. On 29 February 1988, Karimunjawa was established as a Marine National Park through the Minister of Forestry Letter No.161/Menhut-II/1988, which was confirmed through the Minister of Forestry Decree No.185/Kpts-II/1997, dated 31 March 1997. The park is 111,625 ha, consisting of 1285.5 ha of land on Karimunjawa Island, 222.2 ha on Kemujan Island and 110,117.3 ha of the surrounding waters (Figure 6.1). Based on the Decree of the Minister of Forestry No.74/Kpts-II/2001, the 110,117.3 ha of waters around the islands were designated as Water Nature Conservation Areas (Syaifudin, 2012)

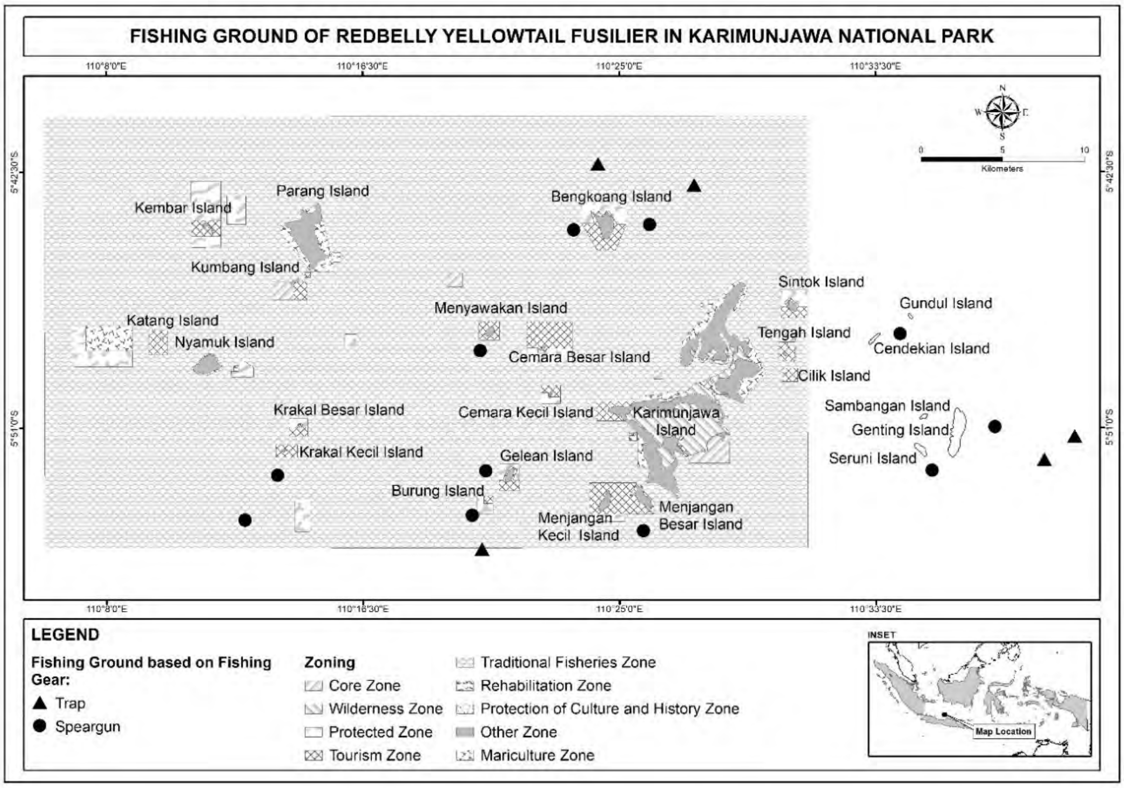

Figure 6.1. Fishing grounds of Redbelly Yellowtail Fusilier (*Caesio cuning*) in the Karimunjawa Islands, central Java Sea, Indonesia (Source: Agustina et al., 2018).

The rainy season (western monsoon season) occurs between November and March with rainfall of more than 200 mm per month and strong winds with large waves. The rainy season is followed by a transition season, which usually occurs between April and May, when the winds are lighter (4–10 knots) and more from the west and east (Syaifudin, 2012).

Historically, RBYF were caught with *muroami* fishing gear. The *muroami* is a weighted encircling net set in coral reef areas; fishers drive fish toward the net using rope and sticks to produce sound (Figure 6.2). This fishing gear was banned in 2011 because of the damage it caused to the coral reefs when the fishers walked and hit the coral with the sticks. After the ban, fishers started using spearguns (Figure 6.3), but this method has since declined due to the ban on using surface-supplied compressed air (hookah) with spearguns (Wiyono and Kartawijaya, 2012). In 2018, 200 speargun fishers fished in Karimunjawa waters, with or without hookahs (Figure 6.3). Fishers using hookahs can fish at depths of 25–30 m; without hookahs, fishers can reach depths of only 1–3 m (Mubarok et al., 2012). The total catch of fishers with hookahs can be three times that of other fishers. However, both groups catch a similar size range of RBYF. The government has banned the use of hookahs in Karimunjawa because the health risks are too high.

Figure 6.2. A *muroami* net set on a coral reef in the Karimunjawa Islands, central Java Sea, Indonesia (left). A fisher walking on the reef to drive fish toward the net (right) (Images: Wildlife Conservation Society – Indonesia Program).

The vessels used by fishers to catch RBYF are traditional wooden boats (Figure 6.3), ranging from 0.5 to 3 GT (Darmawan, 2018), which are classed as small scale (<5 GT before 2016; now <10 GT fishing vessels; Halim et al., 2019). Fishers do not pay license fees and are not required to report their catch at landing centres. Fishers travel only 2–5 nautical miles from their base to the fishing grounds. They do not land at the official landing and fish auction site (*Tempat Pelelangan Ikan*) in Karimunjawa because it is situated far from where the boats are moored and the prices offered there are relatively low. Instead, the catch is brought to collectors who are close to the mooring locations and buy fish at market prices. Fishers retain all their catch as they catch only fish with high selling prices (Ningrum, 2019). Collectors resell fish to locations outside Karimunjawa Islands, such as Jepara or Semarang on mainland Java.

Figure 6.3. Spearguns (above left), air compressor (hookah) (above right) and fishing boat (bottom) used to fish for Redbelly Yellowtail Fusilier (*Caesio cuning*) in Karimunjawa Islands, central Java Sea, Indonesia (Images: Ningrum, 2019).

The main fishing gear aids are compressors, waterproof flashlights and diving masks. Some other aids to support fishing operations are gloves, coral boots, wet suits (clothes to prevent loss of body heat) and weights. Speargun fishing occurs mostly during the night from about 3 pm to 4 am. Speargun fishers complete 2–3 dives for a total dive time of 60–180 min in a day's fishing trip. The depth of the dives is 2–30 m. RBYF is the main species caught, but squid, grouper, snapper and rabbit fish are also caught (Agustina et al., 2018).

Trap-fishing gear, known as *bubu*, is an alternative fishing gear for catching *Caesio*. It is made of net or bamboo and has one or two entrances (Baskoro and Yusfiandayani, 2015) (Figure 6.4). The bamboo *bubu* are 1.75 m long, 1.35 m wide and 0.5 m high. *Bubu* are placed in coral-reef waters; each end of the trap is weighted so that the *bubu* does not overturn when it is lowered to the bottom. *Bubu* are set in selected areas using the fish finder tool and a global positioning system (GPS). The location of the *bubu* is marked with a surface buoy. The *bubu* are hauled using a line hauler two or three days after setting. Hauling takes about 15–20 minutes per *bubu*. The dominant catches with *bubu* are red snapper (*Lutjanus lemniscatus*), rubber grouper (*Epinephelus ongus*), *baronang* (*Siganus javus*), RBYF (*Caesio cuning*) and *abangan* (*Lutjanus malabaricus*) (Darmawan, 2018).

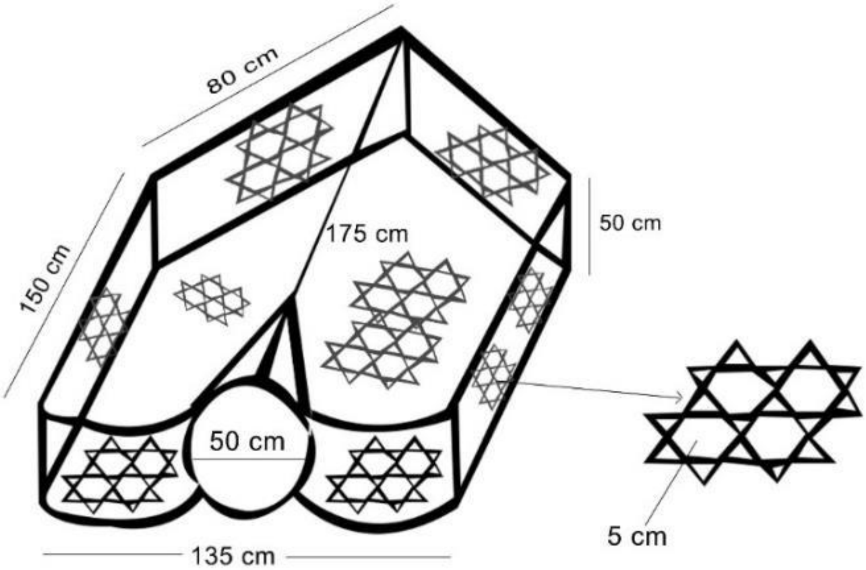

Figure 6.4. Trap fishing gear (*bubu*) operated in Karimunjawa Islands, central Java Sea, Indonesia (Source: Darmawan, 2018).

Four main seasons are recognised in this region: the western monsoon (December, January, February), the first transitional season (March, April, May), the eastern monsoon (June, July, August) and the second transitional season (September, October, November) (Realino et al., 2006). From interviews with fishers, RBYF fishing occurs throughout the year. According to Yuliana et al. (2016), catches of RBYF are relatively uniform throughout the year, but the main fishing times are February to May and September to October.

Around the islands of Menjangan Kecil, Menjangan Besar, Gelean, Cemara Besarm Taka Burung, Krakul Kecil, Menyawakan, Sambangan and Seruni, RBYF are fished with spearguns. Around the islands of Bengkoang, Genting, Burung, North Karimunjawa and South Karimunjawa, they are fished with *bubu* (see Figure 6.1).

6.2.2. Stock depletion and resilience

The SPR for RBYF in Karimunjawa waters, estimated from the length-based spawning potential ratio (LBSPR), is 19% (Table 6.2), which is less than the SPR limit of 20% (Hordyk et al., 2015). This indicates that the stock has been overexploited in the Karimunjawa Islands and efforts to increase the SPR should be initiated.

Table 6.2. Growth and mortality parameters for Redbelly Yellowtail Fusilier (*Caesio cuning*) in the Karimunjawa Islands, central Java Sea, Indonesia

Growth parameter			Mortality			L_m (mm)	L_{max} (mm)	SPR (%)
L_∞ (mm)	k (/year)	t_0 (year)	M (/year)	F (/year)	E			
407	0.32	–0.48	0.66	1.23	0.65	233	590	19

L_∞ = asymptotic length; k = instantaneous growth rate; t_0 = estimated age at 0 length; M = natural mortality; F = fishing mortality; E = exploitation rate; L_M = length at 50% maturity; L_{max} = maximum recorded total length; SPR = spawning potential ratio. (Source: Ningrum, 2019)

6.2.3. Fishing effort: history, variability and changes in fishing efficiency

Data from the WCS-IP show that catch per unit effort (CPUE) of RBYF fluctuated between 37.9 kg/trip and 51.4 kg/trip from 2013 to 2017 (Figure 6.5). Pardede et al. (2016) found fish abundance in Karimunjawa National Park in 2016 was lower than that in 2012. They suggested this might be due to a deterioration in the condition of the coral reefs caused by damaging fishing practices, or to coral bleaching caused by a rise in temperature.

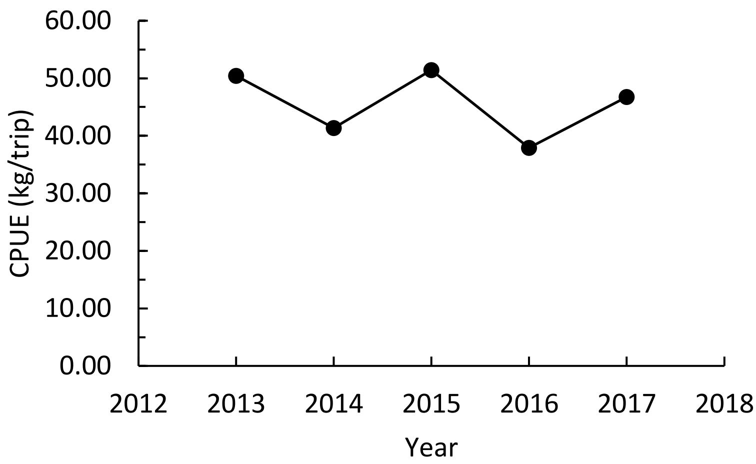

Figure 6.5. Catch per unit effort (CPUE) for Redbelly Yellowtail Fusilier (*Caesio cuning*) in the waters of the Karimunjawa Islands, central Java Sea, Indonesia, from 2013 to 2017. (Data provided by Wildlife Conservation Society – Indonesia Program)

6.2.4. Selectivity of fishing methods and discard rates

Three kinds of fishing gear are used to catch RBYF in Karimunjawa waters: spearguns (64.9% of catch), fish traps (25.8%) and handlines (<9.3%) (Pratiwi, 2017). The selectivity of the speargun fishing gear depends on the fisher; that of the traps is determined by the size of the trap entrance. The average size of fish caught by the traps is larger than those caught by spearguns because juvenile fish can escape from the traps. No fish species are released or discarded because all the fish have high economic value and can be sold by fishers or retained by local residents.

The estimated size at 50% selectivity (SL_{50}) of RBYF caught by all methods is 208 mm (Figure 6.6), which is 25 mm smaller than the estimated size at 50% maturity (L_{50} =

233 mm) (Figure 6.6). These results indicate that the average fish caught is immature ($SL_{50} < L_M$) and raises concerns about the sustainability of the fishery.

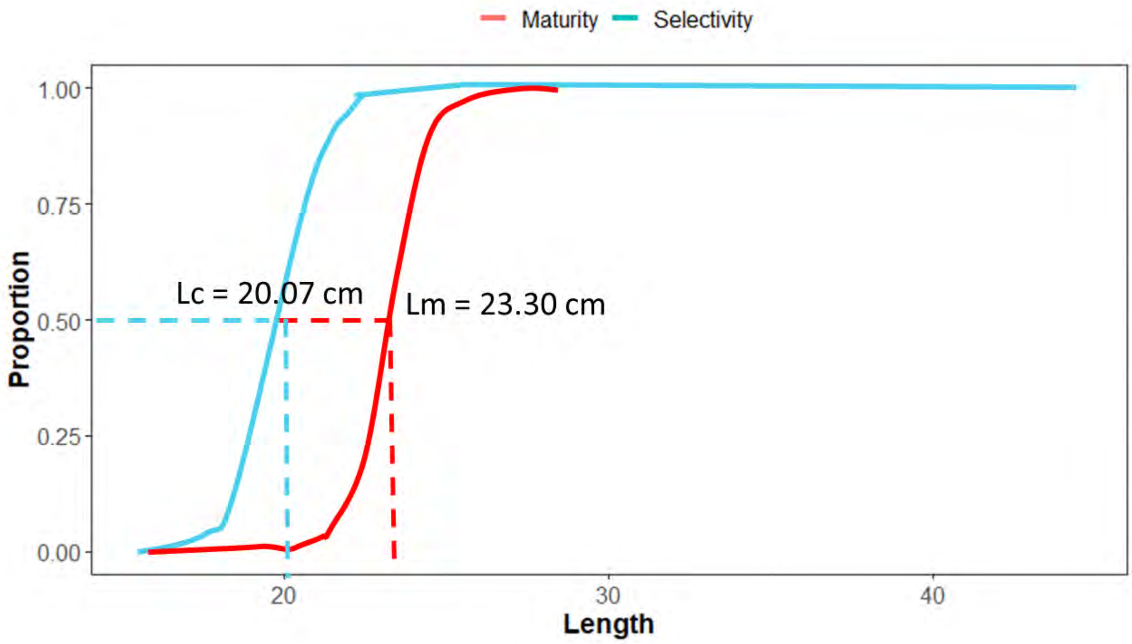

Figure 6.6. Selectivity and maturity curves estimated with the length-based spawning potential ratio (LBSPR) methodology for Redbelly Yellowtail Fusilier (*Caesio cuning*) in Karimunjawa waters, central Java Sea, Indonesia. Length = total length (mm); L_m = length at 50% maturity; L_c = length at 50% selectivity or capture (i.e. equivalent to SL_{50}). (Data provided by Wildlife Conservation Society – Indonesia Program)

The length–frequency distribution of RBYF estimated from WCS-IP data approximates a normal distribution, weighted slightly to the left, which shows that about 51% of fish were caught before they had reached L_M. Of the 1781 fish caught, 912 were below the L_M of 233 mm total length (Figure 6.7). Most of the fish caught measured 210–250 mm.

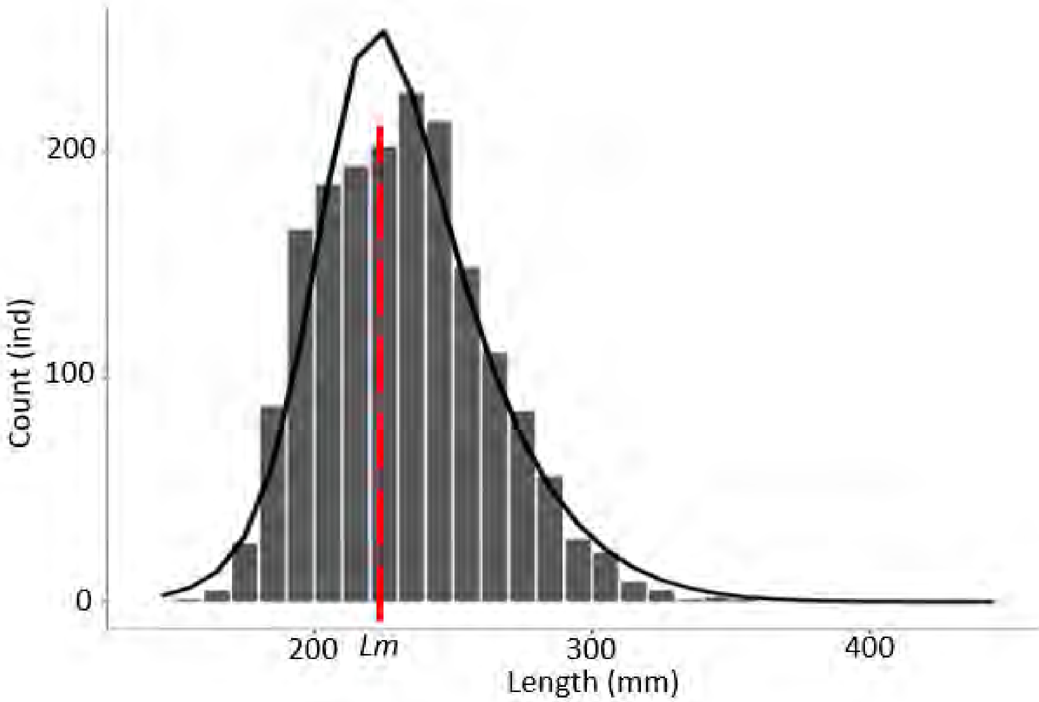

Figure 6.7. Length–frequency distribution of Redbelly Yellowtail Fusilier (*Caesio cuning*) caught in Karimunjawa waters, central Java Sea, Indonesia. *Lm* = length at 50% maturity. (Data provided by the Wildlife Conservation Society – Indonesia Program)

6.3. Management regulations

6.3.1. Current management

Fishing regulations for RBYF are not specified explicitly under government regulations. However, the use of compressor aids is banned under Law No. 45 of 2009 concerning fishing apparatus, because it can cause growth overfishing. Moreover, compressor use can damage the health of fishermen and can cause sudden death. However, the regulation has not been implemented effectively because of the lack of fisheries supervisory officers who oversee fishing activities in the Karimunjawa Islands region.

Karimunjawa National Park consists of nine zones: Core Zone, Wilderness Zone, Protected Zone, Tourism Zone, Traditional Fisheries Zone, Rehabilitation Zone, Protection of Culture and History Zone, Mariculture Zone, and Other Zone. This zoning system is described in Decree Number 28/IV/Set/2012 of the Director General of Forest Protection and Nature Conservation.

The current management of fishery resources is regulated by the National Park Management Body of Karimunjawa (Syaifudin, 2012), including management of reef-associated fish such as *C. cuning*. Because the estimated SPR of RBYF is low, management needs to consider how to rebuild the population. A rebuilding target (SPR >0.2) was set in discussions during the development of the fishery management plan for this species. The estimated SPR of 0.19 indicates that *C. cuning* is a fully to overexploited species in the Karimunjawa Islands (Darmawan, 2018; Ningrum, 2019;

Pratiwi, 2017). The current management procedures for this species in Karimunjawa National Park include measures to reduce the capture of small fish, spatial closures to protect the spawning stock, and limiting destructive fishing practices, including the following specific measures:

1. ***Size limit***: currently, there is no direct regulation on size limit, but some studies indicate that 208 mm is the length at 50% maturity (L50).
2. ***Spatial closures***: enforce the ban on fishing activities inside the Core zone of ~445 ha and the Protected zone of ~2560 ha in the Karimunjawa National Park (see Figure 6.1).
3. ***Destructive fishing***: enforce the ban on destructive fishing practices (e.g. blast fishing, cyanide fishing, compressor spearfishing and muroami) and avoid the use of corals as weights in trap fishing.

Destructive fishing practices and illegal fishing activities remain the main challenges for sustaining fisheries in Karimunjawa National Park because enforcement activities by the Fisheries Agency and National Park Authority are limited. Although fishing in the Core Zone and Protected Zone is not allowed, and a permit is required in the Tourism Zone (Campbell et al., 2013), weak compliance with the fishing regulations has been recorded in the national park (Campbell et al., 2012).

In 2009, the National Park Authority determined that the weak compliance in the no-take zones had caused the abundance and biomass of reef fish to decrease. Since 2010, the Park Authority has, in collaboration with international nongovernment organisations (e.g. WCS-IP), been conducting major education campaigns on the importance of no-take zones to the Karimunjawa fishery, which has increased the understanding of most of the villagers (Kartawijaya et al., 2012). However, violations of the no-take zone, especially by fishermen using handlines, were still recorded in 2011 (Syaifudin, 2012). Some evidence indicates that the fishers' self-imposed 2011 agreement to self-regulate the fishing gear is achieving its purpose. This agreement to regulate the speargun fishery in the National Park contributed to a significant increase in grouper mean biomass and stock size in 2012 (Yulianto et al., 2015). Another contributing factor to this increased biomass may be the decreasing use of Danish seines, a measure also supported by the community.

6.3.2. Future management options

To protect and sustain the fish resources in the region, management needs to implement measures to regulate fishing practices in the parks, in particular, to increase the SPR of *C. cuning*. The following measures may be considered:

1. Limit the allowed catch capacity.
2. Prohibit catching fish under the size at 50% maturity (i.e. <233 mm total length).
3. Prohibit catching fish during the spawning season.
4. Enforce the ban on the use of surface-supply air compressors with speargun fishing.
5. Increase surveillance and enforcement activities in the zones of the marine protected area.

6.4. Data sources

The data sources used to summarise the information on *C. cuning* comprised:

- Bachelor and Masters theses completed at IPB University in 2018–19
- WCS-IP papers and reports for the Karimunjawa field site from 2013 to 2018
- Information from *Balai Taman National Karimunjawa* (National Park Body).

6.5. Management Planning in MERA

We applied the Method Evaluation and Risk Assessment (MERA) approach developed by Carruthers and Hordyk (Blue Matter Science, Canada) (Carruthers and Hordyk, 2019; Hordyk and Carruthers, 2018) to management planning for the RBYF fishery. Questions in the Data Limited Toolkit (DLM tool, merafish.org) were answered based on the current data and information gathered from related references (see Appendix 6.1). In addition to the literature, expert judgment was used in the MERA analyses.

Potential fisheries management approaches for managing RBYF fishing in the Karimunjawa Islands are limiting catch and effort through implementing size limits, and limiting effort and strengthening compliance in the Core Zone (no-take area) of the national park. Based on the management performances of the best 20 management procedures (MPs) determined from the MERA analyses, five MPs were selected based on their probability score and feasibility of implementation: Matlenlim and Matlenlim2 – setting a size limit equivalent to the size at 50% maturity, and setting a limit slightly greater than this size; ITe10 – setting total allowable effort (TAE) with a maximum change of 10% annually; and MRnoreal and MRreal – spatial closure with no reallocation or with reallocation of fishing effort outside the closure (Table 6.3). The main findings from the MERA analyses for managing *C. cuning* in the Karimunjawa Islands based on the probability scores for stock biomass (long-term sustainability, i.e. prob. B >0.5 maximum sustainable yield [MSY] and prob. B > MSY) and yield (fishery performance) (Table 6.3, Figure 6.8) are summarised below.

1. The management procedures with the highest yield for the short and long term were total allowable effort (ITe10), size limit (Matlenlim and Matlenlim2), and spatial management (MRreal and MRnoreal). These three procedures also had a high probability of maintaining the biomass in the population above 0.5 MSY.
2. The selected management procedures (size limit, TAE, and spatial closure) are potentially effective for the Karimunjawa Islands fishery based on these considerations: (a) sufficient data are available, including a commitment from WCS-IP to continue monitoring catches (species composition and size distribution), (b) strong compliance from local fishers, and (c) strong enforcement by the National Park Authority of the zoning regulations. WCS-IP should work with local government (provincial fisheries authority) and the National Park Authority to encourage the allocation of funding and human resources for catch monitoring.
3. Based on the MERA simulations, the selected MPs show reasonably good long-term B/B_{MSY} (biomass/biomass at maximum sustainable yield) performances over 50 years of simulation, with B/B_{MSY} generally >1 (Figure 6.8). In terms of long-term

yield performance, matlenlim (size limit) had lower long-term yield and higher uncertainty than the other MPs. More thorough analysis of the monitoring data on fish landing is required to set more precise regulations on size limit and reduce some of this uncertainty.

Table 6.3. The 10 best-performing management procedures from the Method Evaluation and Risk Assessment (MERA) simulations for Redbelly Yellowtail Fusilier in the Karimunjawa Islands, central Java Sea, Indonesia

Management procedure	Regulation type	Probability $B > 0.5\ B_{MSY}$	Probability $B > B_{MSY}$	Short-term yield	Long-term yield
MRnoreal	Spatial	0.80	0.53	0.85	0.66
matlenlim2	SL	0.77	0.48	0.70	0.51
matlenlim	SL	0.76	0.47	0.75	0.54
ITe10	TAE	0.75	0.46	1.07	0.83
MRreal	Spatial	0.75	0.46	1.09	0.80
MCD4010	TAC	0.83	0.55	0.41	0.57
MCD	TAC	0.79	0.51	0.55	0.62
HDAAC	TAC	0.76	0.50	0.60	0.67
IT10	TAC	0.74	0.51	0.84	0.67
IT5	TAC	0.74	0.50	0.88	0.69

Blue shading = five options with highest likelihood of maintaining long-term catches and maintaining yield. B = biomass; B_{MSY} = biomass at maximum sustainable yield; MRnoreal = marine reserve with no reallocation of fishing effort; matlenlim = size limit; ITe10 = total allowable effort + max change 10%/year; MRreal = marine reserve with reallocation of fishing effort. Regulation types: spatial = spacial closures; SL = size limit; TAE = total allowable effort; TAC = total allowable catch.

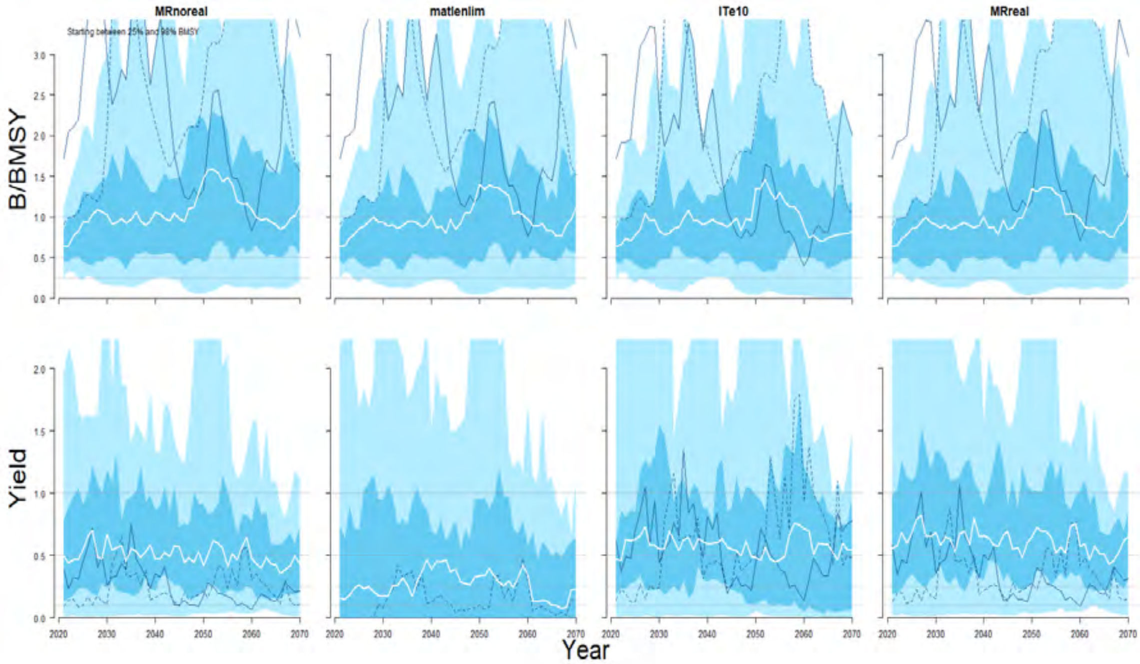

Figure 6.8. Simulated performance (biomass relative to biomass at maximum sustainable yield [B/BMSY]; relative yield) of four management planning options for managing the Redbelly Yellowtail Fusilier (*Caesio cuning*) fishery in the waters of the Karimunjawa Islands, Indonesia. The blue regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference the grey horizontal lines denote values of 0.25, 0.5, and 1. MRnoreal = marine reserve with no reallocation of fishing effort; matlenlim = size limit set at size at 50% maturity; ITe10 = total allowable effort with 10% increase annually; MRreal = marine reserve with reallocation of fishing effort.

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Appendix 6.1

Table 6A1. Questions and answers for the Method Evaluation and Risk Assessment (MERA) operating model to evaluate management options for Redbelly Yellowtail Fusilier (*Caesio cuning*) in the waters of the Karimunjawa Islands, central Java Sea, Indonesia

No.	Questions	Answers
	Fishery characteristics	
1	Longevity or lifespan	Short-lived (7< maximum age <10). 0.56< M <0.39
2	Stock depletion (D)	Moderately depleted (0.15< D <0.3)
3	Resilience	Moderate resilience (0.5< steepness <0.7)
4	Historical effort pattern	Boom–bust; stable, recent decrease
5	Inter-annual catch (IAC) variability in historical effort	Highly variable (maximum IAC between 20% and 50%)
6	Historical fishing efficiency changes	Declining by 1–2% pa (halves every 35–70 years)
7	Future fishing efficiency changes	Declining by 1–2% pa (halves every 35–70 years)
8	Length at maturity (LM)	Moderate (0.6< LM <0.7)
9	Selectivity of small fish (S)	Large (0.6< S <0.8)
10	Selectivity of large fish (SL)	Dome-shaped selectivity (0.25< SL <0.75)
11	Discard rate (DR)	Moderate (10% < DR <30%)
12	Post release mortality rate (PRM)	High (75% < PRM <5%)
13	Recruitment variability	High (max IAC between 120% and 180%)
14	Size of an existing marine protection area (MPA; no-take area A)	Small (A <5%) to small-moderate (5% < A <10%)
15	Spatial mixing (movement) in/out of existing MPA	High (10% < P <20%)
16	Size of a future potential MPA	Moderate (10% < A <20%)
17	Spatial mixing (movement) in/out of future potential MPA	High (10% < P <20%)
18	Initial stock depletion (D1)	Low (0.15< D1 <0.3)
	Management (types of fishery management)	
1	TAC (total allowable catch): a catch limit	All options are selected (no justification)
2	TAE (total allowable effort): an effort limit	All options are selected (no justification)
3	Size limit	All options are selected (no justification)
4	Time-area closures (a marine reserve)	All options are selected (no justification)

No.	Questions	Answers
	Data characteristics	
1	Available data types	[Data poor (inaccurate and imprecise)] Historical annual catches (from unfished); recent annual catches (at least 5 recent years); historical relative abundance index (from unfished); recent relative abundance index (at least 5 recent years); fishing effort; size composition (length samples); age composition (age samples); growth (growth parameters); absolute biomass survey
2	Catch reporting bias	All options are selected (no justification)
3	Hyperstability in indices	All options are selected (no justification)

7. Fisheries management for the Skipjack Tuna (*Katsuwonus pelamis*), in Indonesia's archipelagic waters

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Katsuwonus pelamis, the Skipjack Tuna (English), or *Cakalang* (Bahasa Indonesia)
(Image: White et al., 2013)

Summary

Skipjack Tuna[2] (*Katsuwonus pelamis*, Scombridae) are a highly migratory species and are widely distributed across tropical, subtropical and temperate oceans. With faster growth and a shorter lifespan than other tuna species, Skipjack mature at a younger age than other large tuna species. Skipjack are an important species in global tuna fisheries; catches of this species are the highest of all the tuna species. The stock assessment for this species in the Pacific Ocean is performed by the Secretariat of the Pacific Community and presented to the Scientific Committee of the Western and Central Pacific Fisheries

[2] Throughout this section, Skipjack Tuna will mostly be referred to simply as Skipjack.

Commission (WCPFC). In 2019, the assessment for Skipjack in this ocean revealed that the stock was not overfished. However, it was estimated that the spawning potential of Skipjack in Region 5 of the eight Skipjack stock assessment regions had decreased in recent years; Region 5 includes the territories of Indonesia, the Philippines and Vietnam. Within this region, most Skipjack were caught in the waters of the Philippines and the Indonesian archipelagic fisheries. Most fish were 200–400 mm in fork length.

A large proportion (~76% in 2018) of Indonesia's Skipjack catch in the western and central Pacific Ocean comes from Indonesian archipelagic waters (IAW), including the Indonesian Fisheries Management Areas (FMAs) 713, 714 and 715. Given the importance of these fisheries, sustainable management is a high priority. In the IAW, Skipjack are fished with a variety of gear, but the largest catches are with pole and line and purse seine vessels. They are also caught by handlines, troll lines and gillnets. Indonesia has initiated harvest strategies for tropical tuna, including Skipjack, in the IAW; decision rules based on catch per unit effort (CPUE) and mean length are used, which can be categorised as a data-rich approach. In this study, we employed a data-limited approach using the Method Evaluation and Risk Assessment (MERA) tool to explore potential management measures to support the development of a harvest strategy for the IAW.

The MERA analyses identified four management procedures (MPs) that performed well: depletion corrected average catch (DCAC); a set of size-selective MPs that adjust the retention curve of the fishery (matlenlim); IT10, a procedure based on total allowable catch (TAC) – the TAC is modified according to current index levels (mean index over past 5 years) relative to a target level; and marine reserves with effort reallocation (MRreal). Although the TAC limit gave a lower yield than MPs based on size limit and spatial closure, it performed best: a probability of 85% that the biomass (*B*) is above 0.5 *B* at maximum sustainable yield (B_{MSY}) and a high probability that the biomass is above 0.7 B_{MSY}. The yield is also more sustainable and stable than those of other MPs. The DCAC management procedure largely depends on historical catch data to inform future projections. Further, implementing an IT10 is problematic – TACs would probably need to vary by 10–40% of the actual TAC. The outcome of the rebuilding projection had a wide range of uncertainty; hence, fishery managers should consider a precautionary approach to their decisions, especially when CPUE time-series data by gear and tuna species are limited.

Ringkasan

Cakalang (*Katsuwonus pelamis*) (Scombridae) adalah spesies yang bermigrasi jauh dan tersebar luas di perairan tropis, subtropis, dan beriklim sedang. Dengan pertumbuhan yang relatif lebih cepat dan umur yang lebih pendek dibandingkan dengan spesies tuna lainnya, cakalang mengalami kematangan pada umur yang lebih muda. Di Samudera Pasifik, tangkapan cakalang pada tahun 2018 mencapai 66% dari total tangkapan tuna. Penilaian stok untuk spesies ini di Samudra Pasifik dilakukan oleh Secretariat of the Pacific Community (SPC) dan dipresentasikan kepada Komite Ilmiah Western and Central Pacific Fisheries Commission (WCPFC). Pada tahun 2019, penilaian cakalang di wilayah WCPFC ini menunjukkan bahwa penangkapan ikan berlebih tidak terjadi dan

stoknya tidak ditangkap secara berlebihan. Namun diperkirakan potensi pemijahan cakalang di Region 5 (yang meliputi wilayah territorial Indonesia, Filipina dan Vietnam), dari delapan region pengkajian stok cakalang, mengalami penurunan dalam beberapa tahun terakhir. Di Region 5, mayoritas hasil tangkapan cakalang berasal dari Filipina dan perikanan kepulauan Indonesia dan sebagian besar ikan berada pada kisaran ukuran 200–400 mm FL.

Sebagian besar (~76% pada 2018) tangkapan cakalang Indonesia di western and central Pacific Ocean (WCPO) berasal dari perairan kepulauan Indonesia (IAW), termasuk Wilayah Pengelolaan Perikanan Indonesia (selanjutnya disebut FMA) 713, 714 dan 715). Mengingat pentingnya perikanan ini, pengelolaan perikanan tuna yang berkelanjutan merupakan prioritas utama. Dalam IAW, cakalang menjadi target tangkapan beberapa alat tangkap, dengan tangkapan terbesar berasal dari kapal pole and line dan purse seine. Cakalang juga tertangkap oleh handline, troll line dan gillnet. Indonesia telah menginisiasi strategi pemanfaatan (harvest strategy) untuk tuna tropis, termasuk cakalang, di IAW menggunakan aturan pengambilan keputusan (decision rules) berbasis catch per unit effort (CPUE) dan panjang ikan rata-rata, yang dapat dikategorikan sebagai data-rich approach. Dalam studi ini, pendekatan data terbatas (data-limited approach) yaitu *Method Evaluation and Risk Assessment* (MERA) telah digunakan dalam mengeksplorasi langkah-langkah pengelolaan yang mungkin, sebagai satu upaya untuk mendukung pengembangan harvest strategy di IAW.

Hasil analisa MERA menunjukkan empat prosedur pengelolaan (management procedures/MPs) yang berkinerja baik: depletion corrected average catch (DCAC); seperangkat prosedur pengelolaan selektivitas ukuran yang menyesuaikan kurva retensi dari perikanan (matlenim); IT10, dan sebuah prosedur berdasarkan pada alokasi tangkapan (total allowable catch/TAC) – TAC dimodifikasi sesui dengan level indeks saat ini (artinya indeks selama 5 tahun terakhir) relatif terhadap level sasaran; dan kawasan konservasi dengan realokasi upaya (MRreal). Meskipun batasan TAC memberikan hasil tangkapan yang rendah di bandingkan dengan MP berbasis batasan ukuran dan penutupan spasial, TAC berkinerja terbaik: dengan probabilitas 85% bahwa biomassa (B) berada di atas 0.5 B pada saat tangkapan maksimum lestari (B_{MSY}) dan dengan probabilitas yang tinggi bahwa biomassa berada di atas 0.7 B_{MSY}. Hasil tangkapan juga lebih berkesinambungan dan stabil daripada MP lainnya. Prosedur pengelolaan DCAC lebih banyak tergantung pada historis data tangkapan untuk menentukan proyeksi di masa datang. Selanjutnya, penerapan IT10 bermasalah – TAC kemungkinan harus bervariasi antara 10–40% dari TAC aktual. Keluaran (dampak) dari proyeksi pembentukan kembali (stok) memiliki kisaran ketidakpastian yang luas; sehingga, para pengelola perikanan perlu mempertimbangkan pendekatan kehati-hatian terhadap keputusan yang mereka buat, khususnya jika data runtun waktu CPUE berbasis alat tangkap dan spesies tuna terbatas.

7.1. Biology

7.1.1. Taxonomy

Scientific name: *Katsuwonus pelamis*

Common names: Skipjack Tuna (English) and Cakalang (Bahasa Indonesia)

7.1.2. Key identifying features

Skipjack are categorised as a middle-sized Scombridae fish (Subfamily Scombrinae), with a reported maximum body length that varies between studies from 90 cm (Bayliff, 1980) to 110 cm fork length (FL) (Fishbase). Skipjack grow significantly faster than Yellowfin Tuna (*Thunnus albacares*) and Bigeye Tuna (*Thunnus obesus*) (Hoyle et al., 2011). The body is elongate and strong, with two dorsal fins, is rounded in cross-section, and is scaleless (except along the lateral line and the corselet). They have 40 teeth and lack a swim bladder (Collette and Nauen, 1983; Matsumoto et al., 1984).

7.1.3. Distribution

Worldwide: Skipjack occur in the Pacific, Indian and Atlantic oceans. In the Pacific Ocean, they are distributed across a larger area of tropical and subtropical waters in the Western Pacific; in the Eastern Pacific they only occur in tropical waters (Kiyofuji and Ochi, 2016). Skipjack account for about 70% of the total tuna landings in the Pacific Ocean (IATTC, 2016; Williams and Terawasi, 2016); in 2018, Skipjack comprised 66% of the total tuna catch. Catches are higher in tropical waters (Williams and Reid, 2018). Kiyofuji and Ochi (2016) suggested different migration routes for this species according to their size, with larger Skipjack (>40 cm) inhabiting the tropical waters, where spawning occurs; the smaller fish migrate seasonally into Japanese waters. Fujino (1972) revealed a key migration route for the species: around the Japanese waters, along Kuroshio in the East China Sea, and along the Izu-Ogasawara Islands.

Indonesia: Skipjack are found throughout Indonesian waters, except in the Java Sea and some areas of the Malacca Strait and South China Sea. The Indonesian archipelagic waters (IAW) are located within Region 4 (2014 stock assessment Skipjack region classification) or Region 5 (2019 stock assessment Skipjack region classification). Mark–recapture tagging studies showed that the most of the Skipjack biomass in Region 4 (2014 classification) originated from that region, suggesting a high level of residency (Rice et al., 2014) (Figure 7.1).

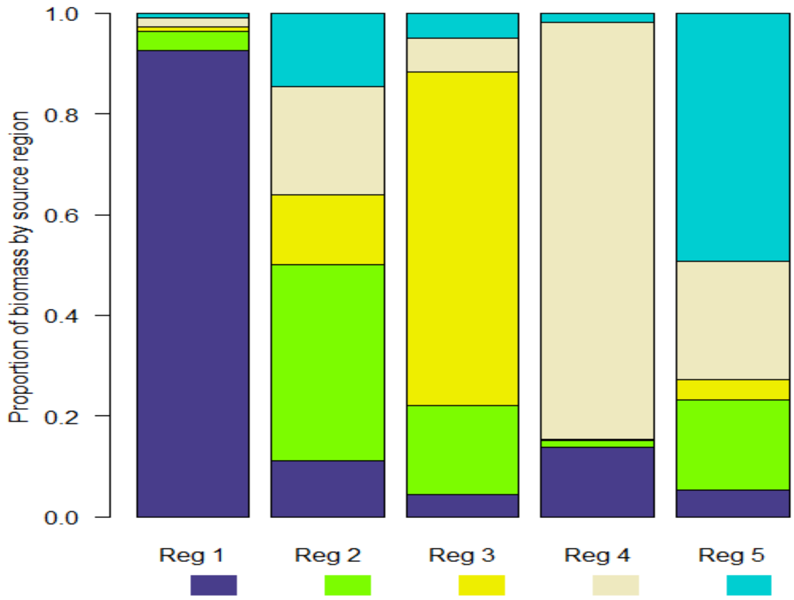

Figure 7.1. Proportional distribution of total biomass (by weight) in each region (Reg) apportioned by the source region of the fish (Rice et al., 2014). Regions are those of the western and central Pacific fisheries. Region 4 = the Indonesian archipelago waters of Fisheries Management Areas 713, 714 and 715.

7.1.4. Maximum length, weight and age

Compared to other tuna species (including Yellowfin Tuna, Bigeye Tuna, Albacore and Bluefin Tuna), Skipjack have a smaller maximum size of 90 cm (Bayliff, 1980) to 110 cm fork length (Fishbase), a younger maximum age of 8–12 years (Fromentin and Fonteneau, 2001), and a lower maximum body weight of 34.5 kg (Collette and Nauen, 1983).

7.1.5. Weight-length relationship

Table 7.1 summarises the weight-length relationships of Skipjack from previous studies in the western and central Pacific Ocean and relevant IAW. The power coefficients range from 2.66 for Ternate females (Susanto and Lumingas, 2014) to 3.37 (Ministry of Marine Affairs and Fisheries, unpublished data).

Table 7.1. Weight-length relationships for Skipjack Tuna (*Katsuwonus pelamis*) in the western and central Pacific Ocean, including relevant Indonesian archipelagic waters

Location	Weight–Length relationship	R^2	N	Source	Notes
WCPO	$W = 3.612 \times 10^{-6} L^{3.278}$	0.98	262	Wang et al. (2010)	L in mm, W in g
WCPO	$W = 0.86388 \times 10^{-6}$e-06 $L^{3.2174}$	NA	NA	Hoyle et al. (2011); Abascal et al. (2014)	
WCPO	$W = 0.0058 L^{3.2996}$	0.98	550	Jin et al. (2015)	Samples from August to Sept 2009; L in cm, W in g
WCPO	$W = 0.0066 L^{3.2398}$	0.97	737		Samples from Nov to Dec 2012; L in cm, W in g
WCPO	$W = 0.0039 L^{3.3668}$	0.97	391		Samples from June to July 2013; L in cm, W in g
Ternate (FMA 715)	$W = 0.0001 L^{2.7232}$	0.73	254	Susanto and Lumingas (2014)	Male
	$W = 0.0002 L^{2.6595}$	0.66	208		Female
Maluku Sea (FMA 715)	$W = 0.0362 L^{2.79}$	0.95	664	Nugraha et al. (2020)	L in cm, W in g
Toli-Toli (FMA 713)	$W = 0.0054 L^{3.318}$	0.97	196	Chodrijah et al. (2020)	Male
	$W = 0.0057 L^{3.3049}$	0.97	249		Female

W = wet weight; L = fork length; WCPO = western and central Pacific Ocean; FMA = Fisheries Management Area; NA = not available.

7.1.6 Growth

Table 7.2 presents the growth parameters of Skipjack, as reported by some of the earlier studies for the species in the western and central Pacific Ocean (WCPO) and IAW. The estimated asymptotic fork lengths range from 70.1 cm (Tadjuddah et al., 2017) to 97.6 cm (Waileruny et al., 2014) and the instantaneous growth rate (*k*) ranges from 0.19 to 0.64 y^{-1} (Table 7.2).

Table 7.2. Growth parameters of Skipjack Tuna (*Katsuwonus pelamis*) in the western and central Pacific Ocean and Indonesian archipelagic waters

Location	**Growth parameters**			**n**	**Source**
	L_∞ (cm)	***k* (year^{-1})**	**t_0 (year)**		
WCPO	70.65	0.64	–0.037	262	Wang et al. (2010)
WCPO	93.6	0.43	–0.49	453	Tanabe et al. (2003)
Banda Sea, FMA 714	75.9	0.19	–0.36		Jamal et al. (2011)
Banda Sea, FMA 714	97.6	0.41	–0.29		Waileruny et al. (2014)
Banda Sea, FMA 714	70.1	0.26	–0.49		Tadjuddah et al. (2017)

L_∞ = asymptotic length, describing the average maximum size of individuals in the population; k = instantaneous growth rate (year^{-1}), describing the rate at which the asymptotic length is reached; t_0 = hypothetical age at which fish have zero length; WCPO = western and central Pacific Ocean; FMA = Fisheries Management Area.

7.1.7. Length and age at maturity

Length at maturity parameters of Skipjack in the WCPO range from 40 to 50 cm fork length (Table 7.3).

Table 7.3. Length at maturity parameters of Skipjack Tuna (*Katsuwonus pelamis*) reported from the western and central Pacific Ocean

Parameter	**Fork length (cm)**	**Source**
L_{50}	47.9 (Female)	Ashida et al. (2009)
	40.7 (Male)	Ashida et al. (2010)
L_{50}	40	Hoyle et al. (2011), Tanabe et al. (2003)
L_{50}	50.3	Ashida et al. (2017)
L_{50}	50 (Female)	Ohashi et al. (2019)
L_{50}	~41	Chodrijah et al. (2020)
L_{95}	~60 (Female)	Ashida et al. (2007)

L_{50} = fork length at 50% maturity; L_{95} = fork length at 95% maturity.

7.1.8 Summary of life history, habitats and movement

Life history

Skipjack are classified into six growth stages (Table 7.4).

Table 7.4. Growth stages of Skipjack Tuna (*Katsuwonus pelamis*)

Growth stage	Fork length (cm)	Age
1. Egg		
2. Larvae	0.1–1	<10 days
3. Juvenile	1–10	10–40 days
4. Young	10–20	40–90 days
5. Immature	20–40	90 days to 1 year
6. Mature	>40	>1 year

Data from presentation by Kiyofuji at the Research Institute for Marine Fisheries in 2019, with combined results from Ueyanagi et al. (1974) and Tanabe (2002).

Studies have estimated length at first maturity for this species (see Section 7.1.7), with a minimum size at first maturity of 40 cm fork length (Ashida et al., 2017). The fecundity varies among studies: 450,570 to 1,707,390 eggs (Chodrijah et al., 2020); 1,000,000 to 14,000,000 eggs (Nugraha and Mardlijah, 2008); and 615,000 eggs (Ashida et al., 2008). Skipjack are known to have multiple spawning events and prefer a sea surface temperature at or above 24 °C (Matsumoto et al., 1984). Spawning occurs throughout the year in tropical areas of the WCPO (Ashida et al., 2007; Ashida et al., 2010).

Habitats

Skipjack mainly occur in tropical and subtropical waters (Collette and Nauen, 1983) but the distribution also extends into temperate waters (see FAO distribution map for the species: http://www.fao.org/fishery/species/2494/en). Tropical waters are considered the primary spawning grounds (Kiyofuji and Ochi, 2016). Their habitat preference is waters from the surface to 260 m. Hoyle et al. (2011) found that the 20 °C surface isotherm limited their migration in the Western Pacific.

The larvae of Skipjack (<1 cm) inhabit the epipelagic zone (depth ≤60 m) with a surface temperature of at least 24 °C (Strasburg, 1960; Ueyanagi, 1969); they are mostly found in the water column between 20 and 60 m (Boehlert and Mundy, 1994; Davis et al., 1990; Strasburg, 1960; Ueyanagi, 1969). Juvenile Skipjack are generally found at depths of 40–120 m with a preferred surface temperature range of 20–30 °C (Tanabe et al., 2017).

7.2. Fisheries

7.2.1. Description of the fisheries

Skipjack are the dominant species in Indonesia's tuna catch, comprising 55% of the total tuna catch in 2018, as reported to the Western and Central Pacific Fisheries Commission (WCPFC) (Satria et al., 2019). In the IAW (Fisheries Management Areas [FMAs] 713–715) (Figure 7.2), Skipjack contributed 54% of the total tuna catch (Satria et al., 2019) and are the main target species for purse seine and pole-and-line fishers (Figure 7.3).

Skipjack are also caught by handline, troll line (Figure 7.3) and gillnets (Figure 7.4). Purse seine is the most common fishing gear used in the IAW, followed by pole and line, and handline (Table 7.5). Key landing places for the tuna fisheries operating in FMAs 713–715 are in Bitung (north Sulawesi), two sites in Kendari Bay in south-east Sulawesi (Kendari Fishing Port and Sodohoa), and sites in Ambon and Ternate (Figure 7.2).

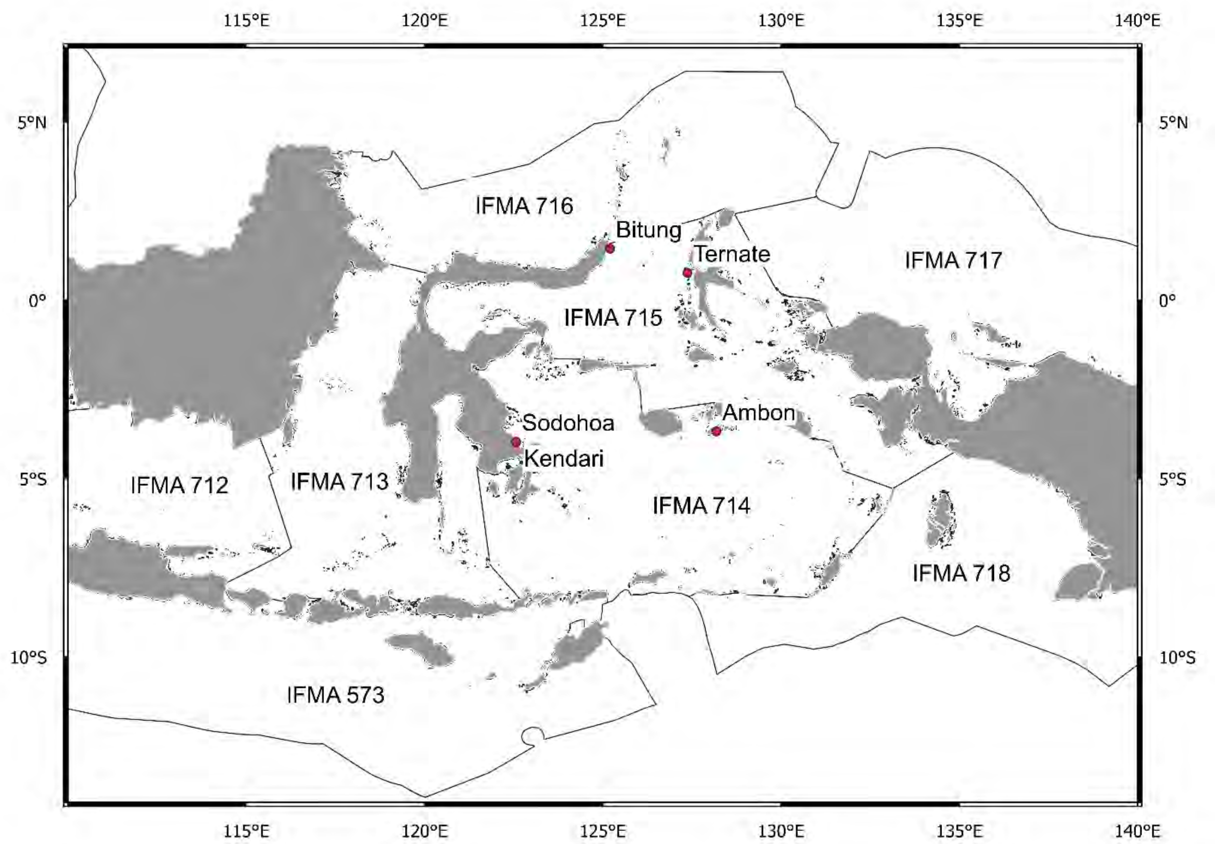

Figure 7.2. Indonesian Fisheries Management Areas (FMAs) and key landing places for Skipjack Tuna (*Katsuwonus pelamis*) in Sulawesi: Bitung, Kendari, Sodohoa, Ambon and Ternate. Source: Ministerial Regulation of Marine Affairs and Fisheries No. 18/2014 on Indonesian Fisheries Management Areas.

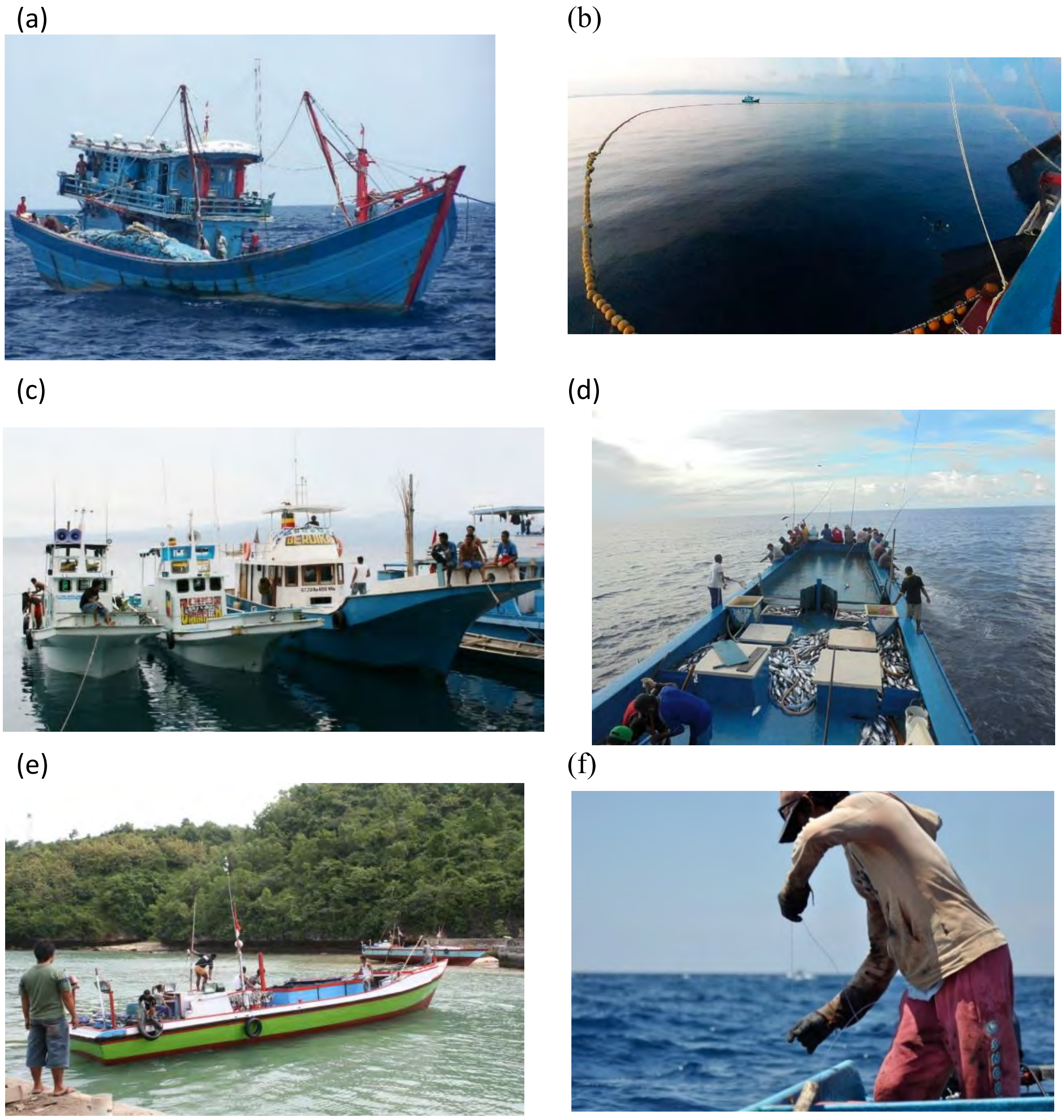

Figure 7.3. Some types of fishing vessels and associated gear used in Indonesia's archipelagic waters (Fisheries Management Areas 713, 714 & 715) to catch Skipjack Tuna. a, b = purse seine; c, d = pole and line; e, f = handline/troll line. Images: Commonwealth Scientific and Industrial Research Organisation (a, c, e), Research Institute of Marine Fisheries (b), Masyarakat Dan Perikanan Indonesia (d, f).

Figure 7.4. Vessels loaded with gillnets for catching Skipjack Tuna in Indonesia's archipelagic waters. Images: Center for Fisheries Research.

Table 7.5. Numbers of fishing gear (2012–18) for Skipjack Tuna in Indonesian archipelagic waters in Fisheries Management Areas 713–715

Type of fishing gear	Year						
	2012	2013	2014	2015	2016	2017	2018
Purse seine	321	371	495	456	447	349	273
Pole and line	64	42	41	37	33	68	85
Handline	13	14	12	26	31	16	9

Note: Numbers of gear are managed under central government (vessels >30 GT). Numbers do not include smaller vessels managed by provincial governments, which also catch significant numbers of Skipjack. Source: Directorate General of Capture Fisheries (Indonesian Tuna Fisheries Annual Catch Estimate Workshop, 2019).

The stock assessments for Skipjack, conducted by the Secretariat of the Pacific Community for the WCPFC, are currently based on the assumption that there is only one stock of this highly migratory species in the WCPO. The most recent stock assessment for Skipjack in the WCPO, presented at the 15th Scientific Committee of the WCPFC in 2019, concluded that overfishing was not occurring and that the stock was not overfished (Vincent et al., 2019).

7.2.2. Stock depletion and resilience

Stock depletion of Skipjack for the WCPO, based on outcomes from the 2019 stock assessment for the WCPFC (Vincent et al., 2019), provides an overall median depletion for 2015 to 2018: $SB_{recent}/SB_{F=0}$ of 0.44 (80th percentile range: 0.36–0.52), where *SB* is the spawning biomass, derived from the eight-region models, and 0.40 (80th percentile range 0.30–0.50) for the five-region models. However, the local Skipjack fishery depletion $SBt/SB_{F=0}$ for regions 4 and 5, which cover the Indonesian and Philippines waters, was close to 0.2 (Vincent et al., 2019).

Skipjack spawning occurs sporadically all year round with no clear seasonal pattern (Itano, 2000). The appearance of a length class of Skipjack with average length of about 23 cm is defined as recruitment in the population. An assessment of tuna that allows movement and recruitment from other regions (using MULTICAN CL) suggests that the estimated recruitment has been increasing in recent years, with most recruitment in regions 5, 7 and 8 (Vincent et al., 2019). The Beverton and Holt stock-recruitment relationship indicates the resilience of Skipjack stocks – the steepness of the curve (h) – is estimated as 0.8, ranging from 0.65 to 0.95, assuming that the spatially aggregated recruitment was weakly related to the total spawning potential in the preceding quarter (Vincent et al., 2019).

7.2.3. Fishing effort: history, variability and changes in fishing efficiency

Since 1980, the catch of Skipjack in the IAW increased steadily, reaching a peak in 2013 (Figure 7.5). The peak was in line with an increase of catch by purse seine vessels operating within the archipelagic waters. Foreign vessels, including purse seiners, had been licensed to fish both within Indonesia's exclusive economic zone and archipelagic waters under a joint venture with local companies. This agreement resulted in a large increase in purse seine catch. However, the purse seine catch dropped sharply in 2015 to a level close to that of 2003. This reversal was a consequence of policy changes, introduced through ministerial decree No. 56/2014. Operation of foreign fishing vessels was prohibited in all of Indonesia's waters to combat illegal, un-reported, and unregulated fishing pratices. After these policy changes, the 'space' created by the absense of foreign vessels was filled by increased activity of Indonesian fishing vessels and the catch of Skipjack increased again.

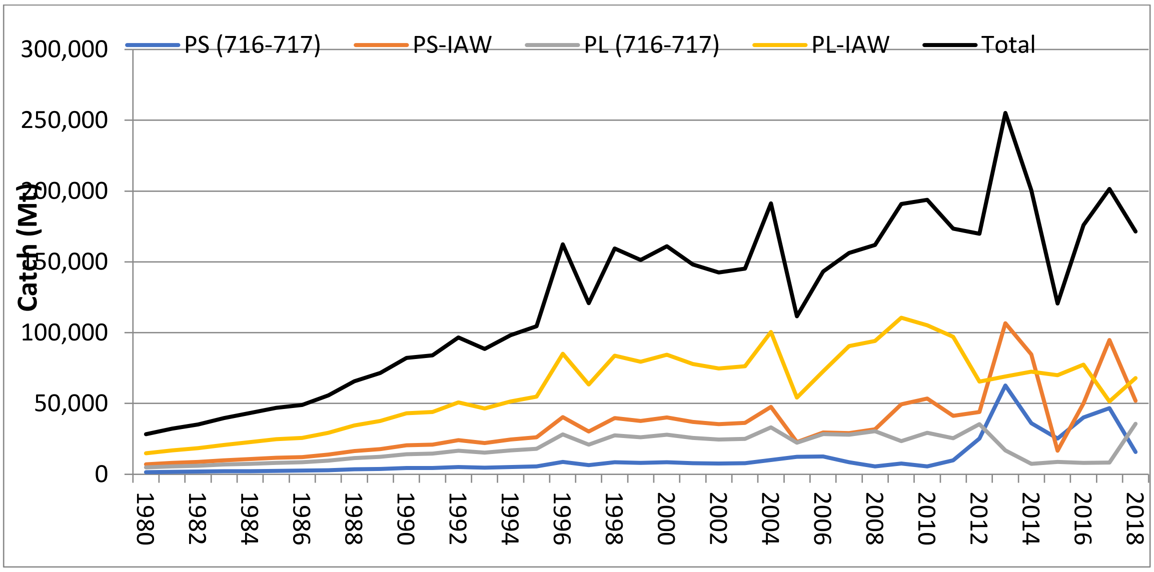

Figure 7.5. Historical catch of Skipjack by purse seine (PS) and pole and line (PL) in Indonesia's archipelagic waters (IAW) within Fishery Management Areas (FMAs) 713, 714 and 715, and including the areas of FMAs 716 and 717 in the Pacific Ocean. (Source: Directorate General of Capture Fisheries, 2019)

7.2.4. Selectivity of methods and discard rates

Selectivity of the fishing gear in the IAW was estimated using fish-length data recorded by the port sampling program under the research collaboration between the Center for Fisheries Research, Ministry of Marine Affairs and Fisheries (MMAF), and the WCPFC (known as the West Pacific East Asia [WPEA] project). The estimated size at 50% selectivity ranges from 42.9 cm for handline to 47.4. cm for troll line (Table 7.6).

Table 7.6. Estimated selectivity of the four main types of fishing gear for catching Skipjack Tuna (*Katsuwonus pelamis*) in Indonesian Archipelagic Waters

Type of fishing gear	SL_{50}	Number
Purse seine	45.4	94,784
Pole and line	43.9	35,938
Handline	42.9	21,127
Troll line	47.4	1928

Source: Presentation by Tri Ernawati (Research Institute for Marine Fisheries) at the Technical Harvest Strategy Workshop, Bogor, Indonesia, October 2019.

7.3. Management regulations

7.3.1. Current management

The MMAF established the National Tuna Management Plan in 2015. The plan is currently under review and is being considered for signing by the Minister of the MMAF to provide a basis for the national management of Indonesia's tuna and neritic tuna fisheries for the next 5 years (2020–2024). The measures within the plan are generally similar to and compatible with the measures agreed by the tuna Regional Fisheries Management Organisations (tRFMOs). The tRFMOs include the Indian Ocean Tuna Commission (IOTC) for the Indian Ocean waters and the WCPFC for Indonesia's Pacific Ocean tuna fishing activity. Indonesia is a full member of both these tRFMOs. For the archipelagic waters of FMAs 713, 714, and 715, a harvest strategy for the tropical tunas (i.e. Yellowfin Tuna, Bigeye Tuna and Skipjack) is being developed; the interim harvest strategy officially launched in 2018 during the Bali Tuna Conference. Five priority management measures were identified and presented in the harvest strategy document (Satria et al., 2018):

1. Limits on the use of fish agregating devices (FADs).
2. Spatial closures (of important spawning or nursery grounds) and temporal closures (during important events such as spawning).
3. Limiting the number of fishing days (per gear, for semi-industrial and industrial vessels).
4. Limiting entry for the number of vessels (per gear through licensing) for semi-industrial and industrial vessels through licensing, permits, taxing and royalties.
5. Total Allowable Catch (TAC) limits per FMA (WCPFC16–2019-DP20_rev01).

To implement the new management measures, it was agreed that there should be no additional fishing effort by semi-industrial and industrial vessels for tuna fishing in the archipelagic waters. In addition, the ban on all foreign fishing vessels operating in Indonesian waters should continue. The process for determining TAC limits for the relevant FMAs, and for their implementation and legalisation, is being developed. In accordance with catch limits for purse seine vessels delivered by the agreement of CMM 01/2018-WCPFC, in 2019 the Government of Indonesia advised the WCPFC, at both the Technical and Compliance Committee meeting (Sept–Oct 2019) and the regular session of the Commission (Dec 2019), that the catch limit for purse seine vessels operating in the exclusive economic zone of FMAs 716 and 717 is now 70,000 tonnes per year.

Under the MMAF regulation No. 12/2012 concerning fishing business on the high seas, the Government of Indonesia will automatically ratify all measures by the RFMOs of which Indonesia is a member; these measures will be applied to Indonesia's tuna fisheries. However, monitoring and enforcing these measures presents challenges because of the multitude of small-scale fishing vessels that operate in Indonesian waters.

There are no specific area or seasonal closures for Skipjack, but targeting of Yellowfin Tuna in the Banda Sea (FMA 714) is prohibited annually from October to December under MMAF Regulation No. 4/2015 on Prohibition of Fishing in FMA 714. In practice, large purse seine vessels fishing for Yellowfin Tuna cannot operate in FMA 714 during these months, which has indirectly benefitted the conservation of Skipjack in this FMA. However, the regulation is currently under review following a request by both the provincial governments within FMA 714 and the fishing industries to ammend the regulation to allow Yellowfin Tuna fishing all year round.

7.3.2. Future management options

Given the complexities of Skipjack fisheries, there are several future management options that may be effective in Indonesian waters. These suggestions are made while acknowledging that few resources are available to monitor these fisheries and enforce regulations, in particular, to manage small-scale tuna fisheries in Indonesia.

1. ***Size limit***: Given that the length at maturity (L_{50}) determined by a number of studies is above 40 cm fork length for Skipjack, we recommend a minimum legal size of >40 cm fork length. However, implementing this limit may be difficult because of selectivity issues with gear. In addition, purse seine and pole-and-line vessels mostly fish in association with FADs, which results in catches that contain a proportion of small, juvenile Skipjack, particularly from purse seine vessels. Excluding the catch of juvenile Skipjack from the FAD-based catches may prove too difficult.
2. ***Closed seasons and spatial closures***: Seasonal and spatial closures to conserve the breeding stock and juveniles are two technical measures that would benefit Skipjack. However, such measures require a co-management approach with relevant stakeholders. Further, such closures may severely affect small-scale ('one by one') fishers, whose livelihoods are a priority. Scientific advice is required for those tasked with managing the fisheries so they can make effective decisions on where, when, and how to apply closures, and can assess the likely impacts.
3. ***Limiting vessels and fishing gear***: As an input control, limiting the number of gear and fishing vessels may be effective and could be implemented by limiting fishing

licences granted by the central government for vessels larger than 30 GT. Such measures are particularly relevant to purse seine activity and are a good fit with the outcomes of the harvest strategy development undertaken since late 2014. However, given the autonomous rights of provincial goverments, we predict that they may be reluctant to limit the number of fishing licences for vessels under 30 GT operating in their territorial waters. Provincial goverments may need to be educated in co-management to enable them to understand the importance of sustainability of the fisheries for both their fishers and their regions.

4. ***Catch limits***: As an output control, defining a total allowable catch (TAC) may be possible, but would be challenging – it would involve central and provincial governments agreeing on an allowable catch, both by gear and by species. The catch limits could be derived from the outcomes of stock assessment combined with various inputs such as historical catch, social and economic factors, and demography. The process is ongoing but enforcement and monitoring of catch limits are likely to be difficult. As a first stage, the catch limits could be applied to vessels licensed by central government before attempting to implement limits for vessels under provincal management.

The implementation, monitoring, enforcement, performance and effectiveness of any of the above management measures would require regular evaluation, with close engagement of scientific agencies and all relevant government authorities, and in collaboration with the fishing industry bodies.

7.4. Data sources

The data used for the Method Evaluation and Risk Assessment (MERA) of the Skipjack fisheries were the port sampling data of the WPEA program, data from the Directorate General of Capture Fisheries, and data from previous studies conducted in the WCPO and within the IAW.

7.5. Management and planning in MERA

The MERA analyses found that, in general, management procedures based on TAC performed best and spatial closures performed worst. TAC limit yielded a probability of 0.85 that the biomass is above 50% of B_{MSY}, and also had a high probability (0.7) that the biomass is above B_{MSY}, even though the yield of this measure was lower than that of other measures (i.e. size limit and spatial closure; Table 7.7, Figure 7.6).

Table 7.7. The best-performing management procedures from the Method Evaluation and Risk Assessment (MERA) simulations for Skipjack Tuna fisheries in the Indonesian archipelagic waters of Fisheries Management Areas 713, 714 and 715

Management Procedure	Regulation type	Prob. $B > 0.5\ B_{MSY}$	Prob. $B > B_{MSY}$	Short-term yield	Long-term yield
DCAC	TAC	0.85	0.7	0.64	0.82
matlenlim	SL	0.8	0.44	0.94	1.01
IT10	TAC	0.51	0.34	1.04	0.75
MRreal	Spatial	0.55	0.22	1.09	0.95

DCAC = depletion corrected average catch; matlenlim = setting a size limit (SL) based on length at 50% maturity; IT10 = mean catch over past 5 years, adjusted by up to 10% per year; MRreal = marine reserve with reallocation of fishing effort; TAC = total allowable catch; SL = size limit; Spatial = special closure.

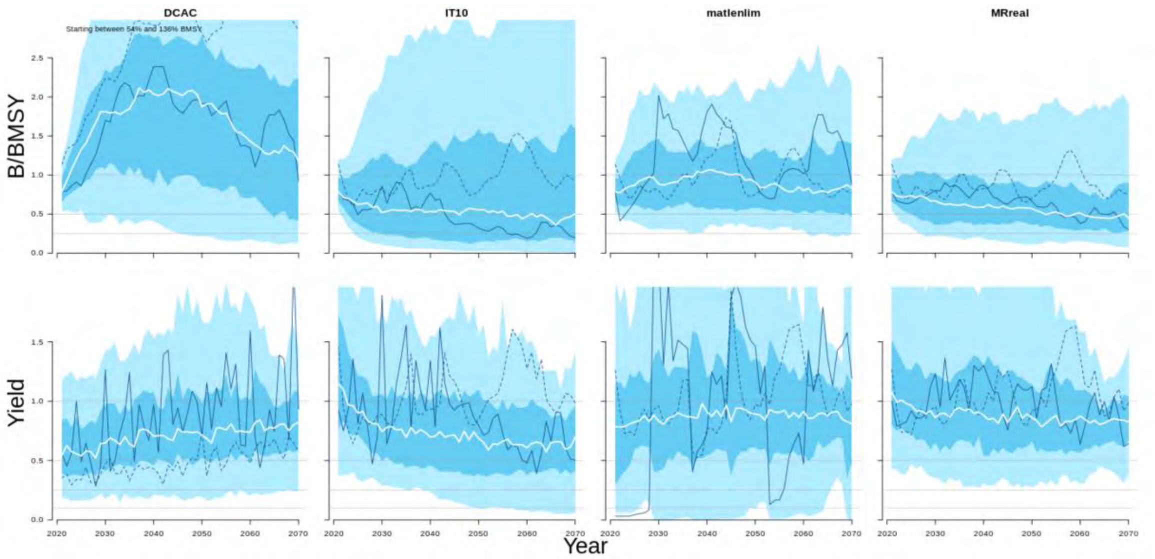

Figure 7.6. Simulated performance (biomass relative to biomass at maximum sustainable yield [B_{MSY}]; relative yield) of four management planning options for Skipjack Tuna fisheries in Indonesian archipelagic waters of Fisheries Management Areas 713, 714 and 715. The blue regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5 and 1. DCAC = depletion corrected average catch; IT10 = mean catch over past 5 years, adjusted by up to 10% per year; matlenlim = setting a size limit based on length at 50% maturity; MRreal = marine reserve with reallocation of fishing effort.

The depletion corrected average catch (DCAC) management procedure, applying a catch limit through a TAC, gave highest probability of the stock rebuilding to B_{MSY}, with a 61% probability of the stock being at $B > B_{MSY}$ (Table 7.8, Figure 7.7).

Table 7.8. The probability that biomass is greater than the biomass at maximum sustainable yield for four candidate management procedures for Skipjack Tuna fisheries in the Indonesian archipelagic waters of Fisheries Management Areas 713, 714 and 715

Management Procedure	Regulation type	*Prob.* $B > B_{MSY}$
DCAC	TAC	0.61
matlenlim	SL	0.28
IT10	TAC	0.26
MRreal	Spatial	0.08

DCAC = depletion corrected average catch; matlenlim = setting a size limit (SL) based on length at 50% maturity; IT10 = mean catch over past 5 years, adjusted by up to 10% per year; MRreal = marine reserve with reallocation of fishing effort; TAC = total allowable catch; B = biomass; B_{MSY} = biomass at maximum sustainable yield.

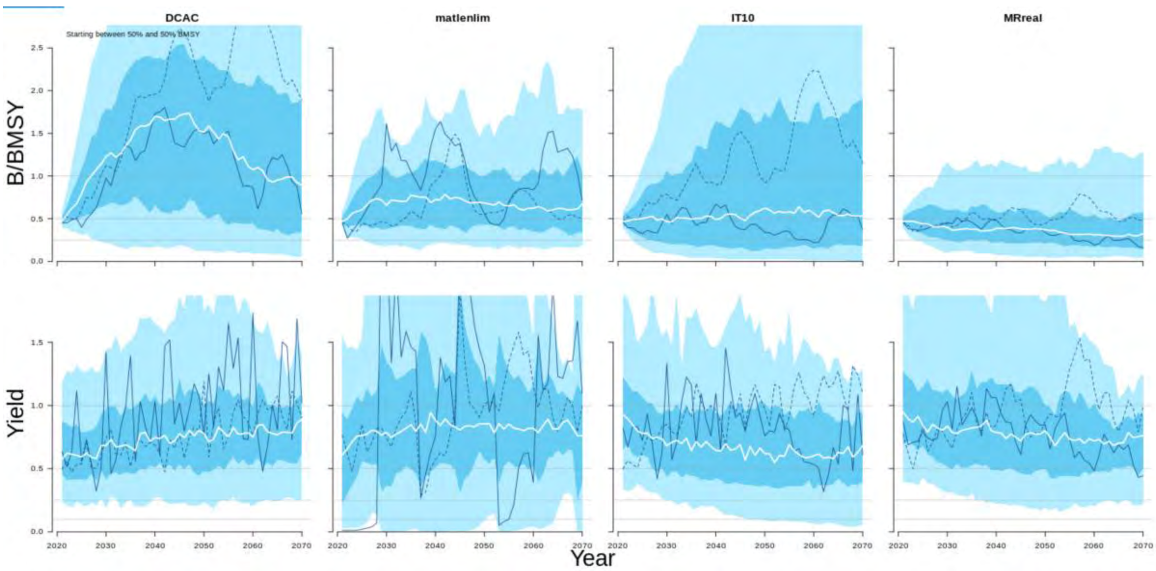

Figure 7.7. Rebuilding projection plots of yield and B/B_{MSY} for four management procedures for Skipjack Tuna fisheries in Indonesian archipelagic waters of Fisheries Management Areas 713, 714 and 715. The blue regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5, and 1). DCAC = depletion corrected average catch; IT10 = mean catch over past 5 years, adjusted by up to 10% per year; matlenlim = setting a size limit based on length at 50% maturity; MRreal = marine reserve with reallocation of fishing effort.

The DCAC management procedure largely depends on historical catch data to simulate catches into the future. Managers should emphasise that implementing a TAC may vary by 10–40% of the actual TAC. Also, the historical catch may not indicate the actual catch and fisheries managers may miss vital information. In addition, the rebuilding projection had a wide probability interval, meaning that fishery managers should take a precautionary approach to their decisions – particularly when the CPUE time series of data by gear by species is limited. Hence, the information on the DCAC procedure in the MERA analysis may help managers decide on specific management measures. Other sources to consider are the Skipjack regional stock asessement and the national harvest strategy of tropical tuna, where available.

Defining catch limits or TAC for the tuna fishery is a common step to undertake from scientific process to management decisions. After the catch limits are identified, often the challange is deciding which fisheries to limit to cause the least social and economic effects. In particular, politicians and managers should protect small-scale fishers, whose fishing activities are their livelihood. The first targets for implementing new TAC regulations are likely large-scale fishing companies, but also smaller ventures (vessels (≤30 GT) whose catch partly goes to processing plants for export. However, the vessels of small-scale fishers comprise more than 90% of the total fleet for Indonesia's tuna fisheries, and these fishers represent most of the people involved in the industry. In addition, effective monitoring and enforcing compliance of small-scale fishers poses a huge challenge because they are licensed by local government.

To ensure appropriate type and quality of fisheries data, the existing landings-based monitoring must continue. The monitoring must be consistent and continually improved to ensure the necessary coverage and data quality. Strengthening and improving the collection of operational catch data through the logbook and observer programs should continue. Fishing companies, fishing associations and fishers must adopt a participatory approach to collect the data required to improve coverage of catches and overall understanding of the fisheries. Information on the reproductive biology of Skipjack is required to reliably determine the biological parameters of the targeted stocks, a key input into the assessment process. Time-series data over longer periods, combined with more accurate data on biological and fisheries parameters, will reduce the uncertainty in stock assessment by scientists and help provide more robust and complete advice to fisheries managers.

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8. Fisheries management for the Leopard Coral Grouper (*Plectropomus leopardus*) in Saleh Bay, West Nusa Tenggara, Indonesia

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Plectropomus leopardus, the Leopard Coral Grouper (English), or *Kerapu Sunu Mera* (Bahasa Indonesia) (Image: Sukmaraharja Tarigan, Wildlife Conservation Society – Indonesia Program)

Summary

The Leopard Coral Grouper, *Plectropomus leopardus*, is a member of the epinepheline tribe of the Epinephelidae family (Grouper). This species is important for capture fisheries and the live reef-fish food trade. It commonly inhabits the western Pacific from southern Japan to northern Australia, and eastward to the Caroline Islands and Fiji. *P. leopardus* is a slow-growing and long-lived species (up to 26 years) with low natural mortality rates. Because of its high market value, the Leopard Coral Grouper, locally known as *Kerapu Sunu Merah*, is one of the major targeted species in Indonesian small-scale reef fisheries. This species has been heavily fished throughout its range, mainly by hook and line and

speargun, but occasionally by trap and cyanide in some areas. In Saleh Bay, Sumbawa, *P. leopardus* is one of the main targeted species and is fished with various types of gear, including speargun, handline, bottom longline, troll line and traps, as well as destructive fishing methods such as blast and cyanide fishing. The Leopard Coral Grouper supplies high-end domestic and international markets and the live-fish trade networks; consequently, fishing intensity is high, and fish smaller than the size at 50% maturity (L_{50}), are taken.

The length-based spawning potential ratio methodology was used to estimate the spawning potential ratio (SPR) from data on length frequency from the fish-landing program of the Wildlife Conservation Society – Indonesia Program (WCS-IP). The estimated SPR is low (0.24); hence, rebuilding the spawning stocks is desirable. Potential management procedures were evaluated using the Method Evaluation and Risk Assessment (MERA) tool to assess the long-term sustainability and yield of *P. leopardus* stocks. The best management procedures to rebuild the spawning stocks are size limit, spatial closures or marine reserves, effort limit and catch limit. Recently, the fishery developed a fishery management plan through consultation with WCS-IP, the Ministry of Marine Affairs and Fisheries, the provincial government, fishers and collectors. Although it performed well under the MERA simulations, a management procedure based on total allowable catch is probably not feasible because of the number of small-scale fishers (vessels <10 gross tons) involved in the fishery and their special considerations under Indonesian law. The current management measures for *P. leopardus* include a size limit (300 g), a gear limit (>102 mm [4 inch] mesh gillnets), a ban on hookah spearfishing, small spatial closures and bans on destructive fishing practises (i.e. blast and cyanide fishing). However, compliance with this last measure is likely to be an issue. To further improve future management, the reproductive seasons and key habitats for this species (e.g. spawning aggregation sites) should be identified. This would allow government, fishers and the fishing industry to consider additional management options such as seasonal closure during the spawning season or spatial closure for known spawning aggregation sites.

Ringkasan

Kerapu Sunu Merah, *Plectropomus leopardus*, adalah anggota suku epinepheline dari keluarga Epinephelidae (kerapu). Kerapu ini merupakan spesies penting bagi perikanan tangkap dan perdagangan ikan karang hidup. Ikan ini ditemukan menyebar dari perairan Pasifik bagian barat di sepanjang Jepang selatan hingga Australia utara serta ke arah timur hingga Kepulauan Caroline dan Fiji. *P. leopardus* adalah spesies yang memiliki pertumbuhan relatif lambat dan berumur panjang (dapat mencapai 26 tahun) dengan tingkat kematian alami yang rendah. Dikarenakan oleh nilai pasarnya yang tinggi, kerapu sunu, yang secara lokal dikenal sebagai kerapu Sunu Merah, adalah salah satu spesies target utama perikanan karang skala-kecil di Indonesia. Spesies ini telah mengalami tekanan penangkapan yang tinggi di seluruh perairan dimana spesies ini ditemukan, utamanya dari pancing ulur (hook and line) dan panah (speargun) tetapi adakalanya dari perangkap (trap) dan sianida (cyanide) di beberapa wilayah, Di Teluk Saleh-Sumbawa,

P. leopardus adalah salah satu spesies target utama yang ditangkap menggunakan berbagai jenis alat tangkap seperti: panah (speargun), pancing ulur, rawai dasar, pancing tonda, dan bubu maupun metode penangkapan ikan yang merusak seperti bom ikan dan sianida. Kerapu Sunu Merah memasok kebutuhan pasar kelas atas domestik dan internasional serta jejaring perdagangan ikan hidup, sehingga spesies ini mengalami intensitas penangkapan yang tinggi dimana ikan yang berukuran lebih kecil daripada ukuran 50% individu di dalam populasi yang telah menjadi dewasa secara sexual atau (L_{50}) juga ikut ditangkap.

Metode rasio potensi pemijahan berbasis panjang (length-based spawning potential ratio) digunakan untuk menduga rasio potensi pemijahan (SPR) berdasarkan data frekuensi panjang ikan dari program pendataan yang dilakukan oleh *Wildlife Conservation Society – Indonesia Program* (WCS-IP). Nilai dugaan SPR rendah (0.24); sehingga pembentukan kembali stok yang siap memijah (rebuilding spawning stock) diharapkan. Prosedur-prosedur pengelolaan yang potensial dievaluasi menggunakan perangkat lunak metode evaluasi dan pendugaan resiko (*Method Evaluation and Risk Assessment*/MERA) untuk menilai keberlanjutan jangka panjang dan hasil tangkapan dari stok *P. leopardus*. Prosedur pengelolaan terbaik untuk membentuk kembali stok pemijahan adalah pembatasan ukuran tangkap, penutupan spasial atau kawasan konservasi, pembatasan upaya tangkap dan total tangkapan. Baru-baru ini, telah disusun sebuah rencana pengelolaan perikanan untuk perikanan ini, melalui konsultasi dengan WCS-IP, Kementerian Kelautan dan Perikanan, pemerintah provinsi, nelayan dan pengumpul. Meskipun terlihat berkinerja baik di dalam simulasi MERA, prosedur pengelolaan berbasis pembatasan total tangkapan barangkali tidak dapat diterapakan oleh karena jumlah dari nelayan skala-kecil (yang menggunakan kapal-kapal berukuran <1 GT) yang terlibat di dalam perikanan ini serta pertimbangan kekhususannya sebagaimana disebutkan di dalam Undang-Undang di Indonesia. Langkah-langkah pengelolaan *P. leopardus* yang diterapkan saat ini berupa pembatasan ukuran tangkap (>300 gram), pengaturan alat tangkap (ukuran mata jaring insang 102 mm [>4 inci]), pelarangan penggunaan hookah untuk speargun, penutupan spasial berskala kecil serta larangan praktik penangkapan ikan yang merusak (seperti bom ikan dan sianida). Namun demikian, kepatuhan terhadap langakah pengelolaan yang terakhir ini kemungkinan akan bermasalah. Untuk memperbaiki pengelolaan lebih lanjut di masa datang, musim-musim pemijahan (reproduksi) dan habitat-habitat kunci untuk spesies ini (seperti lokasi-lokasi pemijahan) harus diidentifikasi. Informasi ini akan memudahkan pemerintah, nelayan dan industri perikanan untuk mempertimbangkan opsi-opsi langkah pengelolaan tambahan seperti penutupan musiman selama waktu pemijahan atau penutupan spasial untuk lokasi-lokasi pemijahan yang telah diketahui.

8.1 Biology

8.1.1. Taxonomy

Scientific name: *Plectropomus leopardus* (Epinephelidae; grouper)

Common names: Leopard Coral Grouper, Leopard Coral Trout, Coral Trout (English), and *Kerapu Sunu Merah* (Bahasa Indonesia)

8.1.2. Key identifying features

The body of *P. Leopardus* is robust and elongate (length = 2.9–3.9 × depth for fish 120–500 mm). Head length is about one-third of the standard length. *P. leopardus* superficially resembles other species of *Plectropomus*. It is often misidentified as *P. maculatus*; however, a blue ring around the eye is a distinctive characteristic of *P. leopardus*, which also lacks ventral spots, and the spots on the head are never elongated (Craig et al., 2011; Fishbase, 2019).

8.1.3. Distribution

Worldwide: The species is distributed in the Western Pacific from southern Japan to Australia (Queensland and Western Australia), and from Thailand and Malaysia eastward to the Solomon Islands, Caroline Islands and Fiji, in depths from 3 to 100 m (Andamari, 2007; Craig et al., 2011; Frisch et al., 2016). *P. leopardus* has been recorded in the waters of Australia, Brunei Darussalam, China, the Disputed Territories (Paracel Is., Spratly Is.), Fiji, Hong Kong, Indonesia, Japan, Macao, Malaysia, Marshall Islands, New Caledonia, Niue, Palau, Papua New Guinea, Philippines, Solomon Islands, Taiwan, Thailand, Timor-Leste, Tonga, Vanuatu, Vietnam, and the Wallis and Futuna Islands (Choat and Samoilys, 2018; Frisch et al., 2016). Records from the western Indian Ocean are likely based on mis-identifications of *P. laevis*.

Indonesia: *P. leopardus* is distributed throughout the Indonesian archipelago and inhabits coral reefs from shallow to deeper waters (3–100 m). Like other species in the genus, *P. leopardus* is a monandric protogynous species: sexual development involves differentiation as immature females, followed later by sex-change to males. However, male *P. leopardus* derive from either immature or mature females, or via diandric protogyny; that is, there are two terminal-phase males – an aggressive, colourful terminal phase and a smaller, drab and relatively non-aggressive initial-phase male that may become a terminal phase after the death or removal of the terminal-phase male (Frisch et al., 2016). The process of sex change in this group is remarkably labile and occurs over wide size and age ranges, suggesting that it is under social control, although this requires confirmation (Frisch et al., 2016). Most studies of Leopard Coral Grouper in Indonesia have not differentiated between males and females, except for that of Alamsyah et al. (2013) (see also Table 8.2).

8.1.4. Maximum length, weight and age

The maximum recorded size (total length, TL) for *P. leopardus* is 1200 mm (male/unsexed; Craig et al., 2011) and the maximum (published) weight, 23.6 kg (Kailola et al., 1993). The maximum age of *P. leopardus* varies between 14 and 26 years, depending on the region (Agustina et al., 2017; Mathews and Samuel, 1987). The maximum recorded total lengths in Fisheries Management Area (FMA) 713 in Indonesia range from 460 mm in the Wakatobi Islands of southeast Sulawesi to 704 mm in Saleh Bay, Sumbawah (Table 8.1; Agustina et al., 2017).

Table 8.1. Total length of Leopard Coral Grouper (*Plectropomus leopardus*) recorded in locations of the Indonesian archipelago

Total length (mm)	Number measured	Location	Reference
200–571	849	Sarrapo Island, Pangkep Regency, south Sulawesi	Ernaningsih et al. (2019)
199–704	1159	Saleh Bay, Sumbawa Island, West Nusa Tenggara	Agustina et al. (2017)
175–525	291	Lumulumu Island, south Sulawesi	Ernaningsih et al. (2015)
290–460	24	Karang Kapota, Wakatobi Islands, southeast Sulawesi	Alamsyah et al. (2013)
320–553	NA	Spermonde Islands, South Sulawesi	Sitepu (2007) in Ernaningsih et al. 2019

NA = not available.

8.1.5. Weight-length relationship

The weight-length relationship of fish varies between locations due to environmental characteristics and fishing pressure (Table 8.2). Currently, the weight-length relationship from Saleh Bay, Sumbawa, is unknown. However, the weight-length relationship of *P. leopardus* in the same FMA (713) in the waters of south Sulawesi and southeast Sulawesi has been recorded (Table 8.2). The power of this relationship ranged from 2.097 (males, Wakatobi Islands) to 2.639 (females, Wakatobi Islands) and was 2.23 for both sexes from Sarrepo Island, south Sulawesi, which was the only location where more than 125 fish were measured (Table 8.2).

Table 8.2. Weight-length relationships for Leopard Coral Grouper (*Plectropomus leopardus*) in the waters of various locations in the Indonesian archipelago

a	b	Sex	Number measured (n)	R^2	Location	Reference
0.22	2.23	Both	849	0.88	Sarrapo Island, Pangkep Regency, south Sulawesi	Ernaningsih et al. (2019)
0.342	2.097	M	24	0.303	Karang Kapota, Wakatobi Islands, southeast Sulawesi	Alamsyah et al. (2013)
1.279	2.639	F	91	0.44	Karang Kapota, Wakatobi Islands, southeast Sulawesi	Alamsyah et al. (2013)

a = constant; b = power; R^2 = cooefficient of determination; M = male; F = female.

8.1.6. Growth

Agustina et al. (2017) reported the growth parameters of *P. leopardus* in Saleh Bay for both sexes combined: L_∞ = 719 mm, k (year^{-1}) = 0.1, and t_0 = –1.2 (n = 1159). Although the Leopard Coral Grouper is a protogynous hermaphrodite, changing sex from female to male as they grow, rarely have growth studies in Indonesia considered the growth of males and females separately. Some growth parameters for *P. leopardus* reported from other locations (including in Indonesia) vary widely; for example, L_∞ (416–924 mm) and k (0.21 to 1.2 year^{-1}) (Table 8.3). Note that two of the studies with estimates of L_∞ <500 and values of k >0.8 were based on relatively few fish (<125).

Table 8.3. Growth parameters of *Plectropomus leopardus* from various studies in Indonesia and Japan

L_∞ (mm)	k (year^{-1})	t_0	Sex	No.	Location	Reference
757.0 TL	0.21	–0.24	Both	519	Indonesia: Teluk Lasongko, Buton Regency, southeast Sulawesi	Prasetya (2010)
924.0 TL	0.75	–0.15	Both	1505	Indonesia: Kolaka Regency, south Sulawesi	Landu (2013)
477.8 TL	0.81	–0.01	Both	123	Indonesia: Napan Yaur, Cendrawasih Bay, Papua	Bawole et al. (2017)
415.8 TL	1.20	–0.06	Both	87	Indonesia: Rumberpon Island, Cendrawasih Bay, Papua	Bawole et al. (2018)
612.0 FL	0.289	0.41	Both	1046	Japan: Okinawa Island	Ebisawa (2013)

L_∞ = asymptotic length; k = instantaneous growth rate; t_0 = age at length 0; TL = total length; FL = fork length.

8.1.7. Length and age at maturity

The lengths at 50% and 95% maturity of *P. leopardus* in Saleh Bay were estimated by Agustina et al. (2017) as 371.8 mm TL (L_{50}) and 480 mm TL (L_{95}) (both sexes, n = 1159). Khasanah et al. (2019) estimated the L_{50} of this species from Kapoposang Islands and Taka Bonerate National Park (both in FMA 713) as 315.6 mm TL (n = 34) and 371.8 mm TL (n = 14), respectively. The estimated L_{50} for Taka Bonerate is identical to that for Saleh Bay. These estimates of L_{50} for Indonesian waters are shorter (>60 mm) than the L_{50} of females in the Okinawa Islands (433 mm fork length, n = 1046; Ebisawa, 2013). The length at maturity (L_M) for this species in Fishbase spans a wide range (210–600 mm; Fishbase, 2019).

8.1.8. Summary of life history, habitats and movement

Habitat: *P. leopardus* inhabits coral-rich areas of lagoon reefs and mid-shelf reefs, from shallow water to 100 m depth. Adults only move locally around resident reefs, even for spawning aggregation sites. They are inactive at night, hiding under ledges (Goeden, 1978; Kailola et al., 1993; Kuiter and Tonozuka, 2001; Zeller and Russ, 1998). Juvenile *P. leopardus* are typically found on small patches of coral rubble near contiguous reef habitat with high coral cover (Frisch et al., 2016).

Feeding: Adults feed mainly on fish (Pomacentridae, Scaridae, Bleniidae Labridae, Clupeidae and Engraulididae); juveniles feed on small fish and invertebrates such as crustaceans and squid. The diet of *P. leopardus* includes many prey species that depend on live coral for food or shelter, but they also consume a substantial proportion of pelagic fishes that do not depend on coral (Frisch et al., 2016). Kingsford (1992) found most pelagic prey were taken on the reef slope in summer by *P. leopardus* >250 mm, whereas smaller fish (<200 mm) from the lagoon had a higher proportion of invertebrates in the diet. *P. leopardus* of all sizes ate small fish, but the larger fish generally consumed larger prey (especially adult scarids and labrids).

Reproduction: *P. leopardus* is a protogynous hermaphrodite. Spawning occurs in relatively small aggregations of ten to several hundred fish (Craig et al., 2011). In eastern Indonesia, spawning occurs around the new moon from October to January, with reproductive peaks in November and December (Khasanah et al., 2019). In the higher latitude waters of Okinawa Islands, Japan, the spawning season is from May to July (Ebisawa, 2013); on the Great Barrier Reef, Australia, spawning occurs from September to December (Frisch et al., 2016). Histological studies show that the size at first reproduction varies from 200–250 mm fork length to 320–360 mm (Craig et al., 2011). The estimated size at sex change in various reports from five locations in eastern Indonesia ranges from 321 mm TL (Allsop and West, 2003) to 420 mm TL (Khasanah et al., 2019).

Life history: The life cycle of *P. leopardus* comprises four stages (Kailola et al., 1993; Masuma et al., 1993):

1. ***Eggs***: The eggs are spherical and float just below the surface. They have a single oil droplet and a narrow perivitelline space. Hatching takes place 26–27 h after spawning.
2. ***Larvae***: The reported average total length of larvae is 22.7 mm. Growth rates averaged 0.38 mm/day, with a maximum of 0.53 mm/day. The average growth rate from days 55 to 83 was 1.00 mm/day. Cannibalism was seen frequently when the fish became completely demersal after about 65 days.
3. ***Juveniles***: Importantly, more than 70% of trout <150 mm TL were found living in close association with live *Acropora* coral colonies.
4. ***Adults***: Adults inhabit coral-rich areas of lagoon reefs and mid-shelf reefs. They are solitary and are inactive at night, hiding under ledges.

The Leopard Coral Grouper has a more distinct genetic population structure than those of two other species in the family: *Epinephelus polyphekadion* (Camouflage Grouper) and *P. areolatus* (Squaretail Coral Grouper). In addition, the Leopard Coral Grouper is a poorer disperser than these species due to smaller and spatially scattered aggregations that are not close to offshore waters (Ma et al., 2018). The phylogeny of *P. leopardus* remains unresolved and warrants further investigation; phylogenetic relationships from inter-species comparisons show contrasts in a range of nuclear and mitochondrial DNA sequences (Frisch et al., 2016). These findings suggest incomplete lineage sorting, independent evolution of genes, and/or introgressive hybridization (Frisch et al., 2016).

8.2. Fishery

8.2.1. Description of the fishery

Saleh Bay is located on the northern part of Sumbawa Island, West Nusa Tenggara (WNT) province, and forms part of the Indonesian Fisheries Management Area (FMA) 713 (Figure 8.1). The WNT province supports a diversity of productive fisheries resources such as pelagic and demersal fish, including grouper and snapper. Grouper production from capture fisheries in Saleh Bay reached 4844 tons in 2016 (Asrial et al., 2018). According to Ministerial Regulation No. 50/2017, FMA 713 is an Indonesian region with high grouper production, with an estimated 28,006 tons of groupers landed from FMA 713 in 2017. High export demand for grouper has caused a continuous increase in exploitation of groupers (see also Halim et al., 2020). The ministerial regulation classifies reef-fish fisheries in FMA 713 as overexploited.

Administratively, Saleh Bay spans two regencies in WNT province, Sumbawa in the west and Dompu in the east (Figure 8.1). The Saleh Bay area comprises 26 villages, with an estimated 67,000 people and approximately 3800 fishers (Agustina et al., 2017). Saleh Bay is an important fisheries area that makes a significant contribution to total reef fisheries production for both WNT province and FMA 713. Capture fisheries in Saleh Bay are dominated by small-scale fishing fleets (vessels <10 gross tonnes) (Halim et al., 2020). Most Saleh Bay fishers live in coastal villages in the region (Agustina et al., 2017). Reef fisheries production from Saleh Bay in 2014 was about 8% of the WNT total capture fisheries production; grouper and snapper production was about 5.5% of the WNT total capture fisheries production (DKP, 2018). The fishing gear used for reef fishing in Saleh Bay is dominated by traps, handlines and longlines (Figure 8.2). Fish resources in Saleh Bay are dominated by the Scombridae (15%), Epinephelidae (13%), Lutjanidae (8%), Carangidae (7%), and Siganidae (6%). Monitoring data on fish landings collected by the Wildlife Conservation Society – Indonesia Program (WCS-IP) from April 2016 to March 2017 on grouper and snapper species landed in Saleh Bay comprised 86% grouper (50 species) and 14% (24 species) snapper. The main landing sites for grouper fisheries in Saleh Bay are Sumbawa Besar City, Labuan Kuris, Labuan Jambu, and Soro (Figure 8.1; Agustina et al., 2017; DKP, 2018).

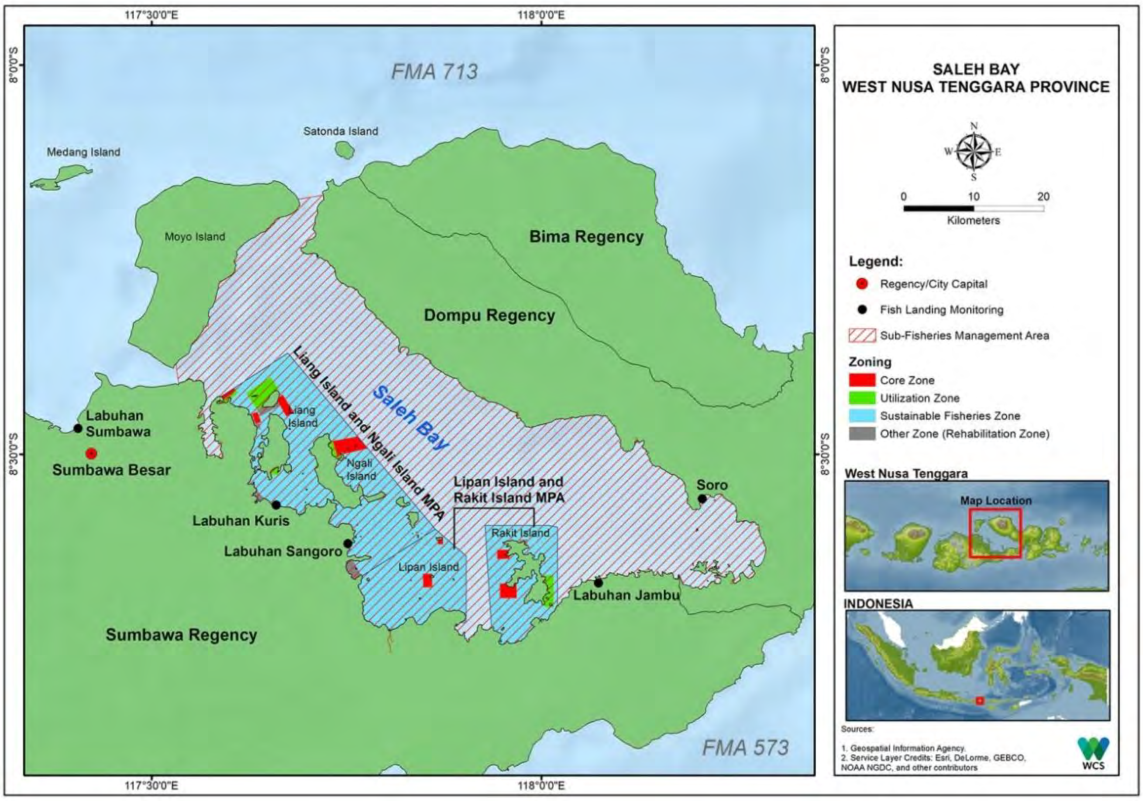

Figure 8.1. Map of Saleh Bay and existing Marine Protected Areas showing the main fishing villages around the perimeter of the bay. Based on the formal regulations, Core Zone (red) and Utilization Zone (neon green) are not accessible to fishing. (Source: WCS Indonesia Program)

8.2.2. Stock depletion and resilience

Fishing pressure on grouper and snapper stocks in Indonesia and in Saleh Bay has been increasing since the early 2000s (Halim, 2018; Halim et al., 2020). The stock of Leopard Coral Grouper in Saleh Bay has been estimated as moderately depleted based on the length-based spawning potential ratio (LBSPR) (Halim et al., 2020; Hordyk et al., 2015; Prince et al., 2015). The LBSPR estimation of *P. leopardus* in Saleh Bay was 0.24 in 2017 (Agustina et al., 2017), even lower (~0.10) according to Halim (2018) and Halim et al. (2020). Species resilience estimated by vulnerability rate – for example, on the Great Barrier Reef – is moderate (Currey et al., 2010).

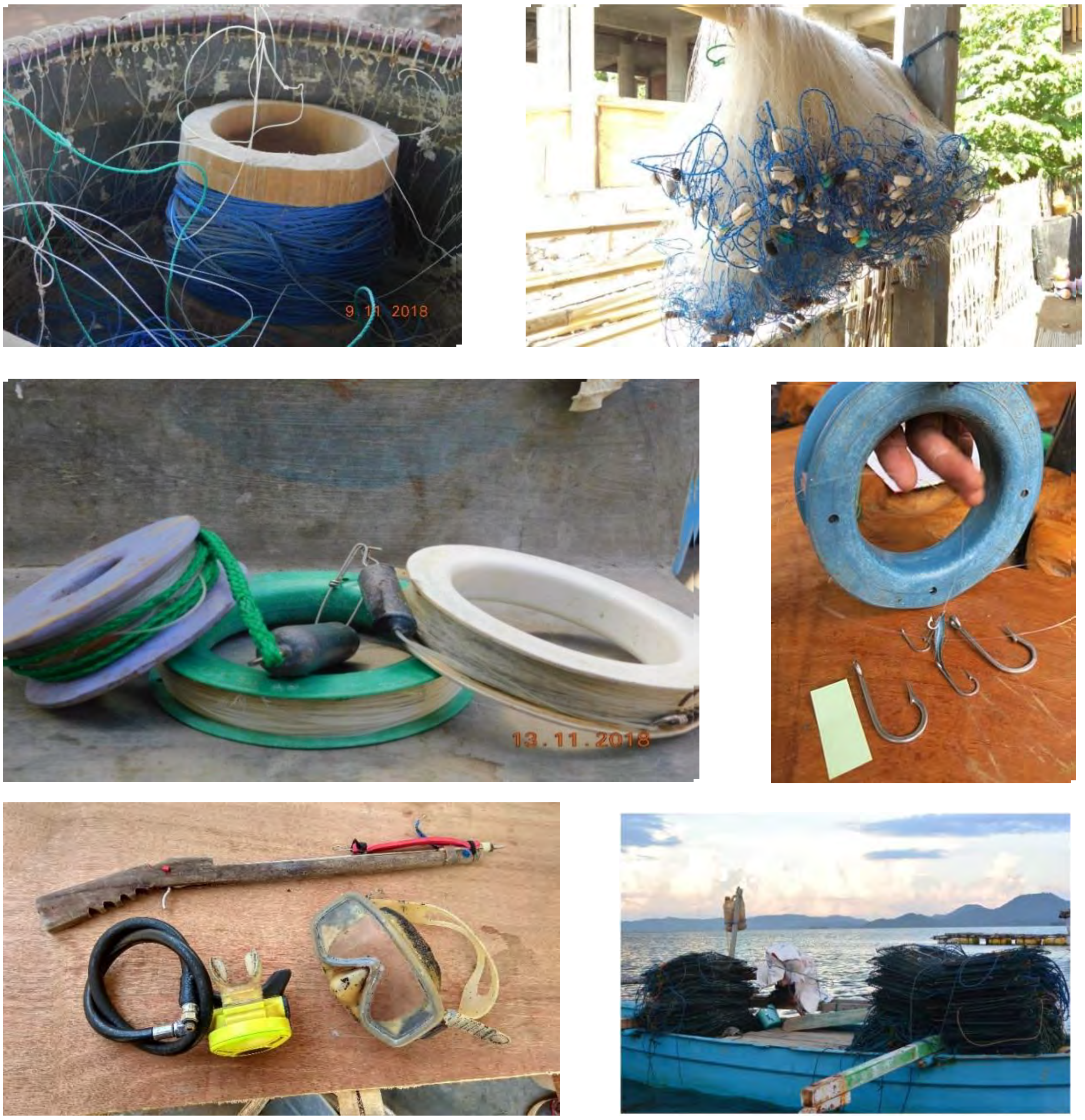

Figure 8.2. Fishing gear used in Saleh Bay, Sumbawa, for grouper fishing: mini-longline (top left), gillnet (top right), dropline (centre left), handline (centre right), speargun (bottom left), and traps (bottom right) (Images: Wildlife Conservation Society – Indonesia Program).

8.2.3. Fishing effort: history, variability and changes in fishing efficiency

In general, the fishing effort in Saleh Bay and FMA 713 has been increasing over time. According to Indonesian fisheries data from 2001 to 2011, the number of fishing trips in FMA 713 increased steadily from 2001 (~10,350) to 2010 (~11,400), then jumped sharply in 2011 (~54,700, Figure 8.3a). In Saleh Bay, fishing efficiency has also been increasing over time due to the use of hookah compressors for spearfishing, the introduction of artificial bait for handline fishing, improved engine power of boats, and communication technology that allows more efficient information exchange among fishers (Saleh Bay fishers, pers. comm., 2019; Halim et al., 2020). According to fisheries data from 2001 to 2011, the annual nominal catch per unit effort (CPUE, i.e. per trip) has increased over time, except in 2011 when it declined markedly, probably because of the knock-on effect of the sudden increased CPUE in 2010 (Figure 8.3b). The expected fishing efficiency depends on the effectiveness of different management actions. For example, enforcing existing fishing regulations should reduce fishing efficiency for some types of gear – for instance, spearfishing (from reduced use of hookah compressors) and gillnets (from increased mesh size). However, fishing effort would probably increase if the existing fisheries management could successfully recover the stock of *P. leopardus* in Saleh Bay. *P. leopardus* fisheries have been heavily depleted in other regions. Prince et al. (2015) estimated the SPR in Palau was only 0.1%, and few fish >400 mm TL were caught.

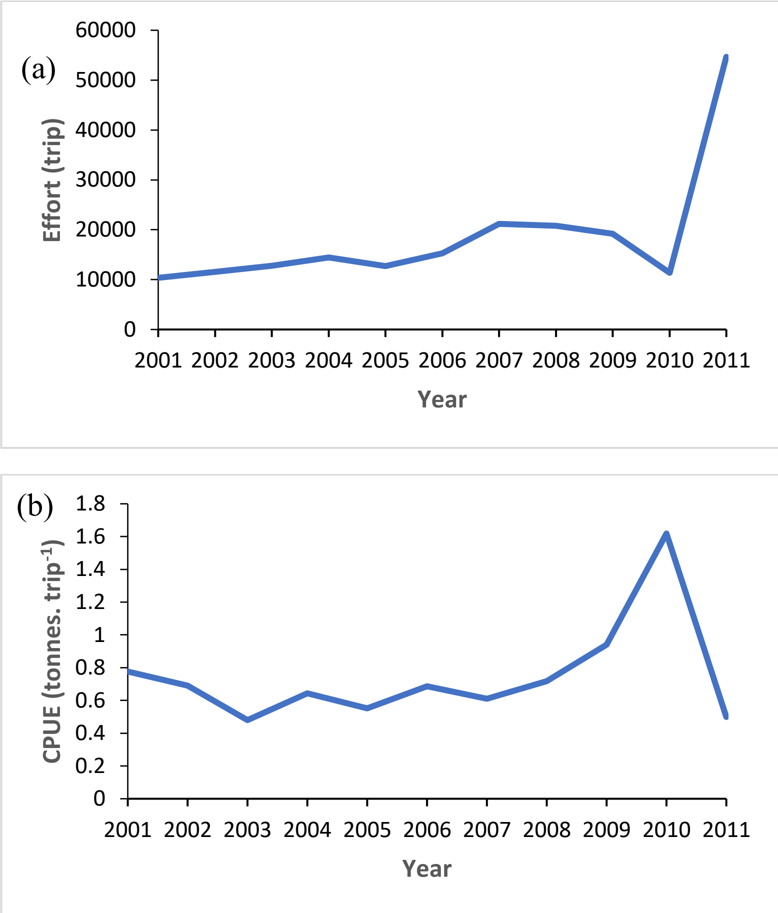

Figure 8.3. The trend in (a) fishing effort, measured by the number of trips for grouper fishing in FMA 713, and (b) catch per unit effort (CPUE, tonnes per trip) between 2001 and 2011. (Source: Indonesian fisheries data, Ministry of Marine Affairs and Fisheries)

8.2.4. Selectivity of fishing methods and discard rates

Halim (2018) reported the overall selectivity (SL_{50}) of all gears for *P. leopardus* – estimated by LBSPR and using length data collected by enumerators around Saleh Bay – as 285 mm TL. Length at first capture was estimated as 285 mm TL (Halim, 2018), and at 298.2 mm based on additional years of data (Agustina et al., 2019). This higher figure indicates that the length of fish landed in the additional years is greater than that of earlier years. Fifty per cent of the surveyed catch of *P. leopardus* in Saleh Bay in 2016–17 was taken with spearguns, 17% with handlines, and 15% with bottom longlines; less than 1% was taken in traps (Table 8.4).

Table 8.4. Catch of *Plectropomus leopardus* by type of fishing gear in Saleh Bay, Indonesia

Fishing Gear	Total catch (%)
Speargun	50
Handline	17
Bottom longline	15
Troll line	10
Dropline	7
Trap	0.5

Based on fish-landing data recorded by enumerators of Wildlife Conservation Society – Indonesia Program, between 2016 and 2017 in Saleh Bay, Sumbawa, Indonesia; n = 1159.

8.3. Management regulations

8.3.1. Current management

The existing management of grouper and snapper species in Saleh Bay aims to improve the current stock health because of the low SPR estimates. A rebuilding target of 0.3 SPR was set during the development of the fishery management plan for *P. leopardus* in Saleh Bay. Under the Fisheries Plan of Action for Saleh Bay, *P. leopardus* is categorised as a fully exploited species with an estimated SPR of 0.24 (DKP, 2018; based on fish-landing monitoring data, WCS-IP, 2016–17). The current management procedures for this species in Saleh Bay include measures to reduce the capture of small fish, spatial closures to protect the spawning stock, and limiting destructive fishing practices:

1. Size limit: increase fishers' awareness of the depleted stocks, the need to avoid catching small fish, and the current size limit for *P. leopardus* in Saleh Bay (300 g).
2. Size limit: control mesh size of gillnet – ≥4 inch stretch mesh (~102 mm).
3. Spatial closure: enforce no fishing activities inside the Core Zone and limited activity in the Utilization Zone of the Liang Ngali and Rakit Lipan marine protected areas (total 4355 Ha, i.e., 2% of total area of Saleh Bay; see Figure 8.1).
4. Non-destructive fishing: ban destructive fishing activities (blast fishing, cyanide fishing, compressor use).
5. Non-destructive fishing: avoid use of corals as weights in trap fishing.

The size-limit regulation for *P. leopardus* (>300 g) is currently being implemented, and its effectiveness is monitored. Based on catch monitoring in 2018, compliance with this regulation appears relatively high. This is due to the collaborative planning process as part of the Fisheries Plan of Action, in which fishers and fish collectors agreed to the minimum size of 300 g. In addition, although the SPR had not increased 12 months after implementing the size limit, in 2018 the SPR was maintained at 0.24 (cf. 2016 baseline SPR of ~0.10; Halim et al. 2020), which is possibly a positive indicator of the effectiveness of the regulation (WCS-IP, unpublished data). Destructive fishing activities remain the main challenges for sustaining fisheries in Saleh Bay because of the limited enforcement activities by provincial government. These destructive fishing practices continue, despite various awareness activities by government and WCS-IP. Further reducing the use of these practices in Saleh Bay will require strong enforcement of regulations and a commitment of human and financial resources from the provincial government.

8.3.2. Future management options

Identifying the reproductive seasons and key habitats for this species (e.g. spawning aggregation sites) is required to further improve management. This information would allow other management options to be considered by government, fishers and the fishing industry, including seasonal closure during spawning season and spatial closure for known spawning aggregation sites.

8.4. Data sources

The following data sources were used to summarise information on the Leopard Coral Trout for this report:

- Agustina et al. (2017)
- Agustina et al. (2019)
- Halim (2018)
- Halim et al. (2020)
- Indonesian fisheries statistical data from the Ministry of Marine Affairs and Fisheries (MMAF)
- West Nusa Tenggara Provincial Working Group for Grouper and Snapper.

WCS-IP conducted a fish-landing monitoring program at six major landing sites in Saleh Bay for 7–15 days every month from 2016 to 2018. All enumerators recorded information on fishing trips (e.g. length of boat, fishing gear, and fishing ground) and catch data (e.g. total catch, catch per species, and length of sampled fish). Additionally, enumerators recorded the length of fish and the fishing ground of capture at selected places in Labuhan Sumbawa.

8.5. Management planning in MERA

Management planning with the Method Evaluation and Risk Assessment (MERA) tool developed by Carruthers and Hordyk (University of British Columbia) involved completing the MERA questions for the species, fisheries, management and data characteristics (see Appendix 8.1). All answers were based on current data, information from the literature, and expert judgment from people who have been working to assist fisheries management planning in Saleh Bay.

Based on characteristics of the fisheries in Saleh Bay, the existing fisheries regulations in Saleh Bay, and regulations in Indonesia in general, feasible, effective approaches to fisheries management for *P. leopardus* fishing in Saleh Bay are (a) limiting catch and effort, (b) implementing size limits, and (c) area closures through establishing marine protected areas. Hence, four management types were selected in MERA for *P. leopardus* management in Saleh Bay: catch limit (total allowable catch, TAC), effort limit (total allowable effort, TAE), size limit, and time-area closure (marine reserve). The processes and outcomes from the MERA application were as follows:

1. From the MERA simulations, four management approaches were selected based on best performance in terms of trade-offs between sustaining the stock and long-term yield (Table 8.5):
   a. setting TAE with a maximum 10% change annually (ITe10)
   b. spatial closure (marine reserve) with reallocation (MRreal) and no reallocation (MRnoreal) of fishing effort outside the closure
   c. setting TAC
   d. setting size limits

   The TAE and TAC based on the delayed-difference stock assessment approach had the lowest $B{:}B_{MSY}$ (biomass relative to biomass at maximum sustainable yield) of the four options (Table 8.5); the predicted yield for the TAE with the ITe10 option was more variable than that of other management procedures (Figure 8.4).
2. In terms of effective implementation of management procedures in Saleh Bay, applying size limits, effort control, and spatial closures are possible within the existing management framework – these measures fit within the objectives of existing fisheries management and the Fisheries Plan of Action. Although MERA showed that a TAC performed well (Table 8.5), introducing a TAC would be difficult because the fishery is dominated by small-scale fishers, with no permit required and no catch documentation system currently in place (Halim et al., 2019).
3. The selected management procedures (size limit, TAE, and spatial closure) could be applied in Saleh Bay provided (a) sufficient data are available, including a commitment from local government and WCS-IP to continue catch monitoring; (b) the current size limit regulation is implemented; and (c) the processes of collaborative management and annual evaluation of the Fisheries Plan of Action in Saleh Bay continue. This information and processes would allow potential new management procedures (e.g. TAE and spatial closure) to be considered if the existing regulations fail to meet management objectives (Table 8.5).

Table 8.5. The 10 best-performing management procedures from the Method Evaluation and Risk Assessment (MERA) simulations for Leopard Coral Grouper (*Plectropomus leopardus*) management in Saleh Bay, Indonesia

Management procedure	Regulation type	Prob. $B > 0.5\ B_{MSY}$	Prob. $B > B_{MSY}$	Short-term Yield	Long-term Yield
ITe10	TAE	0.79	0.61	0.62	0.62
MRreal	Spatial	0.74	0.64	0.61	0.55
MRnoreal	Spatial	0.85	0.66	0.51	0.52
DBSRA_40	TAC	0.76	0.58	0.5	0.47
Matlenlim	SL	0.74	0.65	0.5	0.46
Matlenlim2	SL	0.75	0.65	0.49	0.45
Fratio	TAC	0.51	0.34	1.3	0.57
IT10	TAC	0.70	0.62	0.78	0.3
IT5	TAC	0.67	0.6	0.78	0.3
DCAC_40	TAC	0.98	0.84	0.24	0.25

Blue shading = four options with highest likelihood of maintaining long-term catches and maintaining yield. TAE = total allowable effort; spatial = spatial closure; TAC = total allowable catch; SL = size limit; ITe10 = total allowable effort with maximum of 10% change annually; MRreal = spatial closure with reallocation of fishing effort; MRnoreal = spatial closure with no reallocation of fishing effort; matlenlim = size limit based on size at maturity.

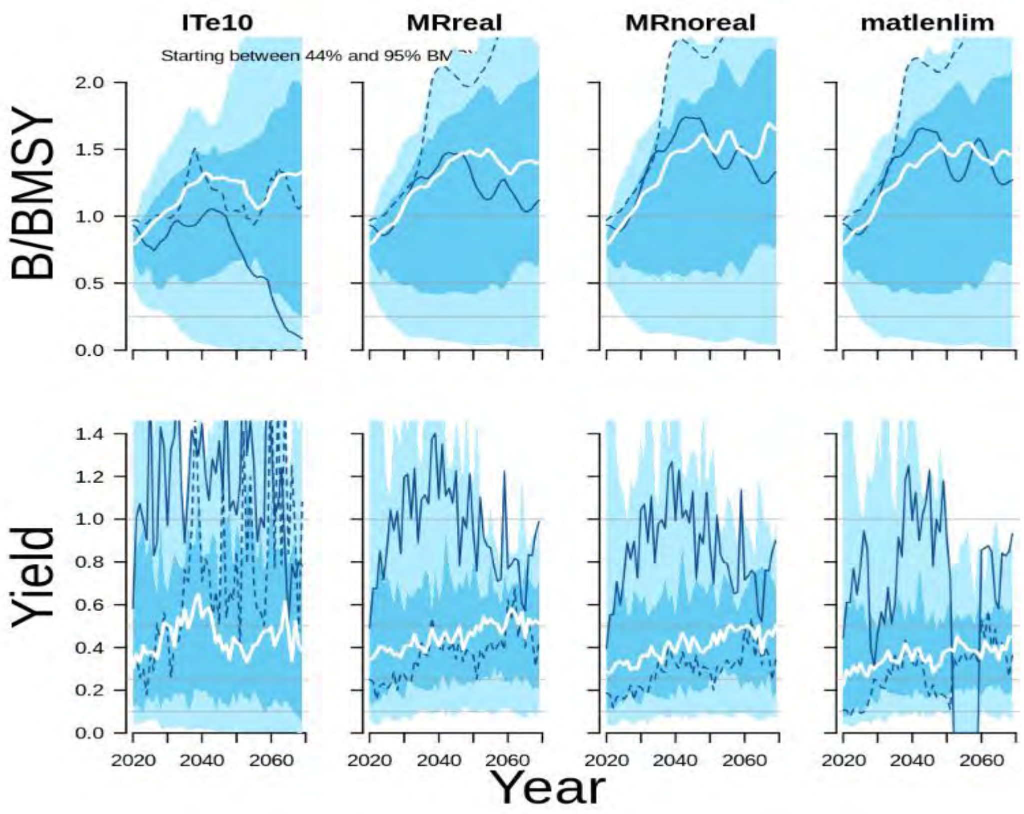

Figure 8.4. Simulated performances (biomass relative to biomass at maximum sustainable yield [B_{MSY}] and relative yield) of four management planning options for Leopard Coral Grouper (*Plectropomus leopardus*) management in Saleh Bay over 50 years. The shaded regions represent the 90% (light blue) and 50% probability (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5, and 1. ITe10 = total allowable effort with maximum of 10% change annually; MRreal = spatial closure with reallocation of fishing effort; MRnoreal = spatial closure with no reallocation of fishing effort; matlenlim = size limit based on size at maturity.

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Appendix 8.1

Table 8A.1. Questions and answers for the Method Evaluation and Risk Assessment (MERA) operating model

No.	Questions	Answers	Reference
	Fisheries characteristics		
1	Longevity or lifespan	Moderate life span (10< maximum age <20) to moderately long-lived (20< maximum age <40)	Agustina et al. (2019); Ferreira and Russ (1994); Russ et al. (1998)
2	Stock depletion (D)	Moderately depleted (0.15< D <0.3)	Expert judgement
3	Resilience	Moderate resilience (steepness 0.5–0.7)	Expert judgement
4	Historical effort pattern	Stable, recent increases	MMAF (Ministry of Marine Affairs and Fisheries) Fisheries Statistics 2016
5	Inter-annual catch (IAC) variability in historical effort	Highly variable (maximum IAC between 50% and 100%)	MMAF Fisheries Statistics 2016
6	Historical fishing efficiency changes	Increasing by 1–2% p.a. (doubles every 35–70 years) to increasing by 2–3% p.a. (doubles every 25–35 years)	MMAF Fisheries Statistics 2016
7	Future fishing efficiency changes	Increasing by 1–2% p.a. (doubles every 35–70 years) to increasing by 2–3% p.a. (doubles every 25–35 years)	MMAF Fisheries Statistics 2016; expert judgement
8	Length at maturity (LM)	Very small (0.4< LM <0.5) to small (0.5< LM <0.6)	Khasanah et al. (2019)
9	Selectivity of small fish (S)	Small (0.2< S <0.4) to half asymptotic length (0.4< S <0.6)	Halim (2018); Agustina et al. (2019)
10	Selectivity of large fish (SL)	Dome-shaped selectivity (0.25< SL <0.75)	Halim (2018); Agustina et al. (2019)
11	Discard rate (DR)	Moderate (10% < DR <30%)	Expert judgment
12	Post-release mortality rate (PRM)	Moderate (25% < PRM <50%)	Expert judgment
13	Recruitment variability	Low (max IAC between 20% and 60%)	Agustina et al. (2019)
14	Size of an existing marine protection	Small (A <5%) to small-moderate (5% < A <10%)	WCS (unpublished data)

No.	Questions	Answers	Reference
		Fisheries characteristics	
	area (MPA; no take area A)		
15	Spatial mixing (movement) in/out of existing MPA	Low (1% < P <5%)	Kailola et al. (1993); Kuiter and Tonozuka (2001); Randall et al. (2003); Zeller and Russ (1998)
16	Size of a future potential MPA	Small (A <5%) and small-moderate (5% < A <10%)	WCS (unpublished data)
17	Spatial mixing (movement) in/out of future potential MPA	Very low (P <1%)	Kailola et al. (1993); Kuiter and Tonozuka (2001); Randall et al. (2003); Zeller and Russ (1998)
18	Initial stock depletion (D1)	Very low (0.1< D1 <0.15) to low (0.15< D1 <0.3	Agustina et al. (2017); Halim (2018)
		Management (Types of fishery management that are possible)	
1	TAC (total allowable catch): a catch limit	All options are selected (no justification)	Expert judgment (WCS)
2	TAE (total allowable effort): an effort limit	All options are selected (no justification)	Expert judgment (WCS)
3	Size limit	All options are selected (no justification)	Expert judgment (WCS)
4	Time–area closures (a marine reserve)	All options are selected (no justification)	Expert judgment (WCS)
		Data	
1	Available data types	[Data poor] Historical annual catches (from unfished); Recent annual catches (at least 5 recent years); Historical relative abundance index (from unfished); Recent relative abundance index (at least 5 recent years); Fishing effort; Size composition (length samples); Age composition (age samples); Growth (growth parameters); Absolute biomass survey	Expert judgment
2	Catch reporting bias	All options are selected (no justification)	Expert judgment

No.	Questions	Answers	Reference
	Fisheries characteristics		
3	Hyperstability in indices	All options are selected (no justification)	Expert judgment

9. Fisheries management for the Humpback Red Snapper (*Lutjanus gibbus*) in the waters of southern Banten province, Indonesia

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Lutjanus gibbus, the Humpback Red Snapper (English), or *kakap merah* (Bahasa Indonesia)
(Image: Prihatiningsih)

Summary

The Humpback Red Snapper, *Lutjanus gibbus*, belongs to the Family Lutjanidae (Snapper). It inhabits waters in the western Indo-Pacific, East Africa, Australia, and northward to southern Japan. It is an important commercially targeted species caught by a range of small-scale to large-scale fishing fleets and is sold mainly as frozen products in both domestic and export markets. The Humpback Red Snapper is a long-lived species with a maximum age of 24 years (in the waters of Okinawa, Japan); it begins to mature at 6 years. Adult Humpback Snapper are mainly found on coral reefs, often forming large, stationary aggregations during the day. In the waters of southern Banten, south Java (Fisheries Management Area [FMA] 573), snapper are targeted by small-scale fishers

using mainly handlines and bottom longlines. Fishing boats of about 3 gross tonnes are equipped with an outboard engine and operated by two people who fish for 1 day per trip for handline and 2–5 days per trip for longline. The length-based spawning potential ratio (SPR) was estimated from length-frequency data for *L. gibbus* collected in the Timor Sea (the eastern part of FMA 573) and information on the growth and size at maturity of this species. The median estimated SPR of 2% indicates that the species has been heavily exploited. Currently, no management measures are in place specifically for *L. gibbus* in the waters of southern Java. However, the fishing grounds in the waters of southern Banten might benefit from the no-take areas (*zona perlindungan bahari*) of Ujung Kulon National Park, located about 55 nautical miles from the fishing ground. Several researchers have recommended larger hook sizes (> No. 10) and reducing the present fishing effort by up to 40% to reduce catches of smaller fish and decrease the overall catch. The results of the Method Evaluation and Risk Assessment (MERA) analyses indicated that all selected best management procedures involved implementation of total allowable catches (TACs). Indonesia, through Fisheries Decree No.50/2017 of the Ministry of Marine Affairs, has adopted the TAC approach for managing fisheries in its 11 FMAs. Nevertheless, TACs are a very coarse measure because they are determined for a group of species (not per species) and for each Indonesian FMA. They are also difficult to implement for small-scale fisheries because fishers are not required to land their catches at official landing sites. A combination of management procedures involving size limits (set to size at maturity + 10%) and spatial closures (marine reserves with no reallocation of fishing effort) may be worth investigating for this small-scale fishery. However, more information on the species is needed, including more precise location of spawning aggregation sites, to make spatial closures most effective.

Ringkasan

Kakap merah (berpunuk), *Lutjanus gibbus*, merupakan anggota dari Family Lutjanidae (Kakap) yang hidup di perairan sebelah barat Indo-Pasifik, Afrika Timur, Australia, sisi utara hingga bagian selatan Jepang. Ikan ini merupakan spesies ikan komersial yang menjadi target tangkapan armada perikanan mulai dari skala-kecil hingga skala-besar dan utamanya dijual dalam bentuk produk beku di pasar domestik dan ekspor. Ikan ini tergolong spesies yang hidupnya lama dengan t_{max} 24 tahun (di perairan Okinawa, Jepang), dan mulai dewasa pada umur 6 tahun. Ikan kakap merah berpunuk dewasa utamanya ditemukan di terumbu karang, seringkali membentuk kumpulan yang besar di siang hari, dan tidak berpindah-pindah. Di perairan bagian selatan Banten, selatan Jawa (Wilayah Pengelolaan Perikanan [WPP] 573) kakap menjadi target nelayan skala kecil yang utamanya menggunakan pancing ulur dan rawai dasar, menggunakan kapal ukuran ~3 GT dilengkapi dengan mesin luar dan dioperasikan oleh dua orang yang menangkap ikan selama satu hari per hari melaut untuk pancing ulur dan dua hingga lima hari per hari melaut untuk rawai dasar. Pengumpulan data frekuensi panjang *L. gibbus* di Laut Timor (di bagian ujung timur WPP 573) dan informasi mengenai pertumbuhan dan ukuran saat dewasa dari spesies ini, memungkinkan untuk dilakukan pendugaan terhadap rasio potensi pemijahan (SPR) berbasis panjang dari spesies tersebut. Hasil dugaan menunjukkan nilai tengah (median) SPR 2%, yang mengindikasikan bahwa spesies ini telah mengalami laju penangkapan yang tinggi. Belum tersedia langkah-langkah pengelolaan yang sudah ada, tetapi lokasi penangkapan di perairan selatan Banten ini mungkin saja memperoleh keuntungan dari keberadaan area-area larang ambil (zona perlindungan bahari) dari Taman Nasional Ujung Kulon, yang berlokasi sekitar 55 mil laut dari lokasi penangkapan. Meskipun demikian, sejumlah penelitian telah merekomendasikan menggunakan mata pancing berukuran besar (ukuran mata pancing > No. 10) dan mengurangi upaya penangkapan saat ini hingga sebesar 40% untuk menghindari penangkapan ikan berukuran lebih kecil dan mengurangi laju kelepasan perikanan. Hasil-hasil dari analisa MERA mengindikasikan bahwa semua Prosedur Pengelolaan terbaik yang terpilih melibatkan penerapan batasan tangkapan yang diperbolehkan (TAC). Indonesia, melalui Keputusan Menteri Kelautan dan Perikanan No. 50/2017 telah mengadopsi pendekatan TAC ini. Namun demikian, TAC yang tersedia masih berupa ukuran yang sangat luas, karena ditetapkan untuk setiap kategori/kelompok spesies (bukan untuk setiap individu spesies) dan per satuan WPP di Indonesia. Pendekatan tersebut juga sulit diterapkan untuk nelayan kecil karena mereka tidak diwajibkan untuk mendaratkan hasil tangkapan di pelabuhan perikanan yang resmi.

9.1. Biology

9.1.1. Taxonomy

Scientific name: *Lutjanus gibbus* (Forsskal, 1775), Family Lutjanidae

Common names: Humpback Red Snapper, Paddle-tail Snapper (English); *kakap merah, tambak, jenaha, kikil* (Bahasa Indonesia)

9.1.2. Key identifying features

Humpback Red Snapper have a vomerine tooth patch lacking a posterior extension. The caudal fin is forked with distinctly rounded lobes and is reddish to greyish. Juveniles have a blackish caudal peduncle and dark caudal fin with a yellow outer margin (White et al., 2013).

9.1.3. Distribution

Worldwide: *L. gibbus* are found in the waters of the western Indo-Pacific, East Africa, Australia and southern Japan (Carpenter and Niem, 2001).

Indonesia: The species is found in the Java Sea, Sunda Strait, Sulawesi Sea, and the waters of the Karimunjawa Islands, southern Java, southern, eastern and western Kalimantan, the Natuna Islands, the Lingga Islands, and other islands of Riau, at depths of 30–100 m (Marzuki and Djamal, 1992; Figure 9.1).

Figure 9.1. Distribution of the Humpback Red Snapper (*Lutjanus gibbus*) in the waters of Indonesian Fisheries Management Areas (Source: Base map from Google Maps).

9.1.4. Maximum length, weight and age

Prihatiningsih et al. (2017) reported the fork length (FL) of *L. gibbus* from the waters of southern Banten, Java, ranged from 103 to 415 mm FL for all fish that were measured, with an average length of 222 mm. The range in fork length for fish whose sex was determined was 103–360 mm for males and 147–324 mm for females. In the Bunaken waters of north Sulawesi, the reported FL of *L. gibbus* is 151–312 mm (Holloway et al., 2015). The wet weight of this species ranges from 40 to 1053 g, with an average weight of 266 g in Bunaken waters. The maximum age reported for male *L. gibbus* from Ishigaki Island, Okinawa, Japan, is 21 years; for females, 24 years (Nanami et al., 2010). There are no studies on the age of *L. gibbus* in Indonesian waters.

9.1.5. Weight-length relationship

The relationship between wet weight (W) and fork length (L) of male *L. gibbus* in southern Banten waters (South Java, Indonesia) is $W = 2\text{x}10^{-5}L^{3.030}$, and for females, $W = 0.019L^{3.033}$; the correlation coefficients (r) are 0.99 and 0.97, respectively (Prihatiningsih et al., 2017). The weight-length relationship for the combined sexes of *L. gibbus* in Bunaken waters is $W = 0.000008L^{3.14}$ ($r = 0.94$) (Holloway et al., 2015).

9.1.6. Growth

The von Bertalanffy growth equations for male and female *L. gibbus* in Japanese waters are $L(t) = 390.5[1\text{-}e^{-0.210\,(t-1.88)}]$ and $L(t) = 303.4[1\text{-}e^{-0.256\,(t-3.05)}]$, respectively (Nanami et al., 2010). Note that the estimated values for t_0 are very large and negative, showing that this relationship is a poor fit for small, young fish. The von Bertalanffy growth equations for male and female *L. gibbus* in southern Banten waters are estimated as $L(t) = 383.25[1\text{-}e^{-0.22\,(t-0.38)}]$ and $L(t) = 341.25[1\text{-}e^{-0.48(t-0.17)}]$, respectively (Holloway et al., 2015).

9.1.7. Length and age at maturity

The length at first maturity of *L. gibbus* in southern Banten waters (South Java) is 311.0 mm FL for males and 271.4 mm FL for females (Prihatiningsih, 2017). The length at 50% maturity has not been estimated.

9.1.8. Summary of life-history, habitats and movement

In general, the species in the red snapper group are dioecious and gonochoristic, that is, each fish has one sex (either male or female) throughout its life (Grimes, 1987). The sex ratio (males to females) of *L. gibbus* in the waters of southern Banten is 0.65:1. The spawning pattern of *L. gibbus* populations is partial spawning, that is, not all eggs are released in one spawning season (Prihatiningsih et al*.,* 2017). The eggs are floating (pelagic), range in size from 0.65 to 1.02 mm, and contain an oil globule reserve. The eggs metamorphose into larvae in 1–3 days (2 mm total length) with a yolk sac, unpigmented eyes and an unformed mouth, which develops when they reach a size of 7–8 mm standard length. The larvae are pelagic and are commonly found in areas close to shore. The pelagic larvae range in size from 12 to 20 mm total length; this stage can last from 25 to 47 days (Allen, 1985; Leis, 1987). The juveniles remain in the nursery areas for 2–4 years until they reach maturity, when they move away to join the adult populations. Red Snapper reach maturity at approximately 43–51% of their maximum length (Allen, 1985; Everson et al., 1989).

The habitats of adult Red Snapper include rocky areas on the coasts and the slopes of coral reefs up to 60 m deep (Badrudin et al*.,* 2008). Juvenile Red Snapper are found in seagrass and sandy areas as well as coral reefs. Fishing grounds for Red Snapper are the waters around coral reefs and waters that are slightly muddy (Badrudin et al*.,* 2008).

Not all Red Snapper species migrate for spawning. Two types of spawning strategies are known. Mid-size Red Snapper form aggregations and spawn – they do not migrate to spawning areas. In contrast, large Red Snapper are solitary and migrate to spawning areas (Martinez-Andrade, 2003). The adult populations that live in deeper waters, usually on the slope of the continental shelf, seem to either not migrate to spawn or migrate short distances during the spawning season. *L. gibbus* are considered mid-size fish; they form an aggregation and do not migrate to spawning areas (Martinez-Andrade, 2003).

9.2. Fishery

9.2.1. Description of the fishery

In general, fishing for snapper on coral reefs and demersal reefs in the waters of southern Banten, southern Java, in Fisheries Management Area 573 (FMA 573) is considered a small-scale fishery. Mostly handlines and bottom longlines are used to target Red Snapper (Figure 9.2). The catch composition for these two types of fishing gear is predominantly from the families Lutjanidae and Serranidae.

Handline fishing in southern Java waters is typically a one-day fishing operation using fishing boats of 3 GT (12 m length, 1.5 m width, 0.9 m depth) operated by two crew; they leave at 17:00 and return at 08:00 on the morning of the following day. Fishers use size

10 or 11 hooks, with about 40–65 hooks per line. They set the lines manually from 2–4 times per trip. Fishers usually use baits of sardine (*Sardinella* spp.) and mackerel tuna (*Euthynnus* spp.). They are also equipped with 15 long, rectangular blocks ('stems') of ice blocks for each trip.

The bottom longline fishers operate with fishing boats of 2 GT (9 m length, 1.25 m width, and 1 m depth) that are equipped with a 15 HP outboard engine and operated by two or three crew. Fishing operations are 2–5 days per trip. The bottom longlines are set with 600 hooks of size 9 and 10, operated at depths of 30–60 m (Figure 9.2). Fishers use about 20 kg of bait, usually sardines (*Sardinella* spp.), in one trip and have 8–20 longline settings per trip.

Figure 9.2. Fishing gear and vessels used in handline (top panel) and bottom longline (bottom panel) fishing for Humpback Red Snapper (*Lutjanus gibbus*) in southern Banten waters, southern Java (Fisheries Management Area 573), Indonesia. (Images: Prihatiningsih, Research Institute for Marine Fisheries)

The Red Snapper catches from handline and bottom longline fishing are landed and brought to a fish auction site for sale (Figure 9.3). The catches serve local and export markets (Prihatiningsih et al., 2017). The Research Institute for Marine Fisheries (BRPL) collected length data on Red Snapper from landing ports in Banten waters of southern Java in 2013, 2015 and 2016. Combined with information on the biological parameters of *L. gibbus,* this data allowed estimation of the spawning potential ratio (SPR) with the length-based spawning potential ratio methodology. The estimated SPR of *L. gibbus* in the Timor Sea in the eastern part of FMA 573 is 2% (Halim, 2018; Halim et al., 2020), which means that they have been very heavily fished.

Figure 9.3. Humpback Red Snapper, *Lutjanus gibbus*, (left and middle) at a fish auction site (right) for a fishery in southern Banten waters, southern Java (Fisheries Management Area 573), Indonesia (Image: Prihatiningsih, Research Institute for Marine Fisheries).

The fishing grounds for handline and bottom longline Red Snapper fisheries are located in the waters around Ujung Genteng, Binuangeun, Tinjil island, Deli island and Panaitan, about 2–5 nautical miles from their home base in Muara Binuangeun, south-western Java (Figure 9.4). Some of the bottom longline fishers operate for 3–5 fishing days and may travel up to 50 nautical miles from their home base (Figure 9.4).

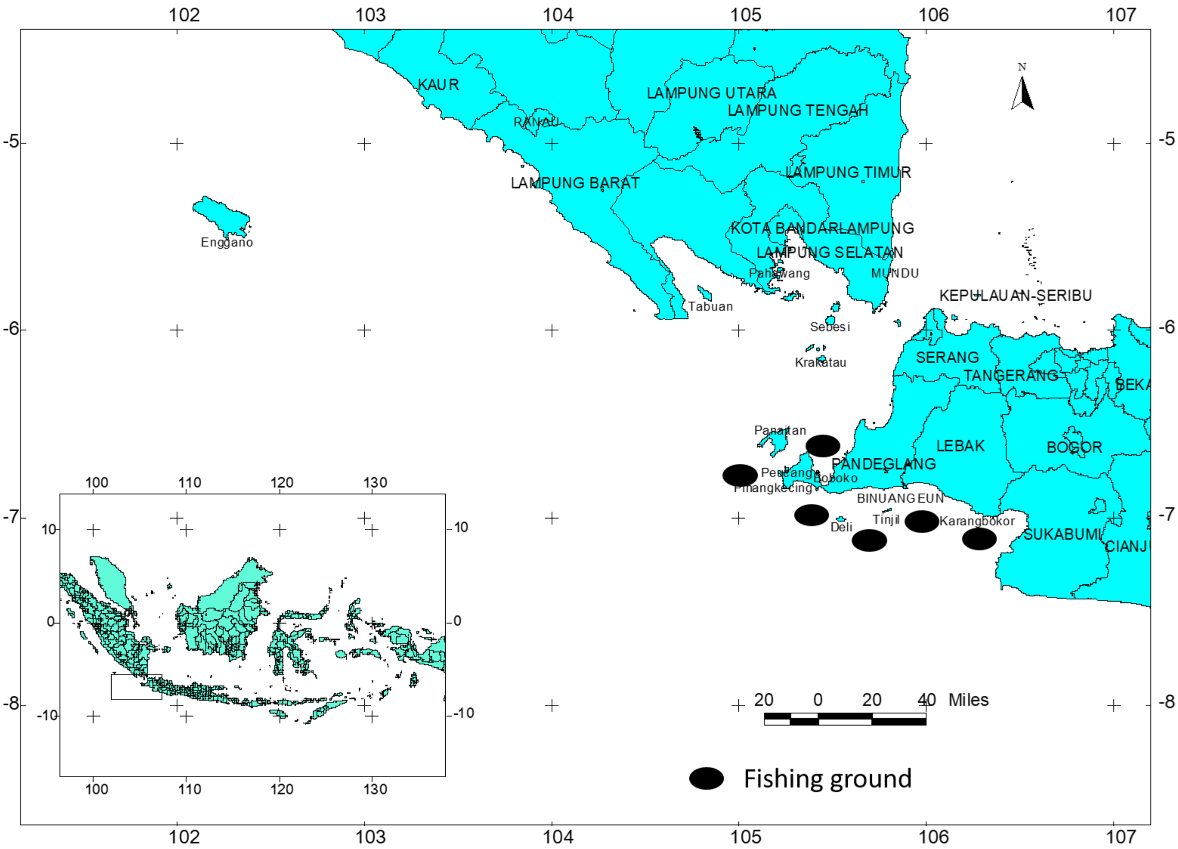

Figure 9.4. Fishing ground of bottom longline and handline fishers for Red Snapper in southern Banten waters, southern Java, Indonesia. (Map: Prihatiningsih, Research Institute for Marine Fisheries)

9.2.2. Stock depletion and resilience

Based on their relatively slow annual growth rate (*k*) of 0.2–0.4, Red Snapper (*L. gibbus*) stock in the waters of southern Banten is depleted (Prihatiningsih, 2017). Sparre and Venema (1999) state that fish with an annual growth rate of less than 0.5 grow relatively slowly and live longer. Red Snapper are therefore included in this category and thus will take a relatively long time to attain an appropriate capture size, and their asymptotic size. The Red Snapper stocks are low but should be moderately resilent because their estimated fecundity ranges from 46,774 to 130,698 eggs per spawning (Prihatiningsih et al., 2017).

9.2.3. Fishing effort: history, variability and changes in fishing efficiency

The catch per unit effort (CPUE) from bottom longlines from February to June is low (<100 kg per trip), which then increases from July to November, peaking from September to November (>100 kg per trip) (Figure 9.5a). This period of peak catches occurs in the second transitional season (September to November), when weather conditions are calmer and facilitate fishing (Prihatiningsih et al., 2017). Based on data from the Directorate General of Capture Fisheries (DGCF) of the Ministry of Marine Affairs and Fisheries (MMAF), the overall catches of red snapper (Lutjanidae) in FMA 573 tended to increase from 2090 ton/year in 2005 to about 8500 ton/year in 2009, and then decreased to 3950 ton/year by 2013; the catch then increased again to about 11,000 ton/year in 2015 (Figure 9.5b). From 2014 to 2016, the total number of vessel trips for the fishing fleet in FMA 573 increased sharply from 14,297 trips to 35,337 trips. From 2005 to 2013, effort fluctuated between a low of 15,472 trips in 2010 and a peak of 26,072 trips in 2013. The two major peaks of fishing effort were in 2013 and 2016 (Figure 9.5b).

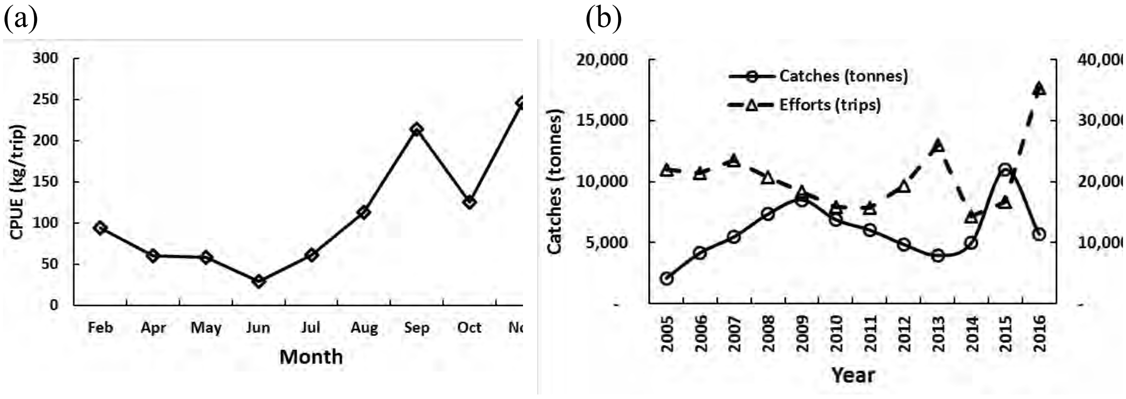

Figure 9.5. (a) Data on monthly catch per unit effort (CPUE) of bottom longliners for Humpback Red Snapper (*Lutjanus gibbus*) in southern Banten waters, Indonesia (Source: Prihatiningsih et al., 2017); (b) catch and effort trends for Red Snapper in part of Fisheries Management Area (FMA) 573, Indonesia, covering the waters of southern Java and Nusa Tenggara. (Data: Directorate General of Capture Fisheries, Indonesia)

9.2.4. Selectivity of fishing methods

Based on length-measurement data collected by the BRPL program in the years 2013, 2015 and 2016, the fork lengths (FL) of *L. gibbus* captured by handline and bottom longline in the waters of Binuangeun, southern Banten (FMA 573) ranged from 103 to 415 mm, with an estimated size at first capture of 240.3 mm FL for males and 207.1 mm FL for females (Prihatiningsih et al., 2017). These measurements are well below length at first maturity (by ~70 mm) for both sexes. The size at first capture for the bottom longline fishery in the waters of Labuhan, Pandeglang, Banten in the Java Sea (FMA 573) is 294.6 mm (Imbalan, 2013), 50 to 80 mm longer than that for the waters of southern Banten, and 20 mm longer than the size at female first maturity.

9.3. Management regulations

9.3.1. Current management

Currently, no management measures are in place for *L. gibbus* in the waters of southern Java, including in the fishing area of southern Banten. However, this fishery may be benefitting from the presence of no-fishing areas that are part of the Ujung Kulon National Park zoning system, located reasonably nearby. Based on several studies, some management measures have been identified for potential implementation: effort reduction by about 40% from the current effort to reduce fish removal; and a minimum hook size (> No. 10) to reduce catches of smaller *L. gibbus* (Prihatiningsih, 2017).

9.3.2. Future management options

There are several options for future management of Red Snapper fisheries, especially those in the waters of southern Java:

1. ***Effort reduction***: Reduce the present effort by up to 40% through adopting measures to control fishing effort (e.g. a boat registration system as the fishery is small scale), supported by relevant regulations at national and provincial level. Regular monitoring programs and law enforcement must accompany these measures.
2. ***Gear modification***: Enforce the use of larger hooks (> No. 10) to prevent catching smaller fish.
3. ***Seasonal closures***: Assess the status of coral reefs and determine the role of no-take areas within Ujung Kulon National Park for Red Snapper fisheries in the waters of southern Banten. This data could inform the national park authority for potentially expanding no-take areas, as well as the best time and areas for seasonal closures.
4. ***Setting target and limit reference points***: Assess the limit reference point and target reference point for *L. gibbus* based on the estimated SPR values in order to better monitor the status of stock over time.

9.3.3. Snapper fisheries harvest strategy in Indonesia

Presently, the snapper fisheries harvest strategy for Indonesian FMA 713 is being finalised. The draft interim harvest strategy (March 2020) states that the operational objective for the snapper harvest strategy is to either maintain or increase the spawning potential ratio (SPR) of the priority species (*Lutjanus malabaricus, Aphareus rutilans, Pristipomoides multidens*) to 40%. The value of the target reference point will be determined in accordance with the availability of data during the first half of 2020, including information on the CPUE of the fisheries. The performance indicators for snapper management will be (a) SPR, (b) length-frequency distribution, and (c) catch per unit effort (CPUE). The limit reference points were determined using both SPR and CPUE indicators, with the SPR set at 20% and the CPUE set at not less than its value at 20% SPR. In addition, the target reference point SPR is set at 40%.

9.4. Data sources

Two data sources on Red Snapper were used to support the analyses performed in this study:

- BRPL/RIMF data collected on red snapper from landing ports in Banten waters of southern Java in 2013, 2015 and 2016
- Fisheries statistics of the Directorate General of Capture Fisheries of the MMAF.

9.5. Management Planning in MERA

Method Evaluation and Risk Assessment (MERA) is a tool to quantitatively evaluate suitable management approaches for a fishery using simulation modelling. This method provides fisheries managers with powerful tools to identify species at risk, select management procedures (MPs) that can achieve their performance objectives, and calculate stock status (Carruthers, 2019). Until recently, fisheries management has often depended on subjective, qualitative frameworks to evaluate biological risks in fisheries, for example, Productivity Susceptibility Analysis (PSA; https://issfoundation.org/glossary/productivity-and-susceptibility-analysis/). The PSA analysis is informed by subjective expert judgement, which sometimes makes it hard to evaluate the validity of the assumptions and the quality of advice provided. Hordyk and Carruthers (2018) found that when the PSA analysis was codified and tested by simulations, it performed poorly.

The MERA methodology involves completing sets of quantitative questionnaires; there are 30 questions, 19 about the fishery dynamics, 7 about the management system, and 4 about the types and quality of available data (Carruthers, 2019). See Appendix 9.1 for the questions and answers for the Red Snapper fishery.

We set a minimum performance limit to exclude management procedures that have too high a risk of causing the stock to decline to low levels. We used the table of results for the 20 management procedures (MPs) to filter all management procedures that had less than an 80% probability that the spawning biomass was above 0.5 B_{MSY} (biomass at 50% maximum sustainable yield), but still resulted in reasonable long-term yields (i.e. ~50% threshold) (Table 9.1).

The results of the analysis indicated that the four best MPs with high values for the probability of B >50% B_{MSY} but still yielding relatively high values for long-term yield were (a) ratio of F_{MSY}/M (Fratio), (b) depletion-based stock reduction analysis (DBSRA), (c) DBSRA_40 (DBSRA that assumes 40 percent current depletion), and (d) depletion corrected average catch (DCAC) (Table 9.1). These four management procedures all recommended TAC (total allowable catch) as the management approach. Two other MPs yielded much higher values for long-term yield (87%): a size limit management procedure (matlenlim2), in which the fishing retention-at-length is set slightly higher than the length at maturity (1.1 × length at maturity); and a spatial control mechanism that prevents fishing in an area and does not reallocate fishing effort to another area (MRnoreal). However, the probability of B >50% B_{MSY} for these options was relatively low (58% and 60%, respectively).

The longer-term projections for two of the selected MPs – Fratio and DBSRA – indicated that the trends for B/B_{MSY} fluctuate and tend to incrementally increase every 20 years; simultaneously, the yields fluctuate around a constant value (50% for Fratio and 40% for DBSRA; Figure 9.6). The projection for B/B_{MSY} for DBSRA_40 tends to increase sharply, but simultaneously the yield decreases sharply (Figure 9.6).

Indonesia, through the Minister of MMAF Decision No. 50/2017, has determined the TAC per group of species per unit of FMA, as per mandate of the Fisheries Law No. 31/2004 as amended through Law No. 45/2009 concerning fisheries. However, this TAC is very coarse (determined for a species group and not a species) and currently is not practicable to implement for the small-scale Red Snapper fisheries in the waters of southern Banten. Considering the nature of small-scale fisheries that land their catches on the beach or small jetties without government officials to inspect and verify compliance with the catch limits, this management measure would also be difficult to implement in other regions.

The combination of management procedures matlenlim2 (size limit) and MRnoreal (spatial control) might work in the context of this particular small-scale fishery. As noted previously, the use of larger hooks (> No. 10) would reduce the likelihood of capturing immature *L. gibbus* of less than 300 mm fork length. The existing no-take area, which is part of the zoning system of Ujung Kulon National Park, could also contribute to protecting Red Snapper stocks and maintaining healthier coral reefs that are possibly critical habitat for spawning, nursery grounds, or both, for this species. This assumption is based on the relatively short distance between the national park closed areas and the Red Snapper fishing grounds in the waters of southern Banten, but the assumption needs to be tested.

Table 9.1. Performance of candidate management procedures from the Method Evaluation and Risk Assessment (MERA) simulations for Red Snapper (*Lutjanus* spp.) in the waters of southern Banten, southern Java, Indonesia

Management procedure	Regulation type	Prob. $B > 0.5\ B_{MSY}$	Prob. $B > B_{MSY}$	Short-term yield	Long-term yield
Fratio	TAC	0.79	0.59	0.57	0.73
DBSRA	TAC	0.76	0.61	0.46	0.56
DBSRA_40	TAC	0.85	0.77	0.50	0.42
DCAC	TAC	0.88	0.74	0.37	0.66
DCAC_40	TAC	1.00	0.94	0.37	0.37
DBSRA4010	TAC	0.81	0.64	0.35	0.56
MCD	TAC	0.97	0.83	0.33	0.51
IT5	TAC	0.54	0.32	0.88	0.55
IT10	TAC	0.53	0.31	0.88	0.54
HDAAC	TAC	0.94	0.82	0.25	0.61
DD4010	TAC	0.42	0.24	1.02	0.45
MCD4010	TAC	0.97	0.85	0.23	0.49
DD	TAC	0.35	0.17	1.03	0.44
matlenlim2	SL	0.58	0.17	0.84	0.89
MRnoreal	Spatial	0.60	0.12	0.84	0.87
matlenlim	SL	0.51	0.11	0.88	0.86
DDe75	TAE	0.13	0.07	1.05	0.21
DDe	TAE	0.06	0.02	1.05	0.19
MRreal	Spatial	0.39	0.02	0.91	0.76
ITe10	TAE	0.12	0.00	1.00	0.49

Blue shading = options with the highest likelihood of maintaining both sustainable stocks (probability $B > 0.5\ B_{MSY}$ is close to 0.8) and long-term yields. Red rectangle encloses three non-TAC management procedures for future consideration. B = bioass; B_{MSY} = biomass at maximum sustainable yield; Fratio = F_{MSY}/M (fishing mortality at maximum sustainable yield/natural mortality); DBSRA = depletion-based stock reduction analysis; DBSRA_40 = depletion-based stock reduction analysis that assumes 40 percent current depletion; TAC = total allowable catch; SL = size limit; Spatial = spatial closure.

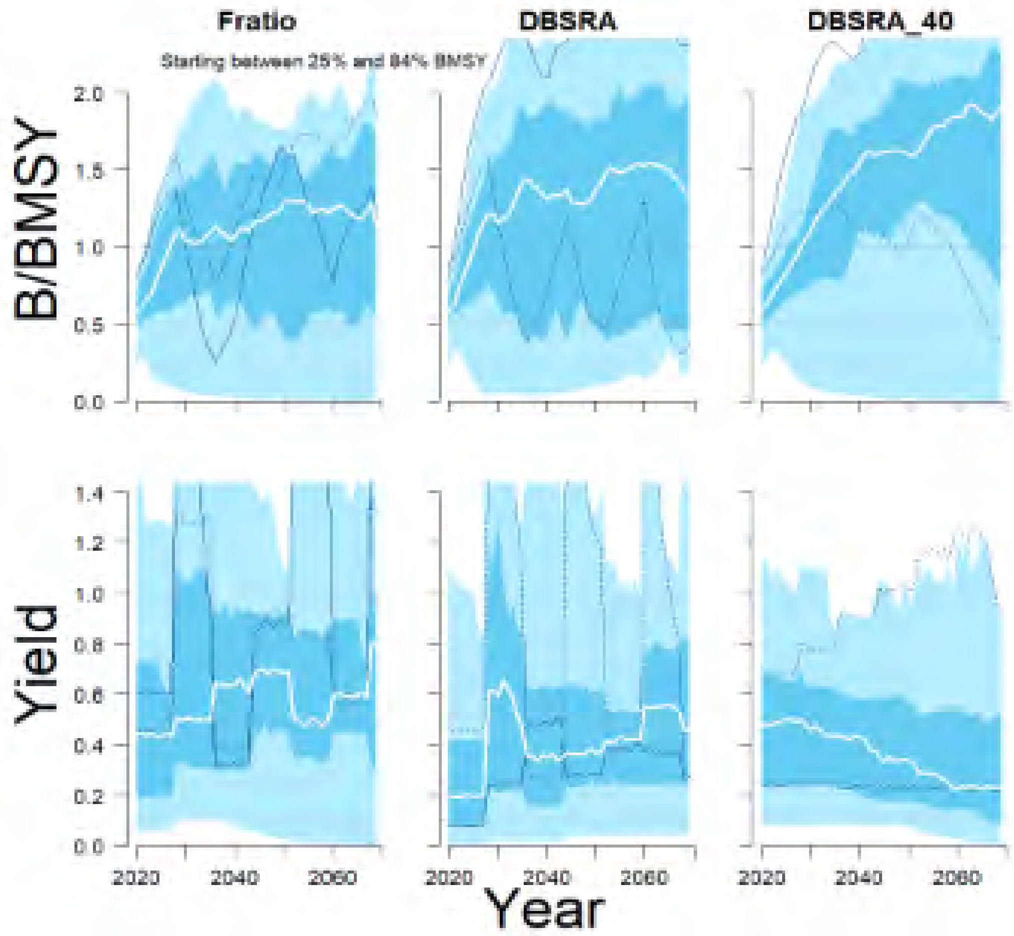

Figure 9.6. Simulated performance (biomass relative to biomass at maximum sustainable yield [B_{MSY}]; relative yield) of three management planning options for the Humpback Red Snapper (*Lutjanus gibbus*) fishery in southern Banten waters, Indonesia. The shaded regions represent the 90% (light blue) and 50% (mid blue) probability intervals, the white solid line is the median and the dark blue lines are two example simulations. For reference, the grey horizontal lines denote values of 0.25, 0.5 and 1. *F*ratio = F_{MSY}/M; DBSRA = depletion-based stock reduction analysis; DBSRA_40 = depletion-based stock reduction analysis that assumes 40 percent current depletion.

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Appendix 9.1

Table 9A.1. Questions and answers for the Method Evaluation and Risk Assessment (MERA) operating model to evaluate management options for Red Snapper in the waters of southern Banten, Indonesia

No.	Questions	Answers
	Fishery characteristics	
1	Longevity or lifespan	Moderate life span (10< maximum age <20)
2	Stock depletion (D)	Depletion (0.1< D <0.15)
3	Resilience	Low resilience (0.3< steepness <0.5)
		Moderate resilience (0.5< steepness <0.7)
4	Historical effort pattern	Gradual increases
		Stable, recent increases
5	Inter-annual catch (IAC) variability in historical effort	Variable (maximum IAC between 20% and 50%)
		Highly variable (maximum IAC between 50% and 100%)
6	Historical fishing efficiency changes	Stable –1% to 1% p.a. (may halve/double every 70 years)
		Increasing by 2–3% p.a. (doubles every 25–35 years)
7	Future fishing efficiency changes	Stable –1% to 1% p.a. (may halve/double every 70 years)
		Increasing by 1–2% p.a. (doubles every 35–70 years)
		Increasing by 2–3% p.a. (doubles every 25–35 years)
8	Length at maturity (LM)	Moderate (0.6< LM <0.7)
		Moderate to large (0.7< LM <0.8)
9	Selectivity of small fish (S)	Half asymptotic length (0.4< S <0.6)
10	Selectivity of large fish (SL)	Dome-shaped selectivity (0.25< SL <0.75)
11	Discard rate (DR)	Low (DR <1%)
		Low to moderate (1%< DR <10%)
		Moderate (10%< DR <30%)
12	Post release mortality rate (PRM)	Low (PRM <5%)
		Low to moderate (5%< PRM <25%)
		Moderate (25%< PRM <50%)
		Moderate to high (50%< PRM <75%)
13	Recruitment variability	Very low (<20% inter-annual changes [IAC])
		Low (max IAC between 20% and 60%)
		Moderate (max IAC between 60% and 120%)
14	Size of an existing marine protection area (MPA; no take area A)	Moderate (10%< A <20%)
15	Spatial mixing (movement) in/out of existing MPA	Moderate (5%< *P* <10%)
16	Size of a future potential MPA (area; A)	Large (20%< A <30%)

No.	Questions	Answers
17	Spatial mixing (movement) in/out of future potential MPA	Moderate (5%< *P* <10%)
18	Initial stock depletion	Asymptotic unfished levels (D1 = 1)
	Management (Types of fishery management that are possible)	
1	TAC (total allowable catch): a catch limit	5683 ton
2	TAE (total allowable effort): an effort limit	4664 units
3	Size limit	310 mm (fork length)
4	Time-area closures (a marine reserve)	Seasonal closures; the spawning season of *L. gibbus* is presumed to occur during January–February and July–August)
	Data	
1	Available data types	*[Data poor*] Historical annual catches (from unfished); recent annual catches (at least 5 recent years); historical relative abundance index (from unfished); recent relative abundance index (at least 5 recent years); fishing effort; size composition (length samples); age composition (age samples); growth (growth parameters); absolute biomass survey
2	Catch reporting bias	not known
3	Hyperstability in indices	not known

10. Conclusions on potential management procedures for seven Indonesian data-limited fisheries

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10.1. Overview of workshop findings

The two workshops held in Bogor, Indonesia, synthesised information for seven data-limited fisheries in Indonesia and built an understanding of both evaluating management strategies for fisheries and how to apply the Method Evaluation and Risk Assessment package (MERA). As part of the process, new data assessments of fisheries were tabled, mainly using the length-based spawning potential ratio, which typically found very low stock levels. These findings are consistent with those reported to the Government of Indonesia on the status of stocks across the 11 Fisheries Management Areas (FMAs). For example, in 2011, 35% of stocks were assessed as fully exploited and 38% as overexploited, while in 2017, 39% were reported as fully exploited and 44% as overexploited (e.g. decision number 50/KEPMEN-KP/2017). The findings also highlight the need to better manage the fisheries and implement effective measures to rebuild stocks.

The synthesis of data and information on the fish and fisheries for the seven species (Tables 2.1, 10.1) provided the essential information to evaluate different management options with MERA (Carruthers and Hordyk, 2018, 2019; Hordyk and Carruthers, 2018). The species examined in these workshops have diverse life-history strategies and are found in a variety of areas within Indonesia's 11 FMAs. The Blue Swimmer Crab (BSC) has a maximum age of 2–3 years; the Scalloped Spiny Lobster (SSL), Redbelly Yellowtail Fusilier (RBYF) and Skipjack Tuna live for about 10 years; and the Scalloped Hammerhead Shark and some of the groupers (e.g. *Plectropomus leopardus*) and snappers (e.g. *Lutjanus gibbus*) live for more than 20 years. Information about the biology of many of these species – particularly age, growth and reproduction – is lacking for the waters of Indonesia (Halim et al., 2020a). Filling these gaps through collaborative research between government, university academics and research students, and nongovernment agencies would prove valuable. The types of fisheries selected for these species also differ markedly. Species are variously captured with traps and gillnets (BSC, SSL), longlines (hammerhead sharks), and a range of handlines and speargunes (RBYF, *L. gibbus*). Skipjack Tuna are captured by the greatest variety of gear types: longlines, purse seines, handlines, pole and line, and gillnets – with or without fish aggregating devices. To provide greater certainty about the extent of fishing, the diverse fishing methods and their contribution to the landings of species throughout Indonesian waters must be better documented, and the significance of unreported and unregulated fishing understood. These data would also increase confidence in the results of stock assessments and evaluation of management strategies.

In all seven case studies, small-scale fishers were identified as a major source of fishing mortality, which provides challenges for both monitoring catches and ensuring fishers comply with management regulations. Because of the unique properties of these fisheries in Indonesia – they are not required to pay a license fee or land fish at an official landing site, and can fish in all waters (inshore of 4 nautical miles and offshore) (Halim et al. 2019, 2020c) – data from official landings likely underrepresent the catches taken, possibly by 40% or more.

These attributes of small-scale fisheries make management procedures based on total allowable catch (TAC) difficult to implement. The simulations of 20 management procedures with MERA (evaluating one procedure at a time) and discussions within the working groups indicated that in these seven fisheries the procedures based on total allowable effort (TAE), size limits and spatial closures are probably more feasible than TAC-based measures (Table 10.1). Designing custom management procedures that combine selected measures would be valuable; these composite options are written as *R* functions and imported into MERA (or run using the *openMSE* package in *R*). However, more data on size at maturity, selectivity, and the spatial dynamics of the fish stocks are needed to increase confidence in these measures.

Implementing new management procedures would require good consultation with the fishers and the fishing industry to ensure that both parties clearly understand the reasons for the new measures and that fishers comply with any new regulations. Here, NGOs can provide a useful interface between government, fishers and the fishing industry. In addition, the importance of small-scale fisheries in Indonesia requires that socioeconomic indicators are included in evaluating fisheries and their management – topics for future research and workshops.

10.2. Existing management and future options

Currently, a range of management measures such as size limits, bans on certain fishing methods, marine reserves, and effort controls are in place for all case studies except Humpback Red Snapper (*L. gibbus*) (Table 10.1). However, in most cases, participants noted that these measures were difficult to enforce because of the nature of small-scale fisheries in Indonesia and limited government resources to enforce regulations. Tuna is a special case because it is a high-value species of regional significance; Indonesia has obligations to the Western and Central Pacific Fisheries Commission and other relevant Regional Fisheries Management Organizations (RFMOs) to report and assess catches of large migratory tuna, such as Skipjack Tuna, within its archipelagic waters (Hoshino et al., 2020). More resources are thus dedicated to tuna fisheries than to the other fisheries studied in the workshops. Ensuring compliance with the existing regulations was identified as a necessary component of any future management options. Despite the inherent difficulties, several local initiatives for management planning and developing harvest strategies could potentially engage fishers, the fishing industry and local communities in supporting management to significantly increase compliance. These initiatives have been tried for Blue Swimmer Crabs, Scalloped Hammerhead Shark, Redbelly Yellowtail Fusilier, and Leopard Coral Grouper. Such an approach has been successful in Sri Lanka in rebuilding and maintaining a sustainable crab fishery through effort and fishing controls and a size limit above the size at maturity (Prince et al., 2020).

In terms of additional future options, MERA analyses found that individual effort controls and marine reserves performed well for five of the species, as did size limits and the fishing mortality ratio to natural mortality for three species (Table 10.1). Some of these measures require further information for their implementation – for example, finer-scale spatial information for designating marine reserves, and data on size at maturity in Indonesian waters for size limits. Management procedures based on total allowable catch were identified for five species but, as noted above, such measures are difficult to implement. The tuna working group emphasised that, even for the relatively data-rich Skipjack Tuna fishery, actual catches 10–40% higher than an implemented TAC may still occur.

10.3. Incorporating socioeconomics in fisheries assessments

Although these workshops focused on biological assessments, participants strongly recommended that the socioeconomics of the fisheries are considered when formulating future management plans. The Government of Indonesia collects information on the socioeconomics of fisheries and calculates an index of 'fishers' prosperity', *nila tukar nelayan* (*NTN).* The index compares the monthly total income with the total expenses in a fisher's household, which provides an indication of the purchasing power of the fishers. If the index is greater than 1 in any month, the fisher's prosperity is seen as improving. Evaluating this index and its relevance for sustainable fisheries production would be valuable; the index could be included when assessing Indonesian fisheries.

In addition to the *NTN*, surveys of fishers, fishing communities and other actors in fisheries can provide valuable insights about changes in fisheries that quantitative data may miss. For example, Jaiteh et al. (2017a, 2017b) surveyed shark fishers and people in shark fishing communities to explore fishers' perceptions of changes in shark fishing grounds, shark abundance, the significance of sharks in the ecosystem, and the importance of income from shark fishing to household livelihoods. Similarly, surveys of recreational and commercial fishers for Blue Swimmer Crabs (*Portunus armatus*) in southwestern

Australia revealed fishers' views of management, the state of the fisheries, and alternative management measures they supported (e.g. stock enhancement, increased enforcement). The findings helped define the fishery network in the Peel-Harvey Estuary (Obregon et al., 2020a, 2020b, 2020c).

In some locations throughout Indonesia, traditional communities (*adat* communities) still practise customary tenure, which is acknowledged under the Constitution and law (Law 1/2014 *in conjunction* with Law 27/2017 on Coastal and Small Islands Management) and respected by migrant communities. These communities have introduced and practised territorial user rights for fisheries along the coastal areas of Indonesia (e.g. Aceh, Maluku and West Papua) (Halim et al., 2017, 2020b; Adhuri, pers. comm., 2019; see also Section 2). Halim et al. (2017, 2020b) concluded that customary marine tenure (*petuanan laut*) can work effectively in locations where tenure rights are recognised and confer the essential elements of exclusivity and security. They also investigated applying territorial user rights to more communities and regions by modifying *petuanan laut* to successfully implement *sasi laut* (a traditional measure to regulate the use of marine resources); this process created modern fisheries management rights for small-scale fisheries. In addition, they identified elements of policy reform – using management principles grounded in science and data-limited stock assessment methods – required for the adaptive management of Indonesian small-scale fisheries.

In appropriate regions, implementing the concept of fisheries management rights could improve management and increase compliance with regulations for small-scale fisheries.

10.4. Recommendations

The following recommendations were developed from the workshop findings and discussions during the workshops:

1. Develop and test protocols to collect data for estimating the scale of unreported catches in the fisheries examined.
2. Inform government of the extent of small-scale fishing and the likely consequences for catch statistics, assessing stock and evaluating management strategies.
3. Develop custom management procedures by combining several management measures (e.g. effort controls, spatial closures and size limits) into one procedure and evaluating its performance through further development of the MERA platform.
4. Develop priorities for biological research on selected species in the Fisheries Management Areas of Indonesia, and implement research on the age, growth and reproduction of priority species in Indonesian waters.
5. Identify training priorities for achieving sustainable fisheries in Indonesia.
6. Incorporate socioeconomic factors when assessing fisheries and evaluating management options.
7. Investigate collecting new socioeconomic information. For example: fishery networks in the fisheries and key actors in these networks (including supply and value chains); perceptions of fishers (and other associated people) about their

fishery, its current management and future management options; and fishers' likely responses to changes in management.

8. Identify potential pathways to develop and implement modern fisheries management rights, based on traditional tenure and measures, for small-scale fisheries in communities with the enabling conditions.
9. Foster ongoing partnerships between government, academics and nongovernment agencies that further the goals of sustainable fisheries management, and identify mechanisms for long-term funding of these partnerships.

10.5. Tinjauan hasil-hasil lokakarya

Kedua lokakarya yang dilakukan di Bogor, Indonesia, menelaah infomasi terhadap tujuh perikanan data terbatas di Indonesia, dan membangun sebuah pemahaman terhadap evaluasi strategi pengelolaan untuk perikanan dan bagaimana menerapkan sebuah paket analisis yang disebut *Method Evaluation and Risk Assessment (MERA)*. Sebagai bagian dari proses, data baru dugaan perikanan disusun, utamanya menggunakan rasio potensi pemijahan berbasis panjang (*length-based spawning potential ratio*), yang pada umumnya diperoleh level stok yang sangat rendah. Temuan-temuan ini mengkonfirmasi hal-hal yang menjadi perhatian dari pemerintah Indonesia sejak tahun 2016, pada saat permasalahan tangkap lebih diseluruh perairan Indonesia diakui secara resmi (Kepmen KP No.47/KEPMEN-KP/2016). Hal yang menjadi perhatian tersebut juga menyorot perlunya mengelola perikanan dengan lebih baik dan menerapkan langkah-langkah pengelolaan yang efektif (*effective measures*) untuk membentuk kembali stok (*rebuild stocks*).

Penelaahan data dan informasi mengenai ikan dan perikanan untuk tujuh spesies (Tabel 2.1, 10.1) memberikan informasi penting untuk mengevaluasi berbagai pilihan pengelolaan menggunakan MERA (Carruthers and Hordyk, 2018, 2019; Hordyk and Carruthers, 2018). Spesies yang dikaji dalam lokakarya ini memiliki strategi riwayat kehidupan (*life history*) yang beragam dan ditemukan diberbagai lokasi di dalam ke-sebelas Wilayah Pengelolaan Perikanan Negara Republik Indonesia (WPPNRI). Rajungan memiliki usia maksimum 2-3 tahun; lobster, ekor kuning, dan cakalang hidup selama sekitar 10 tahun; hiu martil dan beberapa jenis kerapu (contoh: *Plectropomus leopardus*) dan kakap (contoh: *Lutjanus gibbus*) hidup selama lebih dari 20 tahun. Informasi biologis dari kebanyakan spesies ini – khususnya umur, pertumbuhan dan reproduksi masih belum tersedia untuk perairan Indonesia (Halim et al., 2020a). Mengisi kesenjangan informasi ini melalui kolaborasi penelitian antara pemerintah, akademisi di perguruan tinggi, dan lembaga-lembaga non-pemerintah akan terbukti berharga. Jenis perikanan yang dipilih untuk spesies-spesies tersebut juga sangat berbeda. Spesies ditangkap dengan alat tangkap yang berbeda-beda: perangkap dan jaring insang (rajungan dan lobster), rawai (hiu), dan berbagai jenis pancing ulur dan panah (ekor kuning dan kakap merah). Cakalang ditangkap menggunakan alat tangkap yang sangat bervariasi (rawai, jaring lingkar, pancing ulur, huhate, jaring insang – dengan atau tanpa rumpon). Untuk menyajikan kepastian yang lebih tinggi mengenai kisaran penangkapan, berbagai metoda penangkapan dan kontribusinya terhadap spesies yang didaratkan di seluruh perairan Indonesia harus didokumentasikan dengan baik, dan penangkapan yang tidak dilaporkan dan tidak diatur yang cukup signifikan dipahami. Data-data tersebut juga akan meningkatkan keyakinan terhadap hasil-hasil dari pendugaan stok dan evaluasi dari strategi pengelolaan.

Pada semua tujuh studi kasus yang dicermati, perikanan skala kecil diketahui sebagai sumber utama mortalitas penangkapan, yang memberikan tantangan terhadap pemantauan hasil tangkapan dan kepastian kepatuhan nelayan terhadap aturan-aturan pengelolaan. Oleh karena keunikan sifat dari perikanan ini di Indonesia – mereka tidak diwajibkan untuk membayar retribusi perizinan atau mendaratkan ikannya pada tempat-tempat pendaratan resmi, dan boleh menangkap di seluruh perairan (di dalam wilayah 4 mil laut dan lepas pantai) (Halim et al. 2019, 2020c) – data dari pendaratan resmi kemungkinan besar kurang mewakili ikan-ikan yang ditangkap, dengan kemungkinan sebesar 40% atau lebih.

Atribut-atribut dari perikanan skala kecil ini menjadikan prosedur pengelolaan berdasarkan jumlah tangkapan yang diperbolehkan (*total allowable catch/TAC*) sulit diterapkan. Simulasi terhadap 20 prosedur pengelolaan menggunakan MERA (mengevaluasi prosedur satu persatu) dan diskusi diantara kelompok kerja menunjukkan bahwa di dalam ke-tujuh perikanan yang dicermati, prosedur berdasarkan jumlah upaya yang dibolehkan (total allowable effort/TAE), pembatasan ukuran, dan penutupan secara spasial mungkin merupakan yang paling bisa diterapkan daripada langkah pengelolaan berdasarkan TAC (Table 10.1). Merancang patokan prosedur pengelolaan yang memadukan langkah-langkah pengelolaan yang terpilih akan bermanfaat; pilihan-pilihan perpaduan ini ditulis kedalam fungsi-fungsi *R*, dan diimpor kedalam MERA (atau dijalankan menggunakan paket *openMSE* di *R*). Meskipun demikian, diperlukan lebih banyak lagi data ukuran saat dewasa, selektivitas dan dinamika spasial dari stok ikan untuk meningkatkan kepercayaan terhadap langkah-langkah pengelolaan tersebut.

Penerapan prosedur pengelolaan yang baru akan memerlukan konsultasi yang baik dengan nelayan dan industri perikanan untuk memastikan bahwa kedua belah pihak memahami dengan jelas alasan-alasan untuk langkah-langkah pengelolaan yang baru dan kepatuhan nelayan terhadap setiap aturan yang baru. Disini, LSM bisa menjadi penjembatan yang baik antara pemerintah, nelayan dan industri perikanan. Pentingnya perikanan skala kecil di Indonesia memerlukan indikator-indikator sosial ekonomi untuk disertakan kedalam evaluasi perikanan dan pengelolaannya – topik untuk penelitian dan lokakarya mendatang.

10.6. Pengelolaan yang ada dan pilihan di masa datang

Saat ini, kisaran langkah-langkah pengelolaan seperti pembatasan ukuran, pelarangan menggunakan alat tangkap tertentu, kawasan konservasi dan pengendalian upaya, sudah ada dan diterapkan untuk semua perikanan yang dicermati kecuali kakap merah (*L. gibbus*) (Tabel 10.1). Meskipun demikian, pada kebanyakan perikanan yang dicermati, peserta mencatat bahwa langkah-langkah pengelolaan tersebut sulit ditegakkan, dikarenakan oleh sifat dari perikanan skala kecil di Indonesia dan sumberdaya dari pemerintah yang terbatas untuk menegakkan aturan. Tuna merupakan kasus yang khusus, karena merupakan spesies yang bernilai tinggi secara regional, dan Indonesia memiliki kewajiban kepada Komisi Perikanan Barat dan Tengah Pasifik dan Organisasi Perikanan Regional (RFMO) lainnya yang relevan untuk melaporkan dan menduga tangkapan dari tuna besar yang bermigrasi, seperti cakalang di dalam perairan kepulauan Indonesia. Dengan demikian, lebih banyak sumberdaya didedikasikan untuk tuna dibandingkan dengan perikanan lainnya yang dicermati di dalam lokakarya. Memastikan kepatuhan terhadap peraturan yang telah ada, diidentifikasi sebagai komponen yang diperlukan dari setiap pilihan-pilihan langkah pengelolaan di masa datang. Meskipun terdapat kesulitan yang melekat, beberapa inisiatif lokal untuk rencana pengelolaan dan penyusunan strategi penangkapan (*harvest strategy*) barangkali bisa melibatkan nelayan, industri perikanan dan masyarakat setempat dalam mendukung pengelolaan untuk meningkatkan kepatuhan secara signifikan. Insiatif semacam ini telah dicobakan untuk rajungan, hiu martil, ekor kuning, dan kerapu sunu halus. Pendekatan tersebut telah berhasil di Sri Lanka dalam membentuk kembali dan mempertahankan perikanan kepiting yang berkelanjutan melalui pengendalian upaya dan penangkapan dan pembatasan ukuran di atas ukuran dewasa (Prince et al., 2020).

Dalam hal pilihan-pilihan tambahan di masa datang, analisa MERA menemukan bahwa pengendalian upaya individual dan kawasan lindung memberikan hasil yang baik untuk lima species, sebagaimana halnya dengan pembatasan ukuran dan rasio mortalitas penangkapan terhadap mortalitas alami untuk tiga spesies (Tabel 10.1). Beberapa dari langkah-langkah pengelolaan ini masih memerlukan informasi lanjutan untuk penerapannya – sebagai contoh, informasi spasial dalam skala yang lebih rinci untuk penetapan kawasan lindung dan data untuk ukuran ikan dewasa di perairan Indonesai untuk pembatasan ukuran. Prosedur pengelolaan berdasarkan jumlah tangkapan yang diperbolehkan diidentifikasi untuk lima spesies, tetapi seperti telah disebutkan diatas bahwa langkah pengelolaan ini sulit diterapkan. Kelompok kerja tuna menekankan bahwa, bahkan untuk perikanan cakalang yang relatif kaya data, tangkapan aktual yang 10-40% lebih tinggi daripada TAC yang diterapkan masih terjadi.

10.7. Menyertakan aspek sosial-ekonomi di dalam pengkajian perikanan

Meskipun lokakarya ini fokus pada pendugaan parameter biologis, peserta sangat merekomendasikan agar aspek sosioekonomi dari perikanan dipertimbangkan dalam merumuskan rencana-rencana pengelolaan di masa yang akan datang. Pemerintah Indonesia mengumpulkan informasi sosioekonomi perikanan dan menghitung indeks ‘kesejahteraan nelayan’ nilai tukar nelayan. Indeks ini membandingkan total pendapatan dan pengeluaran dalam satu bulan pada rumah tangga nelayan, yang memberikan indikator mengenai daya beli dari nelayan. Apabila nilai indeks lebih besar dari 1 di dalam satu bulan apa saja, kesejahteraan nelayan dipandang telah mengalami peningkatan. Menelaah indeks ini dan relevansinya dengan produksi perikanan yang berkelanjutan akan bermanfaat dan hal itu bisa disertakan pada saat melakukan pendugaan terhadap perikanan Indonesia.

Selain dari nilai tukar nelayan, survei terhadap nelayan, masyarakat nelayan, dan aktor lain dalam perikanan bisa memberikan wawasan yang bernilai mengenai perubahan di dalam perikanan yang mungkin tidak disediakan oleh data kuantitatif. Sebagai contoh, Jaiteh et al. (2017a, 2017b) melakukan survei terhadap nelayan hiu dan orang-orang di dalam komunitas perikanan hiu untuk mengetahui persepsi nelayan mengenai perubahan lokasi penangkapan ikan hiu, kelimpahan hiu, pentingnya hiu di dalam ekosistem, dan pentingnya pendapatan dari penangkapan hiu sebagai mata pencaharian dalam rumah tangga. Serupa dengan itu, survei terhadap nelayan rekreasi dan komersial untuk rajungan (*Portunus armatus*) di bagian barat daya Australia memperlihatkan pandangan nelayan terhadap pengelolaan, status dari perikanan, dan pilihan-pilihan langkah pengelolaan yang mereka dukung (sebagai contoh, penambahan stok (*stock enhancement*), peningkatan penegakan aturan). Temuan-temuan tersebut membantu dalam menentukan jejaring perikanan di estuari Peel-Harvey (Obregon et al., 2020a, 2020b, 2020c).

Di beberapa lokasi di Indonesia, masyarakat tradisional (masyarakat adat) masih menerapkan praktek ulayat adat, yang diakui oleh Undang-Undang Dasar dan undang-undang dan dihormati oleh masyarakat pendatang. Kelompok masyarakat tersebut telah memperkenalkan dan menerapkan hak pemanfaatan teritorial perikanan (*territorial user rights for fisheries*) di sepanjang perairan pesisir Indonesia (seperti: Aceh, Maluku dan Papua Barat; Halim et al., 2017, 2020b; Adhuri, pers. comm., 2019; lihat juga Bagian 2). Halim et al. (2017, 2020b) menyimpulkan bahwa penerapan wilayah ulayat laut (*petuanan laut*) bisa berfungsi secara efektif di wilayah-wilayah dimana hak ulayat dikenali dan menerapkan elemen-elemen penting dari eksklusivitas (*exclusivity*) dan jaminan keamanan (*security*). Mereka juga meneliti penerapan hak pemanfaatan teritorial perikanan pada komunitas dan wilayah yang lebih luas dengan memodifikasi *petuanan laut* untuk menerapkan *sasi laut* (sebuah langkah pengelolaan tradisional untuk mengatur pemanfaatan sumberdaya laut); proses ini menciptakan hak pengelolaan perikanan modern untuk perikanan skala-kecil. Tambahan pula bahwa, mereka mengidentifikasi elemen-elemen untuk reformasi kebijakan – menggunakan prinsip-prinsip pengelolaan yang didasarkan pada sains dan metoda pendugaan stok data terbatas – yang diperlukan untuk pengelolaan yang adaptif dari perikanan skala-kecil di Indonesia.

Pada wilayah yang sesuai, penerapan konsep hak pengelolaan perikanan bisa memperbaiki pengelolaan dan meningkatkan kepatuhan terhadap peraturan-peraturan yang berlaku untuk perikanan skala-kecil.

10.8. Rekomendasi

Rekomendasi berikut, berhasil dikembangkan dari temuan dan diskusi selamat lokakarya:

1. Mengembangkan dan menguji protokol pengumpulan data untuk menduga skala besaran tangkapan yang tidak dilaporkan pada perikanan yang dikaji.
2. Menginformasikan kepada pemerintah mengenai cakupan dari perikanan skala-kecil dan konsekuensinya bagi pendataan statistik hasil tangkapan, pendugaan stok dan evaluasi strategi pengelolaannya.
3. Menyusun prosedur pengelolaan yang disesuaikan dengan mengkombinasikan sejumlah langkah-langkah pengelolaan ke dalam satu prosedur (sebagai contoh, kendali upaya, penutupan spasial, dan batasan ukuran) dan mengevaluasi kinerjanya. Catatan: pengembangan platform MERA akan bermanfaat sebagai bagian dari kegiatan ini.
4. Menyusun prioritas penelitian biologi untuk spesies yang ditentukan di WPPNRI dan melakukan penelitian mengenai umur, pertumbuhan dan reproduksi dari jenis jenis ikan prioritas di perairan Indonesia.
5. Mengidentifikasi prioritas pelatihan untuk pencapaian perikanan yang berkelanjutan di Indonesia.
6. Menyertakan pertimbangan sosial-ekonomi ke dalam pendugaan perikanan dan evaluasi alternatif pengelolaan.
7. Melakukan penelitian dan pengumpulan informasi sosial-ekonomi terkait dengan, sebagai contoh, (a) jejaring dalam perikanan tangkap, dan aktor kunci di dalam jejaring (termasuk rantai pasok dan nilai), (b) persepsi dari nelayan dan pihak terkait dengan nelayan pada perikanan terkait, pengelolaan yang ada saat ini, dan potensi pilihan-pilihan pengelolaannya di masa mendatang, dan (c) kemungkinan perubahan respon mereka di dalam pengelolaan.
8. Mengidentifikasi cara mengembangkan dan menerapkan hak pengelolaan perikanan berdasarkan tradisi dan kebijakan lokal,bagi masyarakat dengan mempertimbangkan berbagai kondisi yang memungkinkannya.
9. Mendorong secara terus-menerus kemitraan antara pemerintah, akademisi, lembaga non-pemerintah untuk memperbaiki perikanan dan mengidentifikasi berbagai mekanisme untuk pembiayaan kerjasama tersebut dalam jangka panjang.

Table 10.1. Summary of current and future management options and the best-performing management procedures determined by the Method Evaluation and Risk Assessment package for seven data-limited fisheries in Indonesian waters

Section. Species [~maximum age]	FMA, location	Main method of capture	Current management	Future management options	Best-performing management procedures in MERA
3. Blue Swimmer Crab (*Portunus pelagicus*) [~3 y]	FMA 712, Coastal Java and eastern Lampung	Trap, gillnet, trawl	TAC for Java Sea; minimum size limit (100 mm carapace width); ban on destructive fishing	Increase size limit (110 mm carapace width); reduce effort; seasonal spawning closure; spatial nursery closure	iTe10; MRnoreal; MRreal; DBSRA4010; matlenlim
4. Scalloped Spiny Lobster (*Panulirus homarus*) [~10 y]	FMA 573, Southern central Java	Trap, gillnet	Export lobster: size limit (>80 mm carapace length, >200 g), not egg-bearing TAC for FMA 573 difficult to implement.	Size limits based on species of lobster; spatial closures based on research; effort controls with CPUE as reference point	iTe10, MRnoreal, MRreal, and DD Note: MRnoreal, MRreal and DD difficult to implement
5. Scalloped Hammerhead Shark (*Sphryna lewini*) [~35 y)	FMA 573, Tanjung Luar, Lombok	Longline target fishery; significant bycatch in many longline fisheries and gillnets in some regions	Ban on export of hammerhead products National Plan of Action: (i) prohibits retention of juvenile and pregnant sharks (ii) bans retention of fins and carcasses of sharks (iii) protected areas for shark pupping grounds in Aceh and Sumbawa Tanjung Luar: agreement with fishers to (a) limit number of hooks on longlines, (b) limit shark fishing days, (c) limit number of shark fishing vessels	Implement current regulations, plans and agreements; improve compliance	MCD; Fratio; DBSRA; MRreal; iTe10 Note: none of the TAC management procedures likely to be successful; iTe10-based measure holds promise but requires consultation with fishers
6. Redbelly Yellow-tail Fusilier (*Caesio cuning*) [~10 y]	FMA 712, Karimunjawa Islands	Speargun, trap, handline	Ban on bounce nets with weights (*muroami*)	Size limits; limit effort; strengthen compliance in closed areas of marine park	Matlenlim; matlenlim10; iTe10; MRnoreal; MRreal

Section. Species [~maximum age]	FMA, location	Main method of capture	Current management	Future management options	Best-performing management procedures in MERA
			Community agreement on where and when speargun fishing with compressed air is allowed WCS-IP continuing to monitor catches and size distribution of catches in the park; more thorough analysis of these data would be valuable		
7. Skipjack Tuna (*Katsuwonus pelamis*) [~12 y]	FMAs 713, 714, 715, Indonesia's archipelagic waters	Purse seine, pole and line, longline, handline, troll line, gillnet	Five priority management measures were identified and presented in the Harvest Strategy 2020–25: 1. Limits on the use of fish aggregating devices (FADs); 2. Spatial closures (of important spawning or nursery grounds) and temporal closures; 3. Limiting the number of fishing days for semi-industrial and industrial vessels; 4. Limiting entry for the number of semi-industrial and industrial vessels through licensing, permits, taxing and royalties; 5. total allowable catch (TAC) limits per FMA (WCPFC16–2019-DP20_rev01)	1. Size limit: a minimum legal size of >40 cm fork length 2. Closed seasons and spatial closures to conserve the breeding stock and juveniles 3. Limiting vessels and fishing gear 4. Catch limits and defining a total allowable catch (TAC) may be possible, but would be challenging as it would involve central and provincial governments agreeing on an allowable catch, both by gear and by species.	DCAC, matlenlim, matlenlim10, iTe10, MRreal
8. Leopard Coral Grouper (*Plectropomus leopardus*) [~25 y]	FMA 713, Saleh Bay, Sumbawah	Speargun, handline, bottom longline, troll line, dropline, trap	Size limit: 300 g Gear: gillnet ⩾102 mm stretch mesh; ban on blast fishing, cyanide, compressor, use of coral as weights on traps Spatial closures: ban on fishing	Applying size limit, effort control, and spatial closures are possible within the existing management framework, as they fit within the existing	ITe10, MRreal, MRnoreal, DBSRA_40

Section. Species [~maximum age]	FMA, location	Main method of capture	Current management	Future management options	Best-performing management procedures in MERA
			in core and limited use zones of two marine protection areas (not effective)	fisheries management objectives and Fisheries Management Plan Strengthen compliance with existing regulations; evaluate potential effectiveness of spatial closures and collect further data on time and location of spawning; evaluate potential effort restrictions Unlikely that allocating a TAC would be feasible because of the number of small-scale fishers in the fishery.	
9. Humpback Red Snapper (*Lutjanus gibbus*) [~20 y]	FMA 573	Dropline, longline	No specific measures. Harvest strategies for snapper (Lutjanidae) in development	No-take areas; increase minimum hook size (> no. 10); reduce effort by 40%	F-ratio; DBSRA; DBSRA40; DCAC

FMA = Fisheries Management Area; MERA = Method Evaluation and Risk Assessment package; TAC = total allowable catch; CPUE = catch per unit effort; DD = delay difference; DBSRA = depletion-based stock reduction analysis; DBSRA4010 = DBSRA assuming 40% of current depletion and maximum of 10% change per year; DCAC = depletion corrected average catch; Fratio = ratio of F_{MSY}/M; iTe10 = individual transferrable effort quota with a maximum change of 10% per year; matlenlim = size limit based on size at 50% maturity; matlenlim10 = 10% larger size limit than for matlenlim; MRreal = marine reserve with reallocation of fishing effort; MRnoreal = marine reserve with no reallocation of fishing effort.

Table 10.2. Ringkasan dari pilihan-pilihan pengelolaan saat ini dan di masa datang dan prosedur pengelolaan yang memberikan tampilan (keluaran) yang terbaik yang ditentukan berdasarkan penerapan *Method Evaluation and Risk Assessment (MERA)* untuk tujuh perikanan data terbatas di perairan Indonesia.

Bagian. Spesies [~umur]	WPP, lokasi	Metoda utama penangkapan	Pengelolaan saat ini	Pilihan-pilihan pengelolaan di masa datang	Prosedur pengelolaan terbaik dari MERA
3. Rajungan (*Portunus pelagicus*) [~3 t]	WPP 712, Pesisir Jawa dan sebelah timur Lampung	Bubu, jaring insang, trawl	TAC untuk Laut Jawa; batas ukuran minimum (100 mm lebar karapas); melarang penangkapan destruktif	Naikan batas ukuran (110 mm lebar karapas); kurangi upaya; penutupan saat musim memijah; penutupan lokasi anakan (*nursery*)	iTe10; mRnoreal; mRreal; DBSRA4010; matlenlim
4. Lobster (*Panulirus homarus*) [~10 t]	WPP 573, Bagian Selatan Jawa bagian tengah	Bubu, jaring insang	Expor lobster: batasan ukuran (>80 mm panjang karapas, >200 g), tidak mengandung telur. TAC untuk WPP 573 sulit diterapkan.	Pembatasan ukuran berdasarkan spesies; penutupan wilayah berdasarkan hasil penelitian; pengendalian upaya dengan CPUE sebagai titik acuan (*reference point*)	iTe10, mRnoreal, mRreal, dan DD Catatan: mRnoreal, mRreal dan DD sulit diterapkan
5. Hiu Martil (*Sphryna lewini*) [~35 t)	WPP 573, Tanjung Luar, Lombok	Rawai dengan target ikan hiu; tangkapan sampingan yang signifikan pada banyak rawai dan beberapa jaring insang di beberapa lokasi	Pelarangan ekspor produk-produk dari hiu; Rencana Aksi Nasional: (i) melarang pengambilan hiu juvenil dan yang hamil (ii) melarang pengambilan ekor dan karakas hiu (iii) kawasan perlindungan untuk lokasi melahirkan hiu di Aceh dan Sumbawa Tanjung Luar: kesepakatan dengan nelayan untuk (a) membatasi jumlah mata pancing pada rawai, (b) membatasi jumlah hari melaut menangkap hiu, (c) membatasi jumlah kapal penangkap hiu	Terapkan aturan-aturan yang ada saat ini, rencana dan kesepakatan; tingkatkan kepatuhan	MCD; Fratio; DBSRA; mRreal; iTe10 Catatan: kelihatannya tidak satupun dari prosedur pengelolaan TAC akan berhasil. Langkah pengelolaan berbasis iTe10 memberi harapan tetapi perlu konsultasi dengan nelayan.

Bagian. Spesies [~umur]	WPP, lokasi	Metoda utama penangkapan	Pengelolaan saat ini	Pilihan-pilihan pengelolaan di masa datang	Prosedur pengelolaan terbaik dari MERA
6. Ekor kuning (*Caesio cuning*) [~10 t]	WPP 712, Kepulauan Karimunjawa	Panah, bubu, pancing ulur	Melarang penggunaan muroami; kesepakatan masyarakat mengenai lokasi dan waktu penangkaoan menggunakan panah dengan alat bantu kompresor diperbolehkan. WCS-IP terus menerus memantau distribusi tangkapan dan ukuran tangkapan di dalam taman nasional. Analisis lanjutan yang lebih mendalam terhadap data-data tersebut akan bermanfaat	Pembatasan ukuran; pembatasan upaya; perkuat kepatuhan di dalam wilayah yang ditutup dalam taman nasional.	Matlenlim; matlenlim10; iTe10; mRnoreal; mRreal
7. Cakalang (*Katsuwonus pelamis*) [~12 t]	WPP 713, 714, 715	Jaring lingkar, huhate, rawai, pancing ulur, pancing tonda, jaring insang	Lima prioritas langkah-langkah pengelolaan diidentifikasi dan dijabarkan di dalam strategi penangkapan (*harvest strategy*) 2020-25: 1. Pembatasan penggunaan rumpon; 2. Penutupan spasial (lokasi penting pemijahan dan pembesaran) dan penutupan temporal; 3. Pembatasan jumlah hari melaut untuk kapal-kapal semi industri dan industri; 4. Pembatasan penambahan jumlah kapal untuk kapal-kapal semi-industri dan industri melalui perizinan, izin, pajak dan royalti; 5. Pembatasan total allowable catch (TAC) di setiap WPP (WCPFC16–2019-DP20_rev01).	1. Pembatasan ukuran: ukuran legal minimum >40 cm panjang cagak; 2. Penutupan musiman dan penutupan spasial untuk melindungi stok yang akan memijah (*breeding stock*) dan juvenil; 3. Pembatasan kapal dan alat tangkap; 4. Pembatasan tangkapan dan penetapan TAC mungkin memungkinkan, tetapi menantang (*challenging*) karena akan melibatkan kesepakatan antara pemerintah pusat dan daerah terhadap tangkapan yang diperbolehkan berdasarkan alat tangkap dan jenis ikan.	DCAC, matlenlim, matlenlim10, iTe10, MRreal

Bagian. Spesies [~umur]	WPP, lokasi	Metoda utama penangkapan	Pengelolaan saat ini	Pilihan-pilihan pengelolaan di masa datang	Prosedur pengelolaan terbaik dari MERA
8. Kerapu sunu halus (*Plectropomus leopardus*) [~25 t]	WPP 713, Teluk Saleh, Sumbawa	Panah, pancing ulur, rawai dasar, pancing tonda, pancing dasar, bubu	Batasan ukuran: 300 g; Alat tangkap: jaring insang mata jaring ⩾102 mm, pelarangan pengeboman, sianida, kompresor, penggunaan batu karang sebagai pemberat bubu Penutupan spasial: pelarangan menangkap di zona inti dan pemanfaatan terbatas di dalam dua kawasan konservasi (tidak efektif)	Terapkan batasan ukuran, pengendalian upaya, dan penutupan spasial memungkinkan di dalam kerangka pengelolaan saat ini, karena sesuai dengan tujuan pengelolaan dan rencana pengelolaan perikanan saat ini Perkuat kepatuhan terhadap aturan yang ada saat ini; evaluasi potensi efektivitas penutupan spasial dan kumpulkan data lebih lanjut mengenai waktu dan lokasi pemijahan; evaluasi potensi pembatasan upaya; Alokasi TAC tidak memungkinkan karena banyaknya nelayan skala kecil di dalam perikanan ini.	ITe10, MRreal, MRnoreal, DBSRA_40
9. Kakap merah (*Lutjanus gibbus*) [~20 t]	WPP 573	Pancing dasar, rawai	Tidak ada langkah pengelolaan tertentu. Strategi penangkapan (*harvest strategies*) untuk kakap (Lutjanidae) masih dalam pengembangan	Kawasan larang ambil; perbesar ukuran minimal mata pancing (> no. 10); kurangi upaya sebesar 40%	F-ratio; DBSRA; DBSRA40: DCAC

WPP = Wilayah Pengelolaan Perikanan; MERA = Method Evaluation and Risk Assessment package; TAC = total allowable catch; CPUE = catch per unit effort; DD = delay difference; DBSRA = depletion based stock reduction analysis; DBSRA4010 = DBSRA assuming 40% of current depletion and maximum of 10% change per year; DCAC = depletion corrected average catch; Fratio = ratio of *F*MSY/*M*; iTe10 = individual transferrable effort quota with a maximum change of 10% per year; matlenlim = size limit based on size at 50% maturity; matlenlim10 = 10% larger size limit than for matlenlim; MRreal = marine reserve with reallocation of fishing effort; MRnoreal = marine reserve with no reallocation of fishing effort.

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Top: Tuna working group at Workshop 1 and Bottom: Sharking working group at Workshop 2, of Crawford workshops on “Management Strategy Evaluation for Data-limited Fisheries”.