Working paper for

Indian Ocean Tuna Commission

15th Working Party on Ecosystems and Bycatch

September 3–7, 2019

Réunion

fishIDER, a new fish identification and training tool for Indonesia

William T. White[1], Helen O'Neill[1],

Enjah Rahmat[2], Fayakun Satria[2], and Craig Proctor[3]

[1] CSIRO Australian National Fish Collection, Hobart, TAS, Australia

[2] Research Institute for Marine Fisheries, Ministry of Marine Affairs and Fisheries, Jakarta, Indonesia

[3] CSIRO Oceans & Atmosphere, Hobart, TAS, Australia

Introduction

Indonesia is one of the largest maritime nations and fish producers in the world. In 2015, marine capture was over 6.2 million tonnes based on 2015 Statistics for Indonesia's Marine Capture Fisheries. Indonesia is the fourth most populous country in the world and about 70 million people are estimated to live in poverty (according to international standards) despite Indonesia's poverty rate being at its lowest in history. For many people, fish is a vital source of protein and the nation's food security depends on fish products. The fishing industry is also vital for Indonesia's economy, employing more than 12.3 million people according to Phillips *et al*. (2016).

Improving the ability of fisheries staff to accurately identify fish species is a high priority for Regional Fisheries Management Organisations (RFMOs) such as the Indian Ocean Tuna Commission (IOTC) and Western and Central Pacific Fisheries Commission (WCPFC). These staff are those from the agencies or offices involved in fisheries data collection which in Indonesia are primarily officers of the Provincial, Regency, Municipal and District level Offices of Marine Affairs and Fisheries (*Dinas Kelatuan dan Perikanan*), and officers of Port Authorities. There are also data collection staff employed within the various Non-Governmental Organisation programs operating in Indonesia, e.g. The Nature Conservancy, Masyarakat Dan Perikanan Indonesia, Sustainable Fisheries Partnership, and the Wildlife Conservation Society, who collect similar fisheries catch data. Catch data is collected from most landing sites and fishing ports daily or at least several times per week.

Accurate species identification is the fundamental requirement for fisheries assessments. Catch data collected by fisheries staff is used to generate stock assessments which inform important management decisions, such as catch quotas and maximum sustainable yields. Stock assessments based on reliable and accurate data can help move a fishery towards sustainability. However, if identifications made by fisheries staff are

incorrect, stock assessments could be compromised or flawed, leading to inappropriate management decisions. Flawed stock assessments could suggest that less or more fish are being caught than is actually the case, resulting in stocks being under-utilised or overexploited.

Global and regional fisheries agencies have long developed species identification guides to assist data collectors to accurately identify fisheries resources. These include fisheries-specific identification cards, regional species catalogues (e.g. the FAO Species Identification Guide for Fishery Purposes series; Moore & Colas, 2016), and country-level field guides (e.g. Almojil *et al.*, 2015; White *et al.* 2006, 2013). These resources either provide images of good quality specimens with fresh coloration and all fins erect, or line drawings of a 'typical' specimen of each species. However, this does not reflect the reality of specimens in fish markets or at landing sites where much of the data collection occurs. In these situations, fish are often in less than fresh condition or damaged, having faded coloration and missing key identifying features, which makes it difficult to assign them to a species using the currently available field guides. Furthermore, most field guides do not detail ontogenetic changes in key characters between species, but different size classes of some species can vary greatly.

Fish identification training workshops, conducted by IOTC in collaboration with Indonesia's Directorate General of Capture Fisheries (DGCF) and marine research institutes, confirmed an overall poor level of fish identification skills among fisheries staff tasked with the responsibility of daily fisheries data collection in Indonesia (IOTC-OFCF 2014; Stobberup and Geehan 2015). There is universal agreement among the relevant tuna Regional Fisheries Management Organisations (RFMOs) – Indian Ocean Tuna Commission, Western and Central Pacific Fisheries Commission, and Commission for the Conservation of Southern Bluefin Tuna, and the NGOs (including The Nature Conservancy, Masyarakat Dan Perikanan

Indonesia, World Wildlife Fund, and Sustainable Fisheries Partnership) who have current fisheries port-based monitoring programs in Indonesia, that improving the species identification skills of fisheries staff, in particular, is a high priority. Improving species identification skills and hence the quality of data collection is seen as essential to the current Harvest Strategy development process and for improved management of Indonesia's tuna fisheries, but also important for improved management of other fisheries.

Two fish species that are considered highest priority in Indonesia, in respect to addressing inaccuracies in identification, are yellowfin tuna *Thunnus albacares* and bigeye tuna *Thunnus obesus*. Identifying these two species at small size (<60 cm FL) is difficult, especially when the fish are in less than fresh condition. There is uncertainty around the true scale of the catch of juveniles of these species in Indonesian and Philippine fisheries. This is exacerbated by recognition that many fisheries staff struggle to discern these two species at small sizes. This situation was highlighted during a recent fisheries project in Indonesia entitled *"Developing research capacity for management of Indonesia's pelagic fisheries resources"* (Australian Centre for International Agricultural Research project FIS/2009/059). In this project, local fisheries staff were found to have an overall low level of skill for accurately identifying these two tuna species at small size if fish condition was less than fresh.

It is important to note that fishery data collection in Indonesian markets and landing sites, and indeed throughout much of the tropical Indo-Pacific, encounters a number of challenges. Firstly, Indonesia is in the megadiverse Coral Triangle with more than 1,000 species of fish having been documented from Indonesian markets alone, with many more yet to be discovered. Secondly, species can be present in the catches at several different life stages and juveniles can sometimes look very different from their adults. Juveniles of some species are very difficult to distinguish from their closest relatives. Another impediment is the limited time often available for data collection as catches can move quickly through the

market place. Lastly, the condition of the catch is a regular challenge in Indonesian markets with fish regularly present in poor condition (Fig. 1). This can be due to long periods at sea with limited ice or being in the market area for an extended period. Also, fish may have had key features removed, such as the bills of billfish or fins of sharks, or whole parts missing, e.g. heads.

Figure 1 Example of the poor condition of the catches which can be encountered in Indonesian fish markets: shark and ray landings at Muara Angke fishing port in Jakarta (left) and pelagic fish bycatch at Cilacap fishing port in Central Java (right).

The problems highlighted above spawned the idea for the development of an on-line fish identification resource (subsequently called fishIDER: fish Identification Database and Educational Resource) that field staff can access in the field if they possess a smartphone or tablet with internet access, and access at time of data entry in their offices.

Methods

Project resourcing

The original concept for fishIDER was funded by the Australian Centre for International Agricultural Research (ACIAR) and CSIRO Ocean & Atmosphere (O&A) in an 18-month small research project between January 2017 and June 2018 entitled “Developing a bilingual

web-based identification tool for field use in Indonesia" (FIS/2016/048). This project was followed by a 12-month project (July 2018 to June 2019), funded by ACIAR and CSIRO National Research Collections Australia (NRCA), entitled "Extending capacity of fish identification skills for improved fisheries assessments" (FIS/2018/116). Between July 2019 and June 2020, CSIRO NRCA has committed some resources for our web content analyst to continue adding content for fishIDER.

Website development

The fishIDER website (www.fishIDER.org) was initially developed on WordPress using the template "Maisha" by Anariel Designs, with additional plugins to allow for the functionality required, e.g. for identification keys and referencing. As the site expanded, professional web developers, Sarox, were contracted to appraise fishIDER on the WordPress platform. This appraisal determined that the WordPress site contained several issues which would reduce its functionality and make maintenance difficult as it continued to expand. Following this, the website developer was contracted to rebuild fishIDER on a Laravel platform to allow for better functionality and data storage as well as allowing for future development of offline apps. An initial 'soft' launch of fishIDER was made to select colleagues and collaborators to test run the website and provide feedback on design, content and usability. After minor glitches and feedback were addressed, the first stage of fishIDER was launched in October 2018 at the Our Ocean Conference in Bali.

Taxonomic coverage

The first 18-month project focused on the families of pelagic fishes which make up the catches of some of the key fisheries in Indonesia, i.e. Scombridae (tunas and mackerels), Istiophoridae (billfish), Xiphiidae (swordfish), Alopiidae (thresher sharks), Lamnidae

(mackerel sharks) and Carcharhinidae (whaler sharks). The second 12-month project focused on the key reef and inshore fish families, i.e. Carangidae (trevallies), Lutjanidae (snappers), Caesionidae (fusiliers), Lethrinidae (emperors) and the Epinephelinae subfamily of the Serranidae (groupers). The two latter families are still under development.

For each family, all species known to occur within Indonesia were included. The taxonomic coverage for each family was obtained from a combination of sources. The first source used was Carpenter & Niem (1998, 1999, 2001a, b), with current nomenclature and distribution checked against the Catalog of Fishes (Fricke *et al.*, 2019).

Image acquisition

The primary images, i.e. the main images used for species pages, were mostly obtained from the image libraries generated for the shark and ray, and bony fish field guides (White *et al*., 2006, 2013). For most species included in White *et al.* (2006 and 2013), the primary images are from vouchered specimens, currently housed at CSIRO's Australian National Fish Collection (ANFC) with associated collection data and DNA barcode results, i.e. CO1 sequences. The images used in the market galleries were mostly obtained from the image libraries of several of us (WW, CP) which were developed over the last two decades during numerous collaborative ACIAR-funded projects between CSIRO and the Ministry of Marine Affairs and Fisheries, containing more than 20,000 images. Images used in the genera and species keys were taken from the image libraries or were taken directly from specimens housed in the ANFC. Additional images were also obtained from colleagues working in Indonesian fish markets and landing sites.

Content acquisition

The text content in the shark and ray, and bony fish field guides (White *et al*., 2006, 2013) was used as the basis for the species pages. For most bony fish families, this species page content was expanded using primarily the Western Central Pacific FAO species catalogues (Carpenter & Niem, 1998, 1999, 2001a, b). In some instances, more recent sources were used, including for recently described species (e.g. White, 2012; Allen *et al.*, 2013) and for group monographs and guide books (Ebert *et al.*, 2013).

The identification keys were adapted from those in Carpenter & Niem (1998, 1999, 2001a, b) and White *et al.* (2006). In the keys, illustrations were produced to highlight the distinguishing features in each couplet. Where possible, images from actual specimens were used. When images were not available or didn't highlight the characters adequately, line drawings were produced using Adobe Illustrator. The key characters used to distinguish between similar taxa were used to generate quizzes within the interactive learning component of fishIDER. Emphasis was placed on those characters which are most reliable and often not dependent on the quality of specimens.

Translation of text

Translation of content to from English to Bahasa Indonesia for all text sections was undertaken by one of us (ER) who attended two training workshops at the ANFC in Hobart, Tasmania on two occasions: June and November 2018. Services of an online translation company, ICanLocalize (https://www.icanlocalize.com/site/) were also sought to facilitate translations into Bahasa Indonesia.

Results and discussion

Website design

fishIDER consists of six main sections: family guide, family pages, species profile pages, interactive learning, image galleries of fish in market condition, and a glossary. The family guide (https://www.fishider.org/family_guide/) provides thumbnails of the key families currently available on fishIDER with a line drawing highlighting the general body shape of members of each family (Fig. 2). It also includes a sidebar with a drop-down list of the families and genera currently available on fishIDER. The use of line drawing thumbnails provides a quick way for users to find a particular family they are looking for.

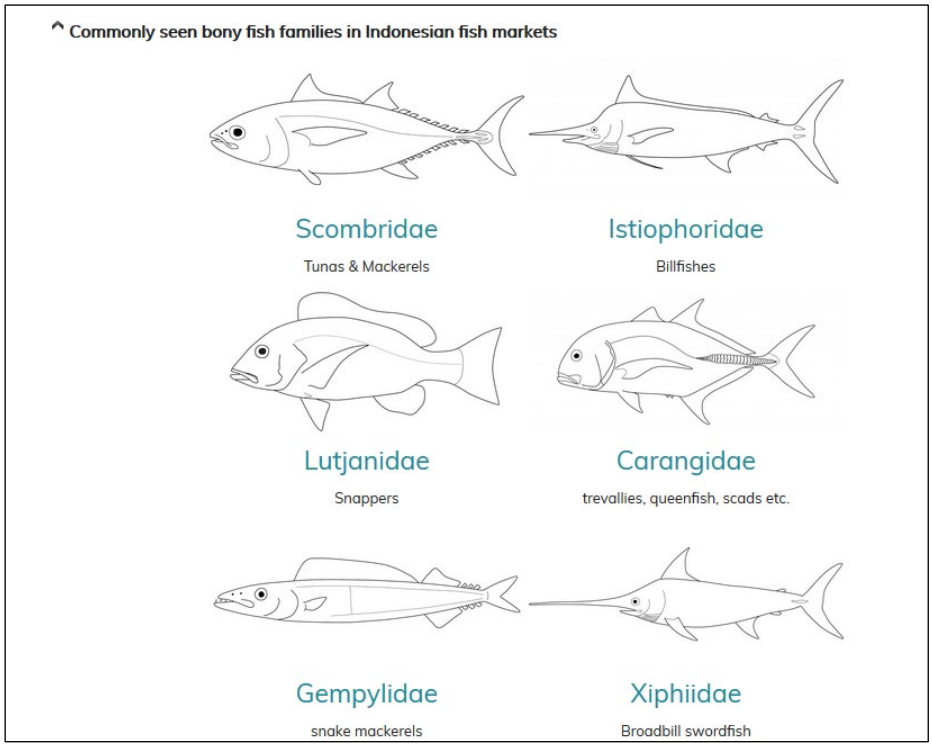


Figure 2 Line drawing thumbnails for bony fish families currently on fishIDER in the family guide section.

Selecting a particular family will take users to a family page which lists the key features of that family, provides key(s) to the genera and species within that family, provides comparisons with other families they could be confused with, and provides thumbnail images

of species. The thumbnail images of species enables users to quickly eyeball members of a family which can often indicate the species, or several species, they are trying to identify. For most families, e.g. Scombridae, a key to genera is provided first, followed by keys to the genera which contain more than one species. Species names for monotypic genera are provided in the generic key. The use of images to illustrate characters used to distinguish similar species in the keys (Fig. 3) is not only beneficial for users to see the characters on specimens similar to what they will be examining in the field, but it also revealed how some characters are not ideal for species determination. This can be a problem of using illustrations to highlight differences in characters between species as they are drawn to highlight a particular feature difference and are not necessarily reflective of what is seen in the field.

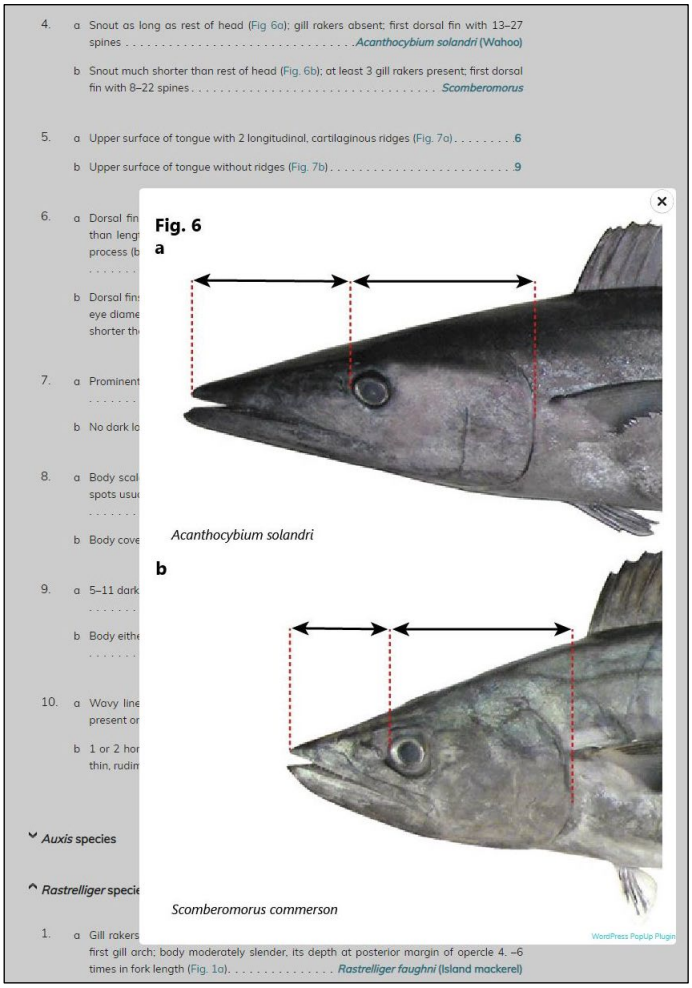
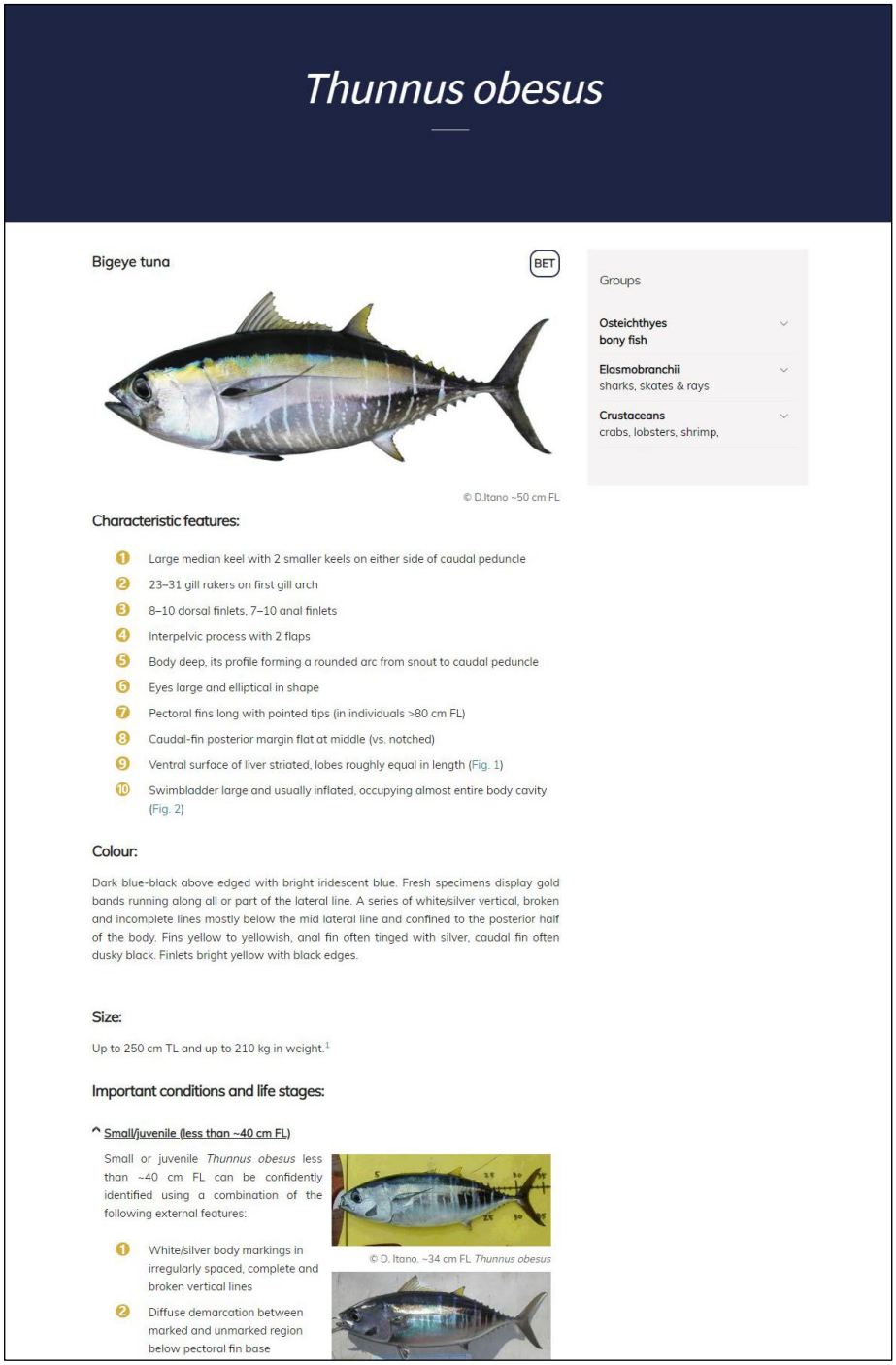


Figure 3 Section of the 'Key to genera of Scombridae' with the figure illustrating the snout length difference between *Acanthocybium* and *Scomberomorus*.

Selecting a species from either within the genera or species keys, or from the species thumbnails below the keys within the family pages will take users to that particular species' profile page (e.g. Fig. 4). The species page first consist of the species' common name (left side), FAO species code (right side) and a primary image of that species. The majority of primary images are taken from White *et al.* (2006, 2013), unless more recent images from ANFC image galleries were available. Beneath the image, the following subsections are provided:

- Characteristic features – a list of key features (usually 5–7);
- Colour – a brief description of fresh coloration;
- Size – maximum length and weight;
- Important conditions and life stages – available where commonly caught species appear in a range of conditions and life stages, e.g. bigeye and yellowfin tuna; contains information on how to accurately identify juveniles of that species, and individuals of varying conditions e.g. poor quality, dressed (billfish);
- Distribution – a brief description of a species' distribution;
- Habitat – a brief description of the general habitat occupied and known depth range;
- Biology – brief comments on general biology, e.g. diet, sizes (at maturity, at birth, etc), ages (maximum, at maturity), behaviour, reproductive cycle;
- Indonesian fisheries – main fisheries catching each species;
- Similar species – thumbnail images and differing features of species most likely to be confused with the species in question;
- Internal links – hyperlinks to market galleries or interactive quizzes available for that particular species on the fishIDER website;

- External links – hyperlinks to other key sources of information for a species, e.g. IUCN Red List assessment species page, FishBase species page;
- References – list of specific references referred to in a species page. These are numbered and link to specific information.



Thunnus obesus

Bigeye tuna BET

© D.Itano ~50 cm FL

Groups

Osteichthyes bony fish

Elasmobranchii sharks, skates & rays

Crustaceans crabs, lobsters, shrimp,

Characteristic features:

1. Large median keel with 2 smaller keels on either side of caudal peduncle
2. 23–31 gill rakers on first gill arch
3. 8–10 dorsal finlets, 7–10 anal finlets
4. Interpelvic process with 2 flaps
5. Body deep, its profile forming a rounded arc from snout to caudal peduncle
6. Eyes large and elliptical in shape
7. Pectoral fins long with pointed tips (in individuals >80 cm FL)
8. Caudal-fin posterior margin flat at middle (vs. notched)
9. Ventral surface of liver striated, lobes roughly equal in length (Fig. 1)
10. Swimbladder large and usually inflated, occupying almost entire body cavity (Fig. 2)

Colour:

Dark blue-black above edged with bright iridescent blue. Fresh specimens display gold bands running along all or part of the lateral line. A series of white/silver vertical, broken and incomplete lines mostly below the mid lateral line and confined to the posterior half of the body. Fins yellow to yellowish, anal fin often tinged with silver, caudal fin often dusky black. Finlets bright yellow with black edges.

Size:

Up to 250 cm TL and up to 210 kg in weight.[1]

Important conditions and life stages:

^ Small/juvenile (less than ~40 cm FL)

Small or juvenile *Thunnus obesus* less than ~40 cm FL can be confidently identified using a combination of the following external features:

1. White/silver body markings in irregularly spaced, complete and broken vertical lines
2. Diffuse demarcation between marked and unmarked region below pectoral fin base

© D. Itano. ~34 cm FL *Thunnus obesus*

Figure 4 First half of the bigeye tuna species page with the Characteristic features, Colour, Size and part of the Important conditions and life stages sections.

The interactive learning section consists of numerous games and quizzes to help improve fish identification skills of users. There is currently two levels of mixed species quizzes (Level 1 – easy to moderate difficulty, 10 questions; Level 2 – difficult, 9 questions). There are also family-specific quizzes for the families Istiophoridae (one quiz) and Scombridae (9 quizzes). Each quiz question provides an image of a fish, or series of images of fish, with users asked to select the correct corresponding species name from four choices (Fig. 5). For each answer, an explanation as to why the answer was incorrect or correct is provided. Additional quizzes are being developed relevant to new families as they are uploaded onto fishIDER.

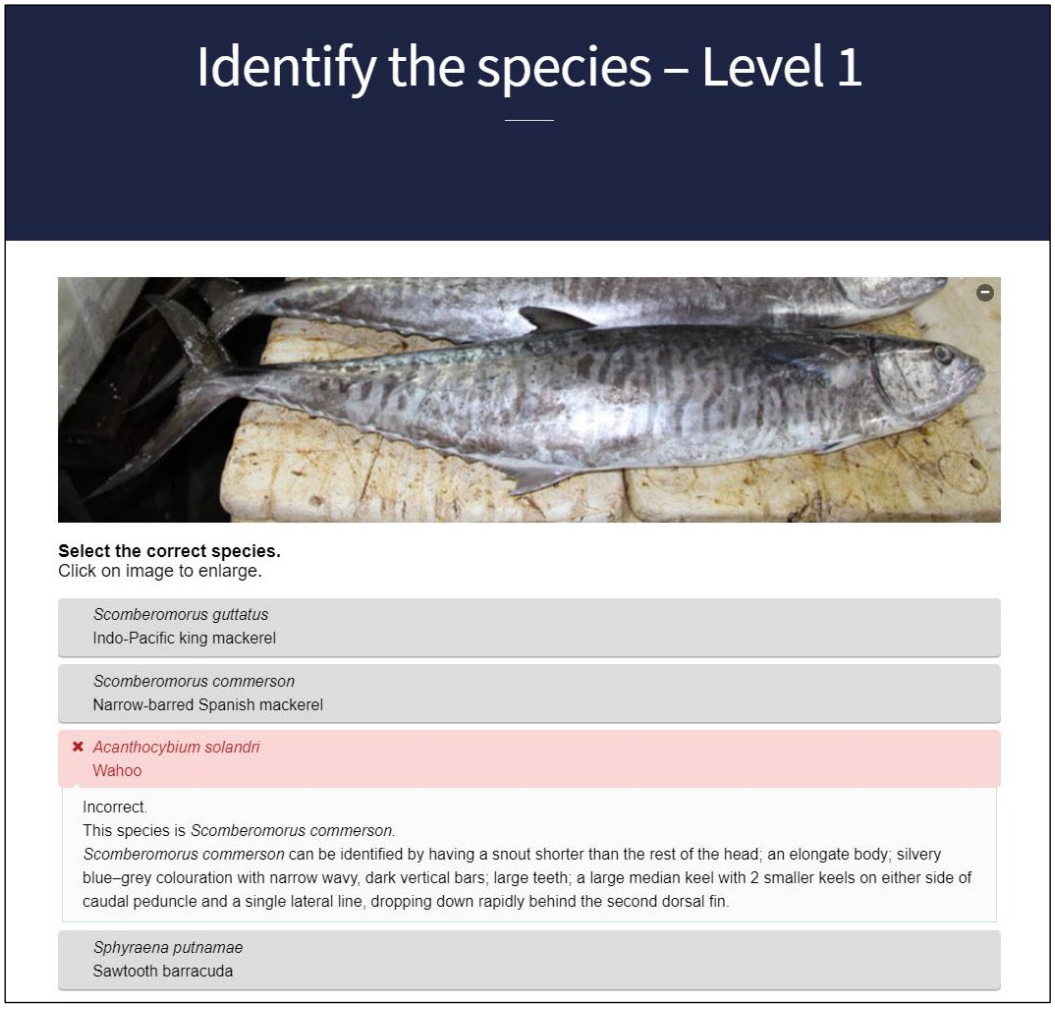


Figure 5 Example quiz question with users asked to select the correct species name to match the image provided from four choices; incorrect selections are followed by the correct species and an explanation why.

The market gallery section consist of albums of fish in the market or landing site situation, thus reflective of the condition likely to be observed in the field in Indonesia (e.g. Fig. 6). The initial release included three market gallery albums, i.e. for Scombridae, Istiophoridae and Xiphiidae. Within each album, market gallery images for the most abundant species are provided. In the Xiphiidae and Scombridae albums, annotated images are also provided. The annotated images consist of images of fish in market condition with annotations of the key characteristics which can be used to identify that particular species.

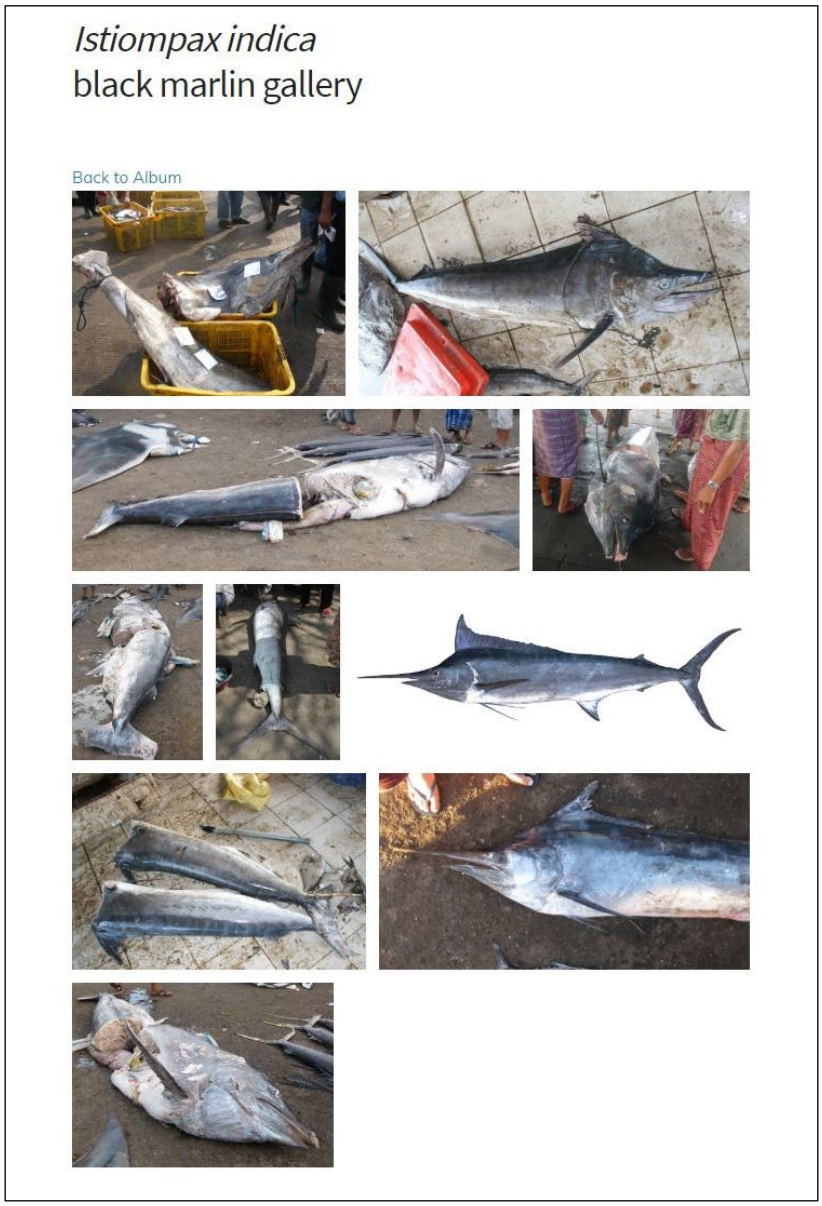


Figure 6 Market gallery images for the black marlin *Istiompax indica* showing images of specimens in market situation and condition.

The glossary is an important resource for users to improve their understanding of taxonomic and other fish-related scientific terms. Illustrations are provided for some of the terms to improve the explanation of those terms.

While the aim is to have fishIDER fully bilingual, only a limited number of families have currently been translated into Bahasa Indonesian. The Bahasa Indonesia text can be accessed by clicking on the language switcher in the menu bar at the top of any page.

Benefits of fishIDER

fishIDER's focus is to facilitate and improve identification of fish caught in Indonesian fisheries. As such, fishIDER is open access and freely accessible to anyone, is designed to facilitate easy navigation by users, provides an enjoyable learning experience to improve fish identification skills. The species listed on fishIDER are verified by experts and in most cases have voucher specimens deposited in the ANFC for referral and have associated DNA barcode sequences available. This is important to account for any future taxonomic changes and to ensure the most up to date taxonomy is always provided. All information provided is verified by experts. Another important aspect to fishIDER is that is has a focus on fish in the market condition, thus provides data collectors with a direct comparison with what they are seeing in the field.

fishIDER can be applied to research (biodiversity assessments), management (accurate catch data to feed into stock assessments) and industry (ensuring accurate identification of species to protect sustainable seafood certification). fishIDER could become the 'one-stop-shop' for fish identification in Indonesia.

fishIDER into the future

The aim of fishIDER is to improve the accuracy of fish identification by data collectors in Indonesia. To date, focus has been placed on the most important food fish groups. The taxonomic coverage will continue to be expanded, focusing on the important food fish species first. Ideally, all fish families represented in the Indonesian fisheries catches (using White *et al*., 2006, 2013 as a starting point) will be represented on fishIDER. This will enable data collectors to use fishIDER for conducting biodiversity estimates or detailed catch composition data from the catches or landings. Some fish families, while not caught in large abundances, can be important indicators of either ecosystem health or fisheries dynamics. For example, many deep-water fishes (e.g. dogsharks, gulper sharks, ratfishes) have distinct depth ranges and can be good indicators of fisheries expanding into deeper water. Also, fish such as lizardfish (Synodontidae) can be found in high abundances in areas with heavy trawling effort. Thus, the aim is to cover as much of the biodiversity as possible within fishIDER for users. The aim is to also include non-fish groups on fishIDER so that all fisheries catches in Indonesia are represented, e.g. seaweed, macroinvertebrates (sea cucumbers, molluscs, crabs, prawns, cephalopods), marine turtles, seabirds and marine mammals.

More comprehensive training modules are also planned for fishIDER. E-learning modules and videos on how to use fishIDER will enable users to begin identifying fish even with limited prior experience. The aim is to have fishIDER as a single tool for data collectors to use for both training and in the field for identifying catches. These training components would be launched through a series of workshops if resources are available, but the aim is for all necessary training to be housed on fishIDER for long-term use by Indonesian fisheries staff. Additional training modules could also be developed to provide information on fish age and growth (including otolith images and vertebral sections) and reproductive biology (including histology images and reproductive tract/gonad staging).

Another developing area is the potential for adding an Artificial Intelligence (AI) component built by Machine Learning (ML) software. The AI field is very active currently and there are many image training projects being investigated. Thus, there are existing platforms which can be applied to fish imagery which can fast-track development of an AI component. For fish, fishIDER's illustrated keys provide an excellent way to identify species and the market galleries show a user those species in market condition which they will likely encounter. However, for data collectors with no or limited taxonomic experience identifying fish, determining which family the fish you are identifying belongs to can be very time consuming. A key to fish families is the traditional solution to this, but given the biodiversity of fish in the Coral Triangle region (>6000 coral reef fish species alone; http://ctatlas.reefbase.org/coraltriangle.aspx), such a key is too time consuming for use in the field. Thumbing through pages of species guides to find the family your fish belongs to is also time consuming. The perfect solution is to have a taxonomist tell you what family or genus of fish you were examining, but this isn't available to most data collectors. This is were AI technology can play an important role. Using the large number of images of fish *in situ* at fish markets and landing sites in Indonesia, ML software could develop an AI app which could instantaneously provide users with the likely family, and sometimes genus or species, of fish they are trying to identify. This would reduce time spent identifying fish in the field considerably. AI technology is unlikely to be able to identify many fish to species level, mainly because in the market situation, fins are not erect, and they are often partly covered or obscured. However, AI technology could quickly tell a user which family, genus or even species group they should progress to on fishIDER to identify the fish(es) in question. The AI solution would be probability based, e.g. 80% probability it is Lutjanidae and 15% probability it is Lethrinidae. The strength of this software depends on the quality of the training images the ML software has to work with.

A final option for fishIDER in the future is for geographic expansion to cover more countries. Initially, fishIDER could be expanded to cover the whole South-east Asian region, but depending on the resources available, could cover a broader region of the tropical Indo-West Pacific. For example, fishIDER could be expanded to cover all taxonomic groups caught by purse seine fisheries in the Indian Ocean so that it can become a complete tool for observers on purse seine vessels to use. The expansion of fishIDER will depend on regional needs, available support and funding, and in-country collaborators.

Acknowledgments

We are grateful to Drs Chris Barlow and Ann Fleming (former and current Managers of ACIAR's Fisheries Program, respectively), and to our CSIRO senior managers – Ms Toni Moate, Dr Tony Worby, Dr Alistair Hobday, Dr Andrew Young, Dr Leo Joseph, Dr David Smith, Dr Peter Thomson for their support and enthusiasm for this project. We also thank the following people for their assistance and support with the organisation of the fishIDER launch at the Our Ocean Conference and associated media releases; Ms Andrea Wild, Mr Matt Marrison, Mr Chris Gerbing, Ms Liz Yuncken, Ms Polly Agrawal (CSIRO), Ms Mirah Nuryati (ACIAR Country Manager for Indonesia). Thanks also to Hon. Malcolm Turnbull for taking the time to view the fishIDER platform during the launch and for allowing us to use his Twitter handle to promote fishIDER.

We wish to thank Mr Andrew Wright and Ms Mingtian Tan (CSIRO) for their assistance in the early establishment of the fish identification website on the CSIRO server. We also thank Mr Chris Gerbing (CSIRO), for his advice on the website's early concept design and options for web development within CSIRO. We thank Mr Nicholas Dewey and Mr Jay Povey for their inputs and work assisting in fishIDER.org's design, and to website design consultant, Ms Diana Reale, for her review of the project's progress and advice.

We thank the following people for providing feedback on the fishIDER content, especially during its 'soft' launch prior to the official launch: Ms Guillermo Moreno (Fisheries Consultant), Dr Antony Lewis (Fisheries Consultant), Mr Alastair Graham (CSIRO), Bayu Sedana (Center for Fisheries Research, Indonesia), Ms Ririk Sulistyaningsih (Research Institute for Marine Fisheries, Indonesia), Dr Mark Bravington (CSIRO), Mr Matt Lansdell (CSIRO), Jan Lammers (Udayana University, Indonesia), Ms Bindi Browning (CSIRO).

We would also like to thank the following people for providing images used in the website: Dr Richard Pyle (Bishop Museum, Hawaii), Mr Mohammad Eusuf Hasan (Institute of Marine Sciences), Mr Thomas Gloerfelt-Tarp (private consultant), Dr David Itano (Fisheries Consultant, Hawaii), Dr Alistair Hobday (CSIRO), Prof. Hiroyuki Motomura (Kagoshima University Museum, Japan), Ms Juliette Tunstall (International Pole and Line Foundation), Mr Grant Johnson (Northern Territory Fisheries), Mr Jonah Yick (Inland Fisheries Service, Tasmania), Ms Afrisa Novalina (Research Institute for Marine Fisheries, Indonesia), and Dr Julian Pepperell (Pepperell Research, Australia). Thanks also to Mr Jeff Johnson (Queensland Museum) and Dr Glenn Moore (Western Australian Museum) for providing taxonomic advice on Serranidae names, and Dr Julian Pepperell for his advice on billfish diagnostic features. Thanks to Ms Carlie Devine for assistance in image manipulation (CSIRO), and thanks to Mr John Pogonoski (CSIRO) for his detailed content reviewing and advice on the taxonomic keys.

Finally, we thank Mr Kobi Colman and Mr Kevin Liebersbach (Sarox web designs) for their useful feedback about the website platform and advice on ensuring longevity and continued expansion into the future.

References

Allen, G.R., White, W.T. & Erdmann, M.V. (2013) Two new species of snappers (Pisces: Lutjanidae: *Lutjanus*) from the Indo-West Pacific. *Journal of the Ocean Science Foundation* 6, 33–51.

Almojil, D.K., Moore, A.B.M. & White, W.T. (2015) *Sharks and rays of the Arabian/Persian Gulf*. MBG (INT) Ltd., London, 178 pp.

Carpenter, K.E. & Niem, V.H. (eds) (1998) *FAO species identification guide for fishery purposes. The living marine resources of the western central Pacific. Cephalopods, crustaceans, holothurans and sharks*. FAO, Rome. Volume 2, 687–1396.

Carpenter, K.E. & Niem, V.H. (eds) (1999) *Species identification guide for fisheries purposes. The living marine resources of the western central Pacific. Bony fishes part 2 (Mugilidae to Carangidae).* FAO, Rome. Volume 4, 2069–2790.

Carpenter, K.E. & Niem, V.H. (eds) (2001a) *Species identification guide for fishery purposes. The living marine resources of the western central Pacific. Bony fishes part 3 (Menidae to Pomacentridae).* FAO, Rome. Volume 5, 2791–3379.

Carpenter, K.E. & Niem, V.H. (eds) (2001b) *Species identification guide for fishery purposes. The living marine resources of the western central Pacific. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals.* FAO, Rome. Volume 6, 3381–4218.

Ebert, D.A., Fowler, S. & Compagno, L. (2013) *Sharks of the world: a fully illustrated guide, 2nd edition*. Wild Nature Press, Plymouth, U.K.

Fricke, R., Eschmeyer, W.N. & Van der Laan, R. (eds) (2019) Eschmeyer's Catalog of Fishes: Genera, Species, References. (http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp).

IOTC-OFCF (2014) Report and documentation of the Indian Ocean Tuna Fisheries of Indonesia West Sumatra Data Collection Workshop: Review of Issues and Considerations. Padang, 18–21 February 2014. *IOTC-OFCF Technical Report*. No. 3. Padang, IOTC. 2014. 47 pp.

Moore, B. & Colas, B. (2016) *Identification guide to the common coastal food fishes of the Pacific Islands region*. Pacific Community, Noumea, New Caledonia.

Phillips, M., Henriksson, P.J.G, Tran N.V., Chan, C.Y., Mohan, C.V., Rodriguez, U.P., Suri, S., Hall, S. & Koeshendrajana, S. (2016) *Menjelajahi masa depan perikanan budidaya Indonesia*. Laporan Program, WorldFish: Penang, Malaysia.

Stobberup, K. & Geehan, J. (2015) *Final Project Report: Collection of Data from Tuna Fisheries in West Sumatra and North Sumatra Provinces, Indonesia* 87 pp.

White, W.T. (2012) A redescription of *Carcharhinus dussumieri* and *C. sealei*, with resurrection of *C. coatesi* and *C. tjutjot* as valid species (Chondrichthyes: Carcharhinidae). *Zootaxa* 3241, 1–34.

White, W.T., Last, P.R., Stevens, J.D., Yearsley, G.K., Fahmi & Dharmadi (2006) *Economically Important Sharks and Rays of Indonesia*. ACIAR Publishing, Canberra, 329 pp.

White, W.T., Last, P.R., Dharmadi, Faizah, R., Chodrijah, U., Prisantoso, B.I., Pogonoski, J.J., Puckridge, M. & Blaber, S.J.M. (2013) *Market fishes of Indonesia*. ACIAR Monograph Series, ACIAR Publishing, Canberra, 438 pp.