# Assessing resource status using length-based spawning potential ratio – A first step towards sustainable resource management on Wallis Island

*Baptiste Jaugeon,[1]* Gabrielle Cotonéa,[1] Benjamin Flais,[1] Savelina Taiava[1] and Jeremy Prince[2]*

## Abstract

Starting in 2019, the Fisheries Unit of the Wallis and Futuna Department of Agriculture, Forestry and Fisheries has been carrying out activities with its partners aimed at sustainable coastal resource management. The unit started collecting data as part of the Pacific Territories Regional Project for Sustainable Ecosystem Management on landed fish catches to assess the status of fisheries resources. The length-based spawning potential ratio (LBSPR) methodology was applied to assess the spawning potential ratio (SPR) of fisheries populations off of Wallis Island. The results suggest that the species assemblage is less overfished than other Pacific Islands. Species catch compositions, however, showed that fishing occurred at lower trophic levels. Some 23 of the 45 species assessed are considered to be sustainably fished (SPR >0.3), and 11 species had an SPR below the replacement threshold of SPR>0.2 (i.e. below the threshold at which species are able to renew their population). These species may be vulnerable because of selective fishing pressure, such as night spearfishing or fishing during spawning periods, which prevents stocks from recovering. This fresh information on Wallis Island's resource status sheds new light for discussions on fishing practices and management measures.

## Introduction

Small-scale coastal fisheries are essential to the food security and subsistence of over 200 million people globally, and over half the world's catches are made by small-scale fisheries (Garcia and Newton 1995). Unlike large-scale commercial fisheries, which are regularly monitored for their economic impact, small-scale fisheries lack the means required for well-informed resource management (Prince et al. 2019). This is the case in most Pacific Island countries and territories, where there are large numbers of reef fish species but data on catch trends and biology are insufficient for applying standard methods for assessing trends in biomass (Prince et al. 2019). The lack of biological information on reef fish catches has been a long-term challenge for their assessment and management (Andrew et al. 2007; SPC 2015).

A new methodology based on assessing reproductive potential in terms of length (LBSPR) has recently been developed for determining the status of data-poor fisheries (Hordyk et al. 2015). It combines the catch-length composition and local estimate of length at maturity to provide the spawning potential ratio (SPR) of a given population (Prince et al. 2019). A stock's SPR indicates its reproductive potential at a

[1] Wallis and Futuna Department of Agriculture, Forestry and Fisheries
[2] Biospherics Pty Ltd
* Author for correspondence: baptiste.jaugeon@agripeche.wf

More than 14 youth gained valuable skills in data collection and analysis during the spawning potential survey in Wallis. They were not afraid to dive into their mission.
@Gabrielle Cotonéa.

given fishing rate as compared with its maximum reproductive potential (Mace and Sissenwine 1993). It can be used as a population status indicator (Hordyk et al. 2015), providing an indication of whether the population is likely to decline, increase or remain stable (Prince et al. 2020).

Unfished or lightly fished stocks complete their full life cycle and reach 100% natural reproductive potential (SPR = 1). Conversely, fishing shortens specimens' average lifespans, thus reducing their potential for spawning to below 100% of the natural unfished level (Prince et al. 2021).

At around 0.5, SPR is considered ideal and results in the best catch rate for fishers (Prince et al. 2019). An SPR between 0.3 and 0.5 may be considered a fishing rate that could provide maximum sustainable yields (MSY) leading to maximum production long term (Prince et al. 2020). An SPR of 0.2 is regarded as the replacement threshold (Mace and Sissenwine 1993). This is the internationally established benchmark above which stocks must be maintained to reduce the risk of long-term decline (Prince et al. 2019). Below this point, the recruitment of young fish is expected to diminish.

Fishing has declined considerably in Wallis and Futuna. In 2020, only 9% of Wallisian households fished and ate fresh fish compared to 35% in 2006 (Bouard et al. 2021). Although these figures are related to a declining (human) population (the territory lost 22% of its population from 2003 to 2018), they also reflect profound societal change and possible dwindling resources (Jaugeon et al. 2022). Despite this, there are very few management measures addressing fishing methods, and the available data on Wallis and Futuna are insufficient for providing an objective picture of resource status. The perception surveys carried out by the Fisheries Unit in 2018, 2019 and 2020, revealed varying perceptions of resource status by stakeholders. Some fishers reported dwindling lengths of fish and catches, but this observation was, however, only infrequently seen as a problem and often came with a degree of fatalism and no expectation of any action to be taken. As far as most respondents were concerned, there was no causal relationship between fishing methods and diminishing resources. External factors, such as global warming and foreign ships were often cited instead. In 2021, Jaugeon and Juncker recommended developing resource monitoring and community-wide communication on the link between the various pressures and changes in resources as the first step towards setting up sustainable, participatory coastal resource management in Wallis and Futuna.

The European Union-funded Pacific Territories Regional Project for Sustainable Ecosystem Management (PROTEGE) enabled the Fisheries Unit of the Wallis and Futuna Department of Agriculture, Forestry and Fisheries to set up its own coastal fisheries observatory. The unit was able to apply the LBSPR method to regularly collected landing data. The method was specifically selected to conduct participatory work with communities and provide objective data for discussions about resource status in order to work towards sustainable marine resources management.

The assessment of resources fished off Wallis and Futuna using the LBSPR methodology is a first. This report presents the results, advantages and limitations of the method and the various implications for introducing participatory sustainable marine resource management on Wallis and Futuna.

## Material and methods

### *Landing surveys*

This study was carried out on Wallis Island in the French overseas territory of Wallis and Futuna. Data collection occurred from January 2020 to March 2023. A Responsible Fishers contest was held in 2021 and throughout 2022 to encourage fishers to take part in data collection. Several prizes were offered to fishers to encourage them to complete daily surveys. The database covered most fishing methods and all fishing grounds off Wallis Island were sampled. Each data collection exercise on catch lengths from a single fishing trip was called a "survey".

From January 2020 to March 2023 21,519 fish were measured. In all, 32 surveys were conducted, and 32 fishers took part in them. Surveys were carried out at the fishers' landing locations, points of sale or at fishers' homes. Samples were taken from some 20 landing sites, and surveys were conducted when fishers returned from their trips.

Data was gathered using the IKASAVEA app developed by the Pacific Community (SPC) in Noumea, New Caledonia.

Table 1: Data collected on fishing trips and effort through landing surveys.

| Trip data | Effort data |
|---|---|
| • Landing site<br>• Departure and return date and time<br>• Targeted fisheries<br>• Reason for fishing<br>• Vessel information (name, vessel type, engine type)<br>• Value (in French Pacific francs) of fuel used for each trip | • Fishing method<br>• Area (high seas, coastal waters, lagoon)<br>• Habitat (coral, seagrass, mangrove)<br>• Time spent fishing<br>• Fishing ground (defined by the Fisheries Unit) |


Collecting data and enjoying pleasant conversations with local fishers. ©Chloé Faure

Several data points were requested from the fishers and entered into the app.

For each fishing trip, all of the caught fish were photographed on a special 100 cm x 70 cm tarpaulin developed by SPC. A ruler and scales were also used. Specimens' fork lengths were measured to the nearest millimetre by image analysis. Older length data had been measured manually to the nearest half centimetre. All data collected were transferred to, and analysed using, a landing survey database and coastal fisheries web application set up by SPC.[3]

### *LBSPR assessment method*

The LBSPR assessment method is based on the fact that a fished population is dependent on the F/M ratio, known as relative fishing pressure, where *F* denotes fishing mortality and *M* natural mortality, and both life history ratios – M/k and $L_m/L_\infty$, where k is the von Bertalanffy growth coefficient. $L_m$, which is also known as $L_{50}$, is length at maturity (i.e. the length class in which 50% of individuals reach maturity, and $L_\infty$ is asymptotic length (i.e. the length an individual would reach if left to grow indefinitely (Hordyk et al. 2015). The model's algorithms calculate SPR by comparing catch lengths to length at maturity (Prince et al. 2020)

The data inputs required for the LBSPR model are:

i. catch size data, indicating fish lengths within a population;
ii. estimated length at maturity, defined by $L_{50}$ (or $L_m$) and $L_{95}$, the lengths at which 50% and 95% of the population become mature (Prince et al. 2020);
iii. the $L_m/L_\infty$ ratio, which is the relative length value obtained by dividing initial sexual maturity ($L_{50}$) by the length a specimen would reach if left to grow indefinitely ($L_\infty$);
iv. the M/k ratio, which is a measure of the speed at which each species grows to asymptotic length ($L_\infty$) (Prince et al. 2021).

Based on the assumed M/k and $L_\infty$ parameters and a given targeted stock's length composition, the LBSPR model estimates the species' selectivity curve. This logistic curve is defined by the selectivity parameters at lengths $SL_{50}$ and $SL_{95}$ and by relative fishing mortality, which are then used to calculate SPR (Hordyk et al. 2015).

[3] https://www.spc.int/CoastalFisheries/FieldSurveys/LdsSurvey

Like many length-based methods, the LBSPR model relies on a number of assumptions that need to be made arbitrarily in data-poor fisheries. Such underlying assumptions include asymptotic selectivity, growth as described by the von Bertalanffy equation, equal catchability between sexes, normal length distribution, constant natural mortality among adult age groups, and a constant growth rate among a stock's cohorts (Prince et al. 2015a).

The M/k and $L_m/L_\infty$ model input parameters used in the study were estimated values taken from a meta-analysis conducted by Jeremy Prince using available studies on age, growth and maturity of Indo-Pacific reef species (Prince et al. 2023)

SPR assessments were carried out on RStudio software using the LBSPR package.

### *Determining length at maturity*

Two methods were used to determine $L_{50}$ and $L_{95}$ lengths at maturity. The first method, based on length frequency was used for all species analysed. The method consists of converting the left-hand side of the catch length-frequency histogram into a cumulative frequency curve, as the 50th percentile of that curve approximates histological estimates of size at maturity. For this method, it is important to have specimens from each length class. This may lead to problems when immature specimens are not targeted or included in catches. When only mature specimens are caught in every length range, this can partially or totally distort the definition of the length-at-maturity curve (Prince et al. 2020). When this occurs, $L_{95}$ is calculated as 15% above $L_{50}$.

A second method, based on macroscopic gonad observation, was used. Because this method requires more time and resources, it was used for the most heavily targeted and eaten species. Macroscopically determined sizes at maturity were used for LBSPR analysis for the following species: *Caranx melampygus, Chlorurus microrhinos, Epinephelus polyphekadion, Etelis coruscans* and *Lutjanus gibbus*.

## Results

More than 271 finfish species were recorded during the study, showing the diversity of catches from Wallis Island. Such diversity also revealed how unselective fishers were and that the environment was ciguatera-free. Because the species were so diverse and so many fishing methods were used, the species recorded were very mixed. Samples of more than 1000 specimens were reached for only three species, namely *Acanthurus xanthopterus* (2908), *Lutjanus gibbus* (2595) and *Crenimugil* spp. (1866). Some 14 species had 300 to 1000 specimens, 18 species had 100 to 300 and 10 other species had 50 to 100 specimens.

Fourteen fishing methods were recorded. Some 7460 fish (38% of catches) were obtained by daytime spearfishing, 5197 (22%) by gillnetting and 4965 fish (21%) by handlining. The remaining fish were caught using manual or electric droplines, cast nets, night spearfishing or line casting.

To ensure the results were viable, a minimum threshold of 50 length measurements was set for each species. Species for which distributions were not representative, or for which SPR values were too variable (confidence interval or

A ruler and scale device was used to measure and weigh fish like this *Monotaxis grandoculis*, the humpnose big eye bream. ©Baptiste Jaugeon

Table 2: LBSPR assessment input parameters. Ideal fishing in green (SPR >0.5); fished at maximum sustainable yields (MSY) in orange (0.3 <SPR <0.5), and overfished in red (SPR <0.3). Values with confidence intervals (95% CI 95%. Average SPR = 0.42 (95% CI 0.33–0.52).

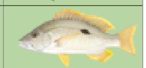
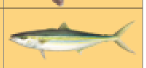
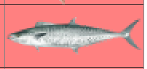
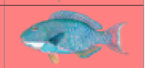
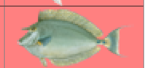
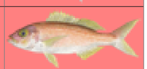
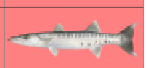
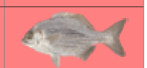
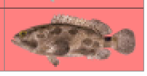
| Species | No. of specimens | SPR | SL$_{50}$ (cm) | SL$_{95}$ (cm) | F/M | M/K | Linf (cm) | L$_{50}$ (cm) | L$_{95}$ (cm) | Fishing technique | Harvest status | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Caranx melampygus* | 570 | 1 (1–1) | 29.62 (28.15–31.09) | 36.88 (33.83–39.93) | 0 (0–0) | 1.15 | 52.93 | 32.29 | 41.24 | Line, net, spearfishing | Optimal |  |
| *Lutjanus bohar* | 346 | 1 (1–1) | 32.13 (29.03–35.23) | 45.49 (39.79–51.19) | 0 (0–0) | 0.75 | 44.59 | 33.00 | 37.95 | Line, net, spearfishing | Optimal |  |
| *Aprion virescens* | 203 | 1 (1–1) | 40.37 (38.94–41.8) | 43.88 (40.88–46.88) | 0 (0–0) | 0.75 | 59.82 | 44.27 | 50.91 | Line and spearfishing | Optimal |  |
| *Epinephelus howlandi* | 78 | 1 (1–1) | 26.34 (24.65–28.03) | 29.08 (25.78–32.38) | 0 (0–0) | 0.96 | 43.15 | 28.48 | 32.75 | Line and spearfishing | Optimal |  |
| *Variola louti* | 68 | 1 (1–1) | 31.15 (23.83–38.47) | 43.51 (30.33–56.69) | 0 (0–0) | 0.96 | 45.53 | 30.05 | 34.56 | Line and spearfishing | Optimal |  |
| *Etelis boweni* | 103 | 0.99 (0.85–1) | 23.29 (20.88–25.7) | 29.33 (24.81–33.85) | 0.01 (0–0.12) | 0.75 | 36.27 | 26.84 | 30.87 | Line | Optimal |  |
| *Acanthurus olivaceus* | 180 | 0.97 (0.53–1) | 19.13 (17.64–20.62) | 22.02 (19.4–24.64) | 0.03 (0–0.45) | 0.47 | 24.78 | 20.07 | 23.08 | Line and spearfishing | Optimal |  |
| *Lutjanus monostigma* | 191 | 0.91 (0.61–1) | 25.19 (23.41–26.97) | 30.05 (27.08–33.02) | 0.07 (0–0.33) | 0.75 | 38.23 | 28.29 | 32.53 | Line and spearfishing | Optimal |  |
| *Etelis coruscans* | 298 | 0.9 (0.65–1) | 49.97 (46.22–53.72) | 62.96 (56.62–69.3) | 0.08 (0–0.32) | 0.75 | 74.41 | 55.06 | 63.32 | Line | Optimal |  |
| *Caranx ignobilis* | 159 | 0.79 (0.52–1) | 55.78 (50.45–61.11) | 71.93 (63.03–80.83) | 0.2 (0–0.51) | 1.13 | 91.44 | 56.69 | 65.19 | Line and spearfishing | Optimal |  |
| *Lutjanus gibbus* | 2595 | 0.6 (0.56–0.65) | 24.21 (23.98–24.44) | 26.86 (26.43–27.29) | 0.5 (0.41–0.59) | 0.75 | 34.34 | 25.41 | 34.20 | Line and spearfishing | Optimal |  |
| *Lethrinus xanthochilus* | 311 | 0.59 (0.44–0.74) | 34.23 (31.47–36.99) | 42.99 (38.53–47.45) | 0.69 (0.22–1.16) | 0.82 | 47.79 | 33.45 | 38.47 | Line and spearfishing | Optimal |  |
| *Crenimugil spp.* | 1866 | 0.52 (0.48–0.55) | 38.04 (37.45–38.63) | 43.64 (42.69–44.59) | 0.97 (0.79–1.15) | 1.66 | 54.88 | 36.77 | 42.29 | Net | Optimal |  |
| *Ellochelon vaigiensis* | 693 | 0.48 (0.43–0.54) | 31.27 (30.93–31.61) | 33.44 (32.85–34.03) | 0.77 (0.59–0.95) | 1.66 | 47.78 | 32.01 | 36.81 | Net | MSY |  |
| *Lethrinus harak* | 137 | 0.46 (0.32–0.6) | 22.54 (21.75–23.33) | 24.86 (23.47–26.25) | 0.81 (0.38–1.24) | 0.82 | 34.09 | 23.86 | 27.44 | Line and spearfishing | MSY |  |
| *Naso hexacanthus* | 476 | 0.45 (0.36–0.54) | 45.17 (43.38–46.96) | 51.95 (49.19–54.71) | 2.1 (1.14–3.06) | 0.47 | 51.14 | 41.42 | 47.63 | Spearfishing | MSY |  |
| *Cephalopholis argus* | 97 | 0.38 (0.24–0.52) | 25.29 (23.92–26.66) | 28.91 (26.45–31.37) | 1.05 (0.46–1.64) | 0.96 | 39.85 | 26.30 | 30.25 | Line and spearfishing | MSY |  |
| *Epinephelus fuscoguttatus* | 166 | 0.37 (0.15–0.59) | 66.54 (54.54–78.54) | 87.99 (71.36–104.62) | 1.89 (0.05–3.73) | 0.96 | 89.55 | 59.10 | 67.97 | Line and spearfishing | MSY |  |
| *Acanthurus xanthopterus* | 2908 | 0.33 (0.29–0.37) | 39.15 (38.23–40.07) | 49.02 (47.69–50.35) | 2.6 (2.15–3.05) | 0.47 | 44.80 | 36.29 | 41.66 | Spearfishing | MSY |  |
| *Epinephelus maculatus* | 145 | 0.33 (0.22–0.44) | 30.46 (28.8–32.12) | 35.74 (32.86–38.62) | 1.25 (0.67–1.83) | 0.96 | 48.24 | 31.84 | 36.62 | Line and spearfishing | MSY |  |
| *Elagatis bipinnulata* | 82 | 0.33 (0.17–0.49) | 53.1 (47.46–58.74) | 64.68 (55.35–74.01) | 1.33 (0.4–2.26) | 1.13 | 87.44 | 54.21 | 62.34 | Line and spearfishing | MSY |  |
| *Acanthurus blochii* | 296 | 0.32 (0.25–0.4) | 31.24 (29.94–32.54) | 37.52 (35.45–39.59) | 2.38 (1.45–3.31) | 0.47 | 38.23 | 30.97 | 35.62 | Spearfishing | MSY |  |
| *Sphyraena qenie* | 260 | 0.32 (0.21–0.43) | 74.87 (65.81–83.93) | 99.14 (84.65–113.63) | 1.68 (0.81–2.55) | 1.01 | 127.17 | 67.4 | 77.5 | Line and spearfishing | MSY |  |

Table 2 con't

| Species | No. of specimens | SPR | $SL_{50}$ (cm) | $SL_{95}$ (cm) | F/M | M/K | Linf (cm) | $L_{50}$ (cm) | $L_{95}$ (cm) | Fishing technique | Harvest status | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chlorurus microrhinos* | *763* | 0.3 (0.27–0.34) | 34.74 (34.08–35.4) | 39.25 (38.04–40.46) | 1.8 (1.48–2.12) | 0.78 | 51.74 | 34.15 | 42.16 | Spearfishing | Overfished |  |
| *Lethrinus olivaceus* | *498* | 0.29 (0.17–0.41) | 59.58 (56.29–62.87) | 77.17 (73.26–81.08) | >5 | 0.82 | 64.36 | 45.05 | 51.81 | Spearfishing, line and net | Overfished |  |
| *Scomberomorus commerson* | *58* | 0.27 (0.1–0.44) | 72.51 (63.09–81.93) | 90.62 (74.8–106.44) | 1.44 (0.36–2.52) | 0.79 | 118.51 | 80.59 | 92.68 | Spearfishing and line | Overfished |  |
| *Monotaxis grandoculis* | *255* | 0.26 (0.07–0.45) | 44.71 (40.72–48.7) | 57 (52.39–61.61) | >5 | 0.82 | 48.94 | 34.26 | 39.40 | Spearfishing and line | Overfished |  |
| *Lethrinus atkinsoni* | *112* | 0.24 (0.16–0.33) | 27.5 (26.09–28.91) | 31.22 (28.85–33.59) | 2.44 (1.23–3.65) | 0.82 | 38.97 | 27.28 | 31.37 | Line | Overfished |  |
| *Caranx sexfasciatus* | *116* | 0.24 (0.03–0.45) | 53.62 (43.9–63.34) | 68.03 (54.92–81.14) | 3.51 (0–7.26) | 1.13 | 74.63 | 46.27 | 53.21 | Spearfishing and line | Overfished |  |
| *Scarus rubroviolaceus* | *319* | 0.23 (0.16–0.3) | 37.54 (35.11–39.97) | 45.58 (41.69–49.47) | 3.08 (1.84–4.32) | 0.78 | 55.09 | 36.36 | 41.81 | Spearfishing and net | Overfished |  |
| *Hipposcarus longiceps* | *334* | 0.23 (0.14–0.32) | 36.66 (33.73–39.59) | 44.67 (40.28–49.06) | 4.01 (1.9–6.12) | 0.78 | 50.64 | 33.42 | 38.43 | Net and spearfishing | Overfished |  |
| *Ctenochaetus striatus* | *64* | 0.23 (0.09–0.37) | 18.81 (17.39–20.23) | 21.38 (19.19–23.57) | >5 | 0.47 | 22.49 | 18.22 | 20.96 | Spearfishing and net | Overfished |  |
| *Cetoscarus ocellatus* | *183* | 0.22 (0.07–0.37) | 45.41 (40.19–50.63) | 56.75 (49.75–63.75) | >5) | 0.78 | 58.41 | 38.55 | 44.33 | Spearfishing | Overfished |  |
| *Paracaesio kusakarii* | *63* | 0.22 (0.04–0.4) | 50 (42.02–57.98) | 64.68 (53.23–76.13) | 2.95 (0.18–5.72) | 0.75 | 65.41 | 48.40 | 55.66 | Line | Overfished |  |
| *Naso unicornis* | *299* | 0.19 (0.06–0.33) | 48.08 (44.87–51.29) | 59.67 (55.8–63.54) | >5 | 0.47 | 51.22 | 41.49 | 47.72 | Spearfishing and net | Overfished |  |
| *Caranx papuensis* | *366* | 0.19 (0.04–0.34) | 55.65 (48.57–62.73) | 78.07 (69.52–86.62) | >5 | 1.13 | 71.06 | 44.06 | 50.67 | Net and spearfishing | Overfished |  |
| *Pristipomoides flavipinnis* | *134* | 0.17 (0.06–0.28) | 40.33 (37.29–43.37) | 49.02 (44.97–53.07) | >5 | 0.75 | 48.62 | 35.98 | 41.37 | Line | Overfished |  |
| *Sphyraena forsteri* | *360* | 0.14 (0.11–0.16) | 43.1 (41.98–44.22) | 48.33 (46.2–50.46) | 3.64 (2.9–4.38) | 1.01 | 79.13 | 41.94 | 48.23 | Line | Overfished |  |
| *Carangoides orthogrammus* | *70* | 0.14 (0.08–0.19) | 36.59 (34.81–38.37) | 41.35 (38.32–44.38) | >5 | 1.13 | 56.94 | 35.30 | 40.60 | Net and spearfishing | Overfished |  |
| *Acanthurus nigricauda* | *709* | 0.13 (0.08–0.17) | 23.27 (22.71–23.83) | 25.74 (25.02–26.46) | >5 | 0.47 | 26.91 | 21.80 | 25.07 | Nett | Overfished |  |
| *Scomberoides lysan* | *331* | 0.12 (0.08–0.16) | 43.39 (41.79–44.99) | 49.32 (46.92–51.72) | >5 | 0.79 | 61.25 | 41.65 | 47.89 | Net | Overfished |  |
| *Sphyraena barracuda* | *185* | 0.11 (0.08–0.14) | 65.86 (63.46–68.26) | 75.8 (71.62–79.98) | 3.86 (2.82–4.9) | 1.01 | 125.28 | 66.40 | 76.36 | Spearfishing and line | Overfished |  |
| *Kyphosus vaigiensis* | *91* | 0.09 (0.03–0.15) | 35.04 (31.43–38.65) | 42.16 (36.46–47.86) | >5 | 0.50 | 50.60 | 34.41 | 39.57 | Spearfishing and net | Overfished |  |
| *Scarus ghobban* | *81* | 0.09 (0–0.19) | 39.51 (35.45–43.57) | 46.36 (41.07–51.65) | >5 | 0.78 | 53.41 | 35.25 | 40.54 | Spearfishing and net | Overfished |  |
| *Epinephelus polyphekadion* | *422* | 0.07 (0.05–0.09) | 39.95 (38.08–41.82) | 48.92 (46.07–51.77) | >5 | 0.96 | 67.97 | 44.86 | 58.59 | Line and spearfishing | Overfished |  |

CI>0.5), were excluded. In total, 45 species were selected for this assessment.

The model results showed varied SPR values for the 45 species assessed. The quality of the model estimates mainly depends on the number of individuals measured. Values were distributed around and above the average SPR value, which was 0.42 (95% CI 0.33–0.52).

However, 11 species fell below the replacement threshold set at 0.2, meaning that the species had a reproductive potential that did not enable it to renew its population and so an "overfished" status was assigned to these species, which was the case for *Caranx papuensis*, *Naso unicornis*, *Epinephelus polyphekadion* and *Scarus ghobban*.

Another 11 species had an SPR of 0.2 to 0.3. Although this was above the international replacement threshold, some authors consider that a stock cannot be sustainably fished below a threshold of 0.3 (Ault et al. 2008). Species such as *Hipposcarus longiceps*, *Scarus rubroviolaceus*, *Scomberomorus commerson* and *Chlorurus microrhinos* were, therefore, also classified as overfished.

A further 10 species, including *Acanthurus xanthopterus* and *Epinephelus fuscoguttatus*, had an SPR of between 0.3 and 0.5, which may be considered a fishing level that is conducive to maximum sustainable yields (MSY) (Prince et al. 2020).

Thirteen species, including *Lutjanus gibbus, Caranx ignobilis* and *Crenimugil* spp., could be considered as fished to ideal levels, with an SPR over 0.5 and were, therefore, classified as well managed and/or moderately fished species, based on the same international benchmarks (Prince et al. 2019).

## Discussion

The LBPSR assessment method was used for the first time on Wallis Island.

With the collaboration of some 30 local fishers, data gathering was carried out over a period of three years and the data collected was used to assess the stock status of the 45 most heavily fished reef and lagoon species, 23 of which could be considered as sustainably targeted (SPR > 0.3).

A tarpaulin, designed by SPC, was used to easily collect data at landing sites. ©Gabrielle Cotonéa


Data collection efforts in Futuna increased in 2023. Findings should be available by the end of the year. ©Gabrielle Cotonéa

## Satisfactory outcomes for the region

The 0.42 average SPR value obtained (CI 95% 0.33–0.52) fell within the international standard interval (0.3-0.4) used as a proxy for fishing levels that may be conducive to MSYs (Prince et al. 2020). The results were more satisfactory than for other Pacific Island countries such as Palau, where the average SPR was only 0.12 for 12 species considered in 2015 (Prince et al. 2015b), or Fiji where the average SPR was 0.19 for 29 species assessed in 2019 (Prince et al. 2019). The SPR for *Lutjanus gibbus* species, for example, was 0.6 at Wallis Island but only 0.09 in Fiji and 0.10 in Palau. Results were closer to those observed in Solomon Islands in 2020, where average SPR was approximately 0.35 (Prince et al. 2020).

## Fishing pressure and methods that prevent fish stocks from replenishing

The results nevertheless call for caution because, of the 45 species considered, 22 may be considered overfished (SPR <0.3). This means that current fishing pressure is preventing fish stocks from replenishing themselves. The results also agree with fishers' testimonies of a fall in fish lengths and numbers as well as fish being harder to catch.

Off of Wallis Island, catch compositions indicated that fishing was tending towards lower trophic levels (Pauly et al.1998). Larger species, such as *Bolbometopon muricatum*, *Cheilinus undulatus* and *Plectropomus laevis* appeared less often in catches, while other species such as *Epinephelus polyphekadion, Scomberomorus commerson* and *Sphyraena barracuda* had SPRs below 0.2. The fact that smaller species such as *Lutjanus gibbus, Lethrinus xanthochilus* and *Lethrinus harak* appeared in catches also showed that fishing effort was focusing on ever smaller species.

Some species caught mainly by spearfishing and netting in the parrotfish family (e.g. *Scarus ghobban, Scarus rubroviolaceus, Cetoscarus ocellatus, Chlorurus microrhinos* and *Hipposcarus longiceps*) and the Acanthuridae family (e.g. *Naso unicornis, Acanthurus nigricauda* and *Ctenochaetus striatus*) had SPRs below 0.3.

One of the most widespread and harmful fishing methods in Wallis and Futuna is undoubtedly night spearfishing. Although prohibited by regulation, it is still deeply rooted in the customs and practices of many fishers. The method brings a selective fishing pressure to bear on certain species, often the most prolific breeders, which prevents populations from rebuilding their numbers. It has also been demonstrated that it could have a major impact on parrotfish and on grouper spawning aggregations (Gillett and Moy 2006). Despite the lack of data on this method, there is no doubt that it has harmful effects on resources. Even during the day, spearfishing cannot be discounted from the methods contributing to overfishing in coastal waters, as it can have fast-acting, deleterious effects on populations due to its effectiveness and selection of species that are unable to withstand the pressure (Gillett and Moy 2006). Stringent management, therefore, needs to be introduced, especially as the method targets herbivorous fish, such as surgeonfish (Arcanthuridae) and parrotfish (Scaridae), both of which provide essential ecosystem services for maintaining coral reefs.

Gonad analysis at the DSA veterinary clinic. ©Baptiste Jaugeon

The camouflage grouper *Epinephelus polyphekadion* had the lowest SPR at 0.07. At that stage, the stock can be considered collapsed, and *E. polyphekadion* is under heavy fishing pressure (F/M >5) and can be caught either by spearfishing, netting or handlining. Like other Serranidae family species, *E. polyphekadion* populations appear to be sensitive to fishing pressure, as seen in Fiji, where stock assessment results highlighted the species' fragility at SPR 0.03 (Prince et al. 2019). These low estimates may be due to the species' breeding method. During the breeding season, they form brief spawning aggregations in which hundreds or even thousands of fish gather and breed in the various inlets (Rhodes and Sadovy 2002). Around Wallis, fishers regularly, even systematically, fish in the inlets, which are passageways for a multitude of species and large specimens that are less commonly found in the lagoon. Some fishers, however, increase their fishing effort during spawning aggregations to catch as many specimens as possible, which may affect breeding in some species.

### *Prospects for sustainable participatory coastal resource management on Wallis Island*

One of the study objectives was to raise awareness among local communities regarding the threats to their marine resources. Such participatory work with fishers is a means of informing them about the causal link between fishing and dwindling resources. Marine ecosystems face many pressures such as climate change, eutrophication of coastal waters, habitat damage and pollution, all of which have increasingly harmful effects on fisheries. Overfishing, however, remains the main human-induced factor (Prince et al. 2021). Before the Wallis and Futuna fisheries observatory was set up, the local community did not seem to be particularly concerned when faced with a decline in some species, and did not see coastal resource management as a priority. Several measures have now been taken under the Wallis and Futuna coastal resource management strategy, enabling various stakeholders (fishers, traditional leaders and managers) to rally around a shared interest. The preliminary study results have recently stimulated discussion over introducing resource restoration management measures and provide a glimmer of fresh hope for reef and lagoon resource management on Wallis Island.

Although some species are not directly in danger of collapse, applying management measures, such as banning night spearfishing, temporarily banning fishing on spawning grounds and imposing minimum catch sizes on Wallis Island would help increase SPR levels to above 0.3, thus ensuring that fishers gain better yields and stocks remain more resilient to global environmental changes. Awareness and communication campaigns in this area must continue in order to ensure management measures are effectively applied.

Despite the limitations encountered, the LBSPR method proved to be the best option for assessing small-scale fisheries on Wallis Island. A more accurate estimate of species size at maturity and SPR can be achieved by collecting larger samples. Data collection has begun on Futuna, and the data gathered will ultimately provide the information required to manage reef and lagoon resources for both islands.

## References

Andrew N.L., Béné C., Hall S.J., Allison E.H., Heck S. and Ratner B.D. 2007. Diagnosis and management of small-scale fisheries in developing countries. Fish and Fisheries 8(3) 227–240.

Ault J.S, Smith S.G, Luo J., Monaco M.E. and Appeldoorn R.S. 2008. Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico. Environmental Conservation 3:221–231.

Bouard S., Brouillon J. Gaillard C. Sabinot C. and Lauffenburger M. 2021. Analyse des données du secteur primaire (agriculture, élevage, pêche, artisanat et chasse) issues de l'enquête BDF 2019 de Wallis et Futuna. Noumea, New Caledonia: New Caledonian Institute of Agronomy.

Garcia S.M. and Newton C. 1995. Current situation, trends and prospects in world capture fisheries. Rome, Italy: Food and Agriculture Organization of the United Nations Fisheries Department.

Gillett R. and Moy W. 2006. Spearfishing in the Pacific Islands: Current status and management issues. FAO Fishcode Review No.19. Rome, Italy: Food and Agriculture Organization of the United Nations.

Hordyk A., Ono K., Valencia S., Loneragan N. and Prince J. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science 72(1):217–231.

Jaugeon B. and Juncker M. 2021. An overview of fishing in Wallis and Futuna: Prospects for the sustainable management of coastal marine resources. SPC Fisheries Newsletter 165:76–88. https://purl.org/spc/digilib/doc/pizcy

Jaugeon B. et collaborateurs du service de la pêche de Wallis et Futuna. 2022. Rapport annuel de l'observatoire des pêches côtières de Wallis et Futuna 2021 : pour une gestion durable des ressources marines. Aka'aka, Wallis and Futuna: Direction des services de l'agriculture de la forêt et de la pêche.

Mace P.M. and Sissenwine M.P. 1993. How much spawning per recruit is enough? Canadian Special Publication of Fisheries and Aquatic Sciences 101–118.

Pauly D., Christensen V., Dalsgaard J., Froese R. and Torres Jr F. 1998. Fishing down marine food webs. Science 279(5352):860–863.

Prince J., Hordyk A., Valencia S.R., Loneragan N. and Sainsbury K. 2015a. Revisiting the concept of Beverton–Holt life-history invariants with the aim of informing data-poor fisheries assessment. ICES Journal of Marine Science 72(1):194–203.

Prince J., Victor S., Kloulchad V. and Hordyk A. 2015b. Length based SPR assessment of eleven Indo-Pacific coral reef fish populations in Palau. Fisheries Research 171:42–58.

Prince J., Lalavanua W., Tamanitoakula J., Loganimoce E., Vodivodi T., Marama K., Waqainabete P., Jeremiah F., Nalasi D., Tamata L., Naleba M., Naisilisili W., Kaloudrau U., Lagi L., Logatabua K., Dautei R., Tikaram R. and Mangubhai S. 2019. Spawning potential surveys reveal an urgent need for effective management. SPC Fisheries Newsletter 158:28–36. https://purl.org/spc/digilib/doc/y6mf4

Prince J., Smith A., Raffe M., Seeto S. and Higgs J. 2020. Spawning potential surveys in Solomon Islands' Western Province. SPC Fisheries Newsletter 162:58–68. https://purl.org/spc/digilib/doc/pb5b3

Prince J., Lalavanua W., Tamanitoakula J., Tamata L., Green S., Radwa S. and Mangubhai S. 2021. Spawning potential surveys in Fiji: A new song of change for small-scale fisheries in the Pacific. Conservation Science and Practice 3(2):e273.

Prince J.D., Wilcox C. and Hall N. 2023. How to estimate life history ratios to simplify data-poor fisheries assessment. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsad026

Rhodes K.L. and Sadovy Y. 2002. Temporal and spatial trends in spawning aggregations of camouflage grouper, Epinephelus polyphekadion, in Pohnpei, Micronesia. Environmental Biology of Fishes 63(1):27–39.

SPC (Pacific Community). 2015. A new song for coastal fisheries pathways to change: the Noumea strategy. Noumea, New Caledonia: Secretariat of the Pacific Community. 16 p. Available at: https://purl.org/spc/digilib/doc/b8hvs