Marine Policy 33 (2009) 64–76

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Planning the use of fish for food security in the Pacific

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ARTICLE INFO

Article history:
Received 26 March 2008
Received in revised form
8 April 2008
Accepted 8 April 2008

Keywords:
Population growth
Allocation of fisheries resources
Coastal fisheries management
Access to tuna
Pond aquaculture

ABSTRACT

Fish is a mainstay of food security for Pacific island countries and territories (PICTs). Recent household income and expenditure surveys, and socio-economic surveys, demonstrate that subsistence fishing still provides the great majority of dietary animal protein in the region. Forecasts of the fish required in 2030 to meet recommended per capita fish consumption, or to maintain current consumption, indicate that even well-managed coastal fisheries will only be able to meet the demand in 6 of 22 PICTs. Governments of many PICTs will need to increase local access to tuna, and develop small-pond aquaculture, to provide food security. Diversifying the supply of fish will also make rural households in the Pacific more resilient to natural disasters, social and political instability, and the uncertainty of climate change.

1. Introduction

Fish[1] are of great importance to the people of the Pacific—everywhere in the region, fish contribute substantially to subsistence and market-based economies [1,2]. For several of the smaller Pacific island countries and territories (PICTs), fish is their most important renewable resource. Tuna are a particularly valuable asset [3–7].

The Pacific Plan [8] recognises that development of PICTs is linked to the effective management of fish, and the habitats that support them. '*Development and implementation of national and regional conservation and management measures for the sustainable use of fisheries resources*' is a priority of the Plan, and the recent 'Vava'u Declaration' [9] reinforces the need for responsible and effective stewardship of the region's fisheries.

The objectives and strategies of fisheries agencies throughout the region repeat the desire to use fish for the benefit of people within the context of sustainable development [10]. These goals are also reflected in the mission and vision statements of the two main regional organisations, the Secretariat of the Pacific Community (SPC) and the Pacific Islands Forum Fisheries Agency (FFA), that assist PICTs to manage their fisheries and fish habitats.

Despite these ideals, national and regional approaches to the sustainable use of fish often fail to specify what the expected benefits are, and how they will be delivered. Basic questions like 'How much fish is needed to feed people? How can it be supplied most efficiently? How many livelihoods can be supported sustainably from the fisheries sector?' and 'How can fisheries contribute best to economic growth?' remain unanswered. Management of tuna is the exception—considerable thought has gone into how to maximise national revenue and jobs from this valuable resource [4,5]. But even for tuna, there is much room for improved national planning, particularly in how to use tuna for food security.

The rapid population growth occurring in many PICTs [11] demands urgent answers to these questions. Better planning and policies are essential. PICTs need to know where the gaps between future requirements for fish and supply will occur, and how to fill them in ways that are resilient to natural disasters, social and political instability, and the uncertainty of climate change.

This paper outlines an approach for planning the contribution of fish to the future food security of the Pacific, where food security is defined as physical, social and economic access to sufficient safe and nutritious food to meet dietary needs and preferences [12]. The focus is mainly on physical access to fish for food, although aspirations for sustainable livelihoods (employment and income) based on fisheries, and their contributions to food security, are also addressed.

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[1] Fish is used here in the broad sense to include fish and invertebrates.

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doi:10.1016/j.marpol.2008.04.002

The approach recommended in this paper involves four main steps that governments can take to plan the use of fish to meet national food requirements, *viz.* (1) identify the per capita fish consumption needed for good nutrition; (2) estimate the current consumption of fish and identify any shortfalls in the recommended intake of fish; (3) forecast the fish needed in the future (to 2030); and (4) harmonise the use and development of fish resources to optimise food security, livelihoods and economic growth.

The analyses that underpin this approach are founded on the reality that many communities in the Pacific depend heavily on subsistence fishing and have limited access to other sources of protein. In this sense, they differ from those of others who have estimated the future demand for fish in Asia and elsewhere based more on market forces [13,14]. The effects of price elasticity on the demand for fish by those in the Pacific unable to catch it for themselves are not discounted, but are not considered here.

2. Fish consumption for good nutrition

The World Health Organisation (WHO) recommends that daily protein intake for good nutrition should be ~0.7 g of protein per kg body weight per day, derived from a variety of sources to prevent micronutrient deficiencies [15,16]. In view of the limited range of crops and animal protein in the Pacific [17,18], a strong tradition of eating fresh fish in the region [2,19], and the nutritional and health benefits of fish [20–23], many PICTs will need to consider developing plans to use fish to provide ~50% of the required dietary protein.

Based on the predicted age structure of populations in the Pacific until 2030 [11], the age–weight relationships typical of the region [24–26], and the fact that fresh fish consists of ~20% protein [27], an annual average per capita fish consumption of 34–37 kg is required to provide ~50% of the recommended protein intake for PICTs.[2]

3. Current consumption of fish in the Pacific

Information from household income and expenditure surveys (HIES) conducted by 15 PICTs, mainly between 2001 and 2006, was used to estimate existing patterns of fish consumption throughout much of the Pacific. HIES were designed to enumerate fish consumption based on both subsistence and cash acquisitions [28,29]. The number of households interviewed ranged from 512 (30% of the total population) in Tuvalu to 4320 (5%) in Solomon Islands. The following aspects of fish consumption were quantified: national, urban and rural annual per capita consumption; the proportions of fish derived from subsistence fishing and purchases; the percentage of fresh and canned fish in the diet; and the contribution of fish to total intake of animal protein. Except for the large countries in Melanesia where there are inland communities, data from rural areas usually represented consumption by coastal communities.

No HIES was available for Papua New Guinea (PNG). Instead, other information on the economic and nutritional importance of household food production was used for PNG [30]. Guam, Marshall Islands, Northern Mariana Islands and American Samoa were not included in the analyses because HIES from these PICTs make no distinction between cash transactions and subsistence.

To gain more detailed information on consumption of fish by coastal fishing communities, data from socio-economic surveys [31,32] conducted by the PROCFish-C project within the SPC Coastal Fisheries Programme between 2004 and 2007 were also analysed. The socio-economic surveys (SES) usually involved 25–30 households at each of four or more sites per PICT.

Estimates of fish consumption in rural areas made using HIES and SES varied not only due to the methods used and the fact that they were carried out at different times, but also for two other reasons: (1) in Melanesia, HIES in rural areas included coastal and inland households, whereas only coastal fishing villages were involved in SES and (2) HIES did not include fish received as gifts, whereas SES measured all fish consumed.

Five strong patterns emerged from these analyses.

(i) *Fish consumption in many PICTs is remarkably high*: National consumption of fish in six PICTs in Micronesia and Polynesia was at least twice the level needed to supply ~50% of the recommended protein requirements (Table 1). In another five countries, national fish consumption was close to, or well in excess of, the 34–37 kg per year needed for good nutrition. National fish consumption was below the proposed recommended levels in Fiji, New Caledonia, Vanuatu and Tonga, and well below this level in PNG (Table 1).

(ii) *Many rural communities depend heavily on fish*: In Polynesia, fish consumption by rural communities was twice that in urban centres (Table 1). In Micronesia, differences between urban and rural areas were less pronounced when assessed by HIES, although SES also pointed to large differences in the consumption of fish between coastal fishing communities and urban dwellers. In Melanesia, rural communities in PNG, and to some extent Solomon Islands, ate much less fish than their urban counterparts due to poor access to fish in inland areas. In contrast, many coastal fishing communities in

Table 1
Annual per capita fish consumption (kg) for Pacific island countries and territories (PICTs), determined from household income and expenditure surveys (HIES)

PICT	HIES			SES
	National	Urban	Rural	Coastal ± SE
Melanesia				
Fiji	20.7	15.0	25.3	113.0 ± 6.18
New Caledonia[a]	25.6	10.7	54.8	43.2 ± 3.16
Papua New Guinea	13.0	28.1	10.2	53.3 ± 2.29
Solomon Islands	33.0	45.5	31.2	118.3 ± 3.98
Vanuatu	20.3	19.3	20.6	29.9 ± 3.10
Micronesia				
FSM	69.3	67.3	76.8	96.0 ± 6.36
Kiribati	62.2	67.3	58.0	115.3 ± 5.32
Nauru[b]	55.8			62.3 ± 2.78
Palau	33.4	27.8	43.3	78.6 ± 7.91
Polynesia				
Cook Islands	34.9	24.8	60.9	78.5 ± 4.90
French Polynesia	70.3	52.2	90.1	60.9 ± 4.16
Niue[b]	79.3			49.5 ± 2.01
Samoa	87.4	45.6	98.3	94.1 ± 4.35
Tonga[b]	20.3			84.6 n/a
Tuvalu	110.7	68.8	147.4	145.5 ± 5.45
Wallis & Futuna[b]	74.6			56.2 ± 5.13

For coastal fishing communities, consumption was determined from socio-economic surveys (SES). See http://www.spc.int/sdp/index.php?option=com_docman&task=cat_view&gid=28&Itemid=42 for the proportion of the total population of PICTs in urban and rural areas. SE = standard error; n/a = not available because sample size was only two villages.

[a] HIES done in 1991; independent analysis in 1998 [99] found that mean annual per capita fish consumption in the Northern Province was 28.0 kg.

[b] Represents entire PICT.

[2] The estimated ranges in the recommended annual average per capita fish consumption between 2010 and 2030 vary from 33.7 to 35.4 kg for Melanesia; 35.6–37.6 kg for Micronesia; and 35.4–37.1 kg for Polynesia due to predicted differences in age/gender structures of populations among regions.

Table 2
Percentage of annual per capita fish consumption derived from subsistence fishing and purchases of fish in urban and rural areas of Pacific island countries and territories (PICTs), determined by household income and expenditure surveys

PICT	National		Urban		Rural	
	% Subsistence	% Purchased	% Subsistence	% Purchased	% Subsistence	% Purchased
Melanesia						
Fiji	35	65	7	93	52	48
New Caledonia[a]	78	22	42	58	91	9
Papua New Guinea					64	36
Solomon Islands	64	36	13	87	73	27
Vanuatu	51	49	17	83	60	40
Micronesia						
FSM	74	26	73	27	77	23
Kiribati	63	37	46	54	79	21
Nauru[b]	66	34				
Palau	47	53	35	65	60	40
Polynesia						
Cook Islands	51	49	27	73	76	24
French Polynesia	72	28	60	40	78	22
Niue[b]	56	44				
Samoa	44	56	21	79	47	53
Tonga[b]	37	63				
Tuvalu	77	23	56	44	86	14
Wallis and Futuna[b]	86	14				

[a] HIES done in 1991; independent analysis in 1998 [99] showed that 92% of fish consumed in the Northern Province was caught when gifts of fish were included.
[b] Represents entire PICT.

Table 3
Contributions of fresh fish to fish consumption, and all fish consumed to total animal protein, in Pacific island countries and territories (PICTs), determined by household income and expenditure surveys (HIES)

PICT	% Consumption comprising fresh fish				% Animal protein		
	HIES			SES			
	National	Urban[a]	Rural	Coastal	National	Urban	Rural
Melanesia							
Fiji	59	45	66	92			
New Caledonia				85			
Papua New Guinea	77	76	77	87			
Solomon Islands	90	80	90	97	92	83	94
Vanuatu	60	38	65	72	56	43	60
Micronesia							
FSM	92	91	97	76	82	83	80
Kiribati	92	91	93	95	84	80	89
Nauru[b]	96			75	71		
Palau	78	75	81	93	52	47	59
Polynesia							
Cook Islands	81	75	86	89	35	27	51
French Polynesia	82	76	86	93	65	57	71
Niue[b]				66			
Samoa				74			
Tonga[b]	80			87			
Tuvalu	98	97	99	98	71	41	77
Wallis & Futuna[b]	98			91			

For coastal fishing communities, contributions of fresh fish to total fish consumption were determined from socio-economic surveys (SES).
[a] Includes frozen fish in some PICTs.
[b] Represents entire PICT.

Melanesia consumed as much fish as rural (coastal) people in Micronesia and Polynesia (Table 1).

(iii) *Rural communities have a high dependence on subsistence fishing*: For most PICTs, 60–90% of fish consumed in rural areas was caught by the household (Table 2). The high proportions of national populations residing in rural areas [11] and the substantial dependence on subsistence fishing even in urban areas also resulted in high levels (>50%) of subsistence fishing nationwide for many PICTs (Table 2).

(iv) *Fresh fish dominates the diet*: For the great majority of PICTs, a consequence of the high levels of subsistence fishing was that fresh fish dominated national fish consumption in general, and rural consumption in particular (Table 3). Indeed, in rural areas, fresh fish often contributed >80% of fish consumption. Similar patterns applied to urban areas, where fresh fish usually accounted for ⩾75% of consumption (Table 3). The remainder comprised canned fish.

(v) *Fish provide the majority of animal protein*: Not surprisingly, given the remarkably high levels of fish consumption, and the limited opportunities for agriculture and animal husbandry in PICTs, fish usually contributed the majority of animal protein in the diet at the national level (Table 3).

These patterns of fish consumption are similar to those reported previously from the region [2,19,33]. They demonstrate that PICTS still have an extraordinary dependence on fresh fish, and that it should continue to be a mainstay of food security.

4. Forecast needs for fish for food security to 2030

The predicted age and sex structures of future urban and rural populations for each PICT [11] can be used to forecast the fish needed in the Pacific for good nutrition in the years ahead, as described in Section 2. However, a different approach is needed for PNG, where the large inland population (Fig. 1), defined as people living >5 km from the coast or the major river systems,[3] has poor access to fish. Planning to supply 34–37 kg of fish per person per year to inland PNG by 2030 is unrealistic—current estimates of per capita fish consumption in inland PNG are

[3] Sepik/Ramu and Fly/Purari river systems.

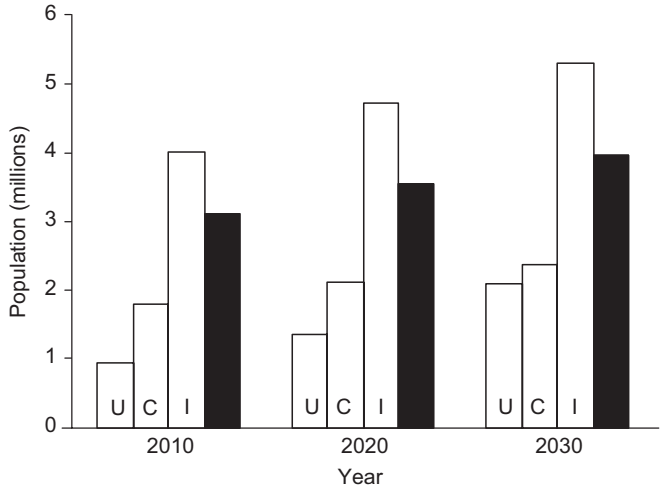

Fig. 1. Projected population growth for urban (U), coastal/riverine (C) and inland (I) Papua New Guinea (PNG), and for all other Pacific island countries and territories (solid columns) combined. Inland populations in PNG are defined as those further than 5 km from the coast or the Sepik/Ramu and Fly/Purari river systems.

Table 4
Forecasts of fish required in Melanesia (tonnes) to meet per capita consumption of fish for good nutrition

Country/territory	Year		
	2010	2020	2030
Fiji	30,000	33,200	37,500
Urban	16,000	19,500	24,200
Rural	14,000	13,700	13,300
New Caledonia	9500	11,000	12,300
Urban	6200	7600	9100
Rural	3300	3400	3200
Papua New Guinea	111,400	142,800	182,300
Urban	31,500	46,500	73,400
Coastal/riverine	59,900	72,600	83,300
Inland	20,000	23,700	26,500
Solomon Islands	18,000	25,500	29,900
Urban	3400	5400	8700
Rural	14,600	18,100	21,200
Vanuatu	8200	10,700	13,600
Urban	2100	3300	5200
Rural	6100	7400	8400
Total Melanesia	177,100	223,300	276,500

See text for explanation of estimates for inland Papua New Guinea.

unavailable but are likely to be very low or negligible in many areas (D. Coates, J. Wani, pers. comm.). Consequently, the forecast for inland PNG is based on providing access to 5 kg of fish per person per year between 2010 and 2030. This forecast is considered ambitious and responsible (J. Wani, pers. comm.). Ultimately, the physical and social complexity of inland PNG demands a separate thorough analysis of the potential for fish to help relieve malnutrition.

Forecasts for countries and territories in Micronesia and Polynesia also need to be modified from the basic calculations of fish needed for good nutrition. For these PICTs, traditional and current patterns of fish consumption are very high (Table 1) and it is more appropriate to forecast the need for fish based on expected demand, derived from current consumption, instead of estimates based on fish required for good nutrition. In making the forecasts for rural areas of Micronesia and Polynesia, the per capita fish consumption values from HIES and SES were averaged because both represent rural consumption in the relatively small countries involved.

Forecasts for Melanesia (Table 4), Micronesia (Table 5) and Polynesia (Table 6) not only alert governments to how much fish should be made available between 2010 and 2030, but also indicate how the access to fish should be partitioned between rural and urban populations. In Melanesia, there will be strong growth in the requirements for fish in both the urban and coastal areas of PNG (Fig. 1, Table 4); however, the relative increases in the fish required will be greater in urban areas. Similar conclusions also apply for Solomon Islands and Vanuatu. Urbanisation has already been much more pronounced in Fiji and New Caledonia than in the other Melanesia countries [11]. Consequently, increased demand for fish will occur only in urban areas for these PICTs (Table 4).

In Micronesia and Polynesia, the forecasts of fish needed for food based on the expected demand in 2030 are often twice as high as those based on fish required for good nutrition (Tables 5 and 6). In these regions, the effects of urbanisation are so strong that future increases in demand for fish will be limited to urban areas.

5. Development of plans to supply fish for the future

The forecasts above provide PICTs with clear targets for access to the fish needed for food security. They also pose three key challenges for national planners. (1) Where will the fish come from to supply the requirements? (2) How can it be made available to rural communities in ways in which they can catch or produce it themselves cost-effectively? (3) How can growing urban populations be supplied with the fish they need for good nutrition without adversely affecting the resources needed for subsistence in rural areas? PNG faces the additional challenge of introducing even modest amounts of fish into the diets of inland communities to overcome chronic protein deficiencies [34].

To provide PICTs with access to the fish required for food security to 2030 and beyond, national planners and managers need to: (1) assess whether the potential sustainable production from oceanic (tuna), coastal and freshwater fisheries, and aquaculture, can meet future demand for fish; (2) identify how best to 'allocate' access to the necessary proportions of production available from these various sources of fish; (3) develop 'vehicles' (i.e., systems for catching/producing and distributing fish) to deliver these allocations effectively; (4) implement policies to support the necessary allocations and vehicles; and (5) oversee efficient management of the vehicles and other steps in the process (Fig. 2). Some of the main issues that need to be considered for each of these actions are set out below.

5.1. Assessments

The distributions and abundances of the four main species of tuna in the tropical Pacific (skipjack, yellowfin, bigeye and albacore), and the way they vary with the El Niño Southern Oscillation (ENSO) [35], are increasingly well understood [36,37]. This information provides PICTs with a sound basis for assessing the sustainable catches of tuna available to them each year [38]. Potential issues affecting the assessments of tuna available to PICTs are the uncertainty of how future climate change may affect their distribution and abundance, and the incentives to maintain and improve the regional arrangements for sharing harvests of these highly migratory species [6,39].

Table 5
Forecasts of fish required in Micronesia (tonnes) to meet per capita consumption of fish for good nutrition (nutritional base), and to maintain current rates of fish consumption (expected demand) (see text for details)

Country/territory	Year					
	2010		2020		2030	
	Nutritional base	Expected demand	Nutritional base	Expected demand	Nutritional base	Expected demand
CNMI[a]	3360		4070		4720	
Urban	3200		3920		4570	
Rural	160		150		150	
Guam[a]	6920		8490		9390	
Urban	6550		8120		9030	
Rural	370		370		360	
FSM	3820	8250	4180	9650	4550	9920
Urban	870	1670	1050	2000	1380	2510
Rural	2950	6580	3130	7650	3170	7410
Kiribati	3480	7730	4240	9050	5040	10,230
Urban	1790	3500	2500	4780	3290	6080
Rural	1690	4230	1740	4270	1750	4150
Marshall Islands[a]	1780		2090		2390	
Urban	1210		1490		1790	
Rural	570		600		600	
Nauru	360	630	450	760	550	890
Palau	800	930	860	980	890	1000
Urban	560		620		670	
Rural	240	370	240	360	220	330
Total Micronesia	20,520	29,600	24,380	35,090	27,530	38,540

Expected demand has been calculated only where existing consumption exceeds fish required for good nutrition (see Table 1).
[a] Forecasts based on expected demand not possible due to lack of suitable HIES.

Table 6
Forecasts of fish required in Polynesia (tonnes) to meet per capita consumption of fish for good nutrition (nutritional base), and to maintain current rates of fish consumption (expected demand) (see text for details)

Country/territory	Year					
	2010		2020		2030	
	Nutritional base	Expected demand	Nutritional base	Expected demand	Nutritional base	Expected demand
American Samoa[a]	2340		2820		3330	
Urban	2180		2670		3180	
Rural	160		150		150	
Cook Islands	470	620	470	560	510	590
Urban	370		370		420	
Rural	100	250	100	190	90	170
French Polynesia	10,170	17,200	11,530	18,840	12,620	19,950
Urban	5250	7300	6200	8400	7420	9910
Rural	4920	9900	5330	10,440	5200	10,040
Niue	55	120	45	90	45	90
Samoa	5990	15,180	6380	15,210	6840	15,600
Urban	1400	1920	1730	2280	2270	2970
Rural	4590	13,260	4650	12,930	4570	12,630
Tokelau[b]	45	100	45	100	45	100
Tonga[a]	3490		3690		3900	
Urban	880		1110		1440	
Rural	2610		2580		2460	
Tuvalu	350	1050	380	1050	390	1050
Urban	175	340	210	390	240	450
Rural	175	710	170	660	150	600
Wallis & Futuna	580	1170	630	1240	680	1300
Total Polynesia	23,490	41,270	25,990	43,600	28,360	45,910

Expected demand has been calculated only where existing consumption exceeds fish required for good nutrition (see Table 1).
[a] Forecasts based on expected demand not possible due to lack of suitable HIES.
[b] Expected demand based on average of Kiribati, Tuvalu and Samoa.

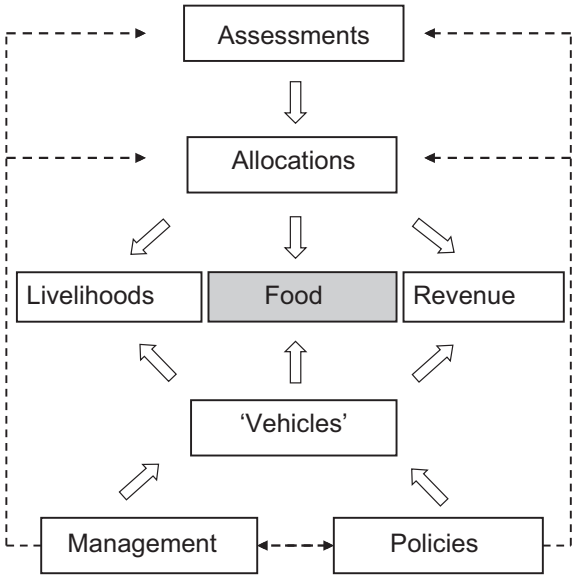

Fig. 2. Role of assessments, allocations, vehicles, policies and management in using oceanic, coastal and freshwater fisheries resources, and aquaculture, to meet national needs for food, and aspirations for livelihoods and economic growth (revenue). Note that allocations to economic growth apply mainly to oceanic (tuna) fisheries.

For coastal fisheries,[4] broad estimates of production have previously been pieced together for all PICTs from a variety of sources, such as national annual and technical reports, and the FAO Yearbook of Fisheries Statistics [19]. The information used varies in quality and accuracy (and may have included landings from offshore tuna fisheries in some cases) and hence needs to be interpreted with much caution. To provide another indicator, the latest information on national areas of coral reef habitat, and the median harvest estimate of 3 tonnes km^{-2} yr^{-1} across a wide range of islands [40], were used to assess the sustainable coastal fisheries production for each PICT (Table 7). Based on both types of estimates, coastal fisheries appear to be capable of supplying the forecast needs for fish for food in a practical way for only 6 of 22 PICTs (Table 7).

The reality is that reliable estimates of maximum sustainable production from the complex and diffuse small-scale coastal fisheries of the Pacific [19,41] are proving to be an unattainable goal for most PICTs. The main impediments are: (1) the diverse, multi-species nature of coastal fisheries [19], resulting in abundances of most species that seldom justify the investments in fisheries science needed to estimate sustainable yields; (2) differences in natural productivity among coastal areas within PICTs [42,43], often exacerbated by highly variable recruitment [44], over-exploitation [40] and habitat degradation [45–48]; and (3) lack of national capacity in coastal fisheries science.

The best that can be done is to identify simple management measures that will keep harvests from coastal fisheries within sustainable bounds [49–51] and then develop ways to measure and monitor total catches at the spatial scales relevant to management (see Section 5.5 for more details). Surveys outside the fisheries sector, particularly HIES but also censuses and nutrition assessments, promise to be useful tools for estimating total catch [2,19,52–54] (see also Section 7).

Assessments of how aquaculture can contribute to food security [55,56] differ from those for fisheries. With the exception of commodities based on the culture of wild juveniles, sustainable aquaculture production is not limited by the capacity of stocks to replenish themselves. Instead, it is constrained by technical, physical, socio-institutional and economic limitations, such as the availability of viable culture methods, suitable sites and feeds, and opportunities to supply fish for food more cost-effectively than capture fisheries or imports.

5.2. Allocations

For food security, the necessary proportions of estimated potential harvests from capture fisheries and aquaculture will need to be distributed to meet the forecast needs for fish of populations in rural and urban areas. This will entail economic analyses to identify the scenarios that harmonise access to fish from different resource sectors in ways that optimise food security, livelihoods and, in the case of tuna, economic growth (Fig. 3). A particular challenge for managers of coastal fisheries will be reconciling the need to make fish available for subsistence in rural areas with the opportunities to create rural livelihoods through supplying the demands for fish by burgeoning urban populations (see Section 6).

5.3. Vehicles

In many PICTs, the vehicles for catching, producing and distributing the fish required for food security have been in place for many years. These vehicles range, for example, from artisanal subsistence fisheries, to small-scale coastal commercial fisheries, to industrial domestic tuna fleets and associated processing facilities (e.g., canneries and loining plants). However, projected shortfalls in supply, the need to use one resource in preference to another to provide fish for urban or rural populations most cost-effectively, and objective evaluations of the efficiency of existing vehicles (such as those for internal distribution) may require the development of new vehicles to provide access to the necessary fish.

5.4. Policies

As the paths PICTs need to take to provide access to the fish required for good nutrition or to maintain existing per capita consumption are identified, new policies may be needed to change the ways fish are distributed, and to pave the way for establishment of the required vehicles. In particular, governments will need to develop frameworks to provide improved access to fish for subsistence in rural areas, and for rapidly growing urban populations. There is potential for such frameworks to conflict [51] and care will be needed to dovetail the use of fish for food security with its use for livelihoods. Raising awareness of the limits to how much food, and how many livelihoods, small-scale coastal fisheries can deliver sustainably will be vital to the success of this process.

5.5. Management

For fisheries in the Pacific, the key roles of management, which is defined here as interventions in support of specific objectives, should be to: (1) ensure that the vehicles for accessing the fish resources allocated to optimise benefits for food security, livelihoods and economic growth are operating in sustainable and effective ways; (2) monitor the status of resources; and (3) adjust and diversify exploitation of resources as required.

Much of the necessary management for tuna is already in place in the Pacific via a series of regional and international

[4] Includes fish and shellfish associated with coral reefs and other inshore benthic habitats, and inshore pelagic fish but not tuna.

Table 7
Pacific island countries and territories (PICTs) where estimated production from the entire national coastal fisheries resources (a) is expected to meet the forecast needs for food security; (b) has the potential to meet the forecast needs but redistribution to population centres is likely to be a problem due to the high cost of infrastructure and large distances; and (c) is insufficient to meet the forecast needs

PICT	Est. production based on coral reef area (tonnes p.a.)[a]	Est. production based on catches (tonnes p.a.)[b]	2010 Demand (tonnes)	2030 Demand (tonnes)
(a) *PICTs where coastal fisheries will meet forecast needs for fish*				
New Caledonia	66,500	12,600[c]	9500	12,300
Marshall Is	41,250	2350	1780	2390
Palau	8900	1500	930	1000
Cook Is	2000	1000	620	590
Tokelau	600	190	100	100
Pitcairn Is	<5	8	<5	<5
(b) *PICTs where redistribution of coastal fisheries production may be a problem*				
French Polynesia	45,400	6000	17,200	19,950
FSM	45,200	6900	8250	9920
Tonga	18,500	2400	3490	3900
Kiribati	12,500	12,300[d]	7730	10,230
Tuvalu	4000	950	1050	1050
(c) *PICTS where coastal fisheries will not supply the fish needed for food security*				
PNG	66,600	25,500[e]	108,400	178,900
Fiji[f]	30,000	23,250	30,000	37,500
Solomon Is	13,800	11,150	18,000	29,900
Vanuatu	3750	2500	8200	13,600
Samoa	1400	3500	15,180	15,600
Wallis & Futuna	800	900	1170	1300
Guam	660	590	6920	9390
American Samoa	210	270	2340	3330
CNMI	150	3,000	3360	4720
Niue	45	100	120	90
Nauru	20	375	630	890

[a] Based on total area of coral reef, lagoon and shallow shelf habitat down to a depth of 40 m (but excluding remote emergent and shallow 'drowned' reefs >200 km from inhabited islands), calculated from satellite images using data from the Millennium Coral Reef Mapping Project [100], UNEP World Conservation Monitoring Centre [101] and NOAA [102]. Sustainable annual production of coral reef fisheries was estimated by multiplying total area (km^2) by 3 tonne km^{-2} yr^{-1}, i.e., the median sustainable fisheries production value for island coral reef fisheries [40].

[b] After Dalzell et al. (1996) [19].

[c] Based on estimated potential production from the Northern Province only [99].

[d] Presumably an over-estimate that includes tuna.

[e] Presumably an under-estimate.

[f] Preliminary analysis by the Millennium Coral Reef Mapping Project, suggests that this is an under-estimate, which means that Fiji could be re-allocated to category b.

arrangements and treaties designed to sustain catches and share the benefits within the context of an ecosystem approach to fisheries management. Within the Exclusive Economic Zones (EEZs) of PICTs, the management regimes are national responsibilities, requiring sound governance [57]. On the high seas, the Western and Central Pacific Fisheries Commission (WCPFC) [58] has the mandate to manage the fishing activities of Distant Water Fishing Nations (DWFNs) and fleets based in PICTs. FFA coordinates and harmonises the national tuna management systems for the 16 members of the Pacific Islands Forum, and their position within WCPFC [59]. These comprehensive arrangements must continue to evolve to ensure stocks are maintained at levels where they can make their full potential contributions to food security, livelihoods and economic growth. Recently, there have been calls for rights-based management to be introduced [6,60]. This would assist PICTs to identify how much tuna they have access to, and to plan the allocation of the proportion needed for their food security.

The management of coastal fisheries in the Pacific has received much less attention, although it has long been recognised that coral reef resources are vulnerable to over-exploitation—only exceptionally do they support market fisheries [42,61–63]. Management of these subsistence and small-scale fisheries to provide food security in the Pacific must be strengthened to protect the numbers of spawning fish needed to produce regular, albeit variable harvests, and the habitats on which the large mix of target species depend. The main measures required are outlined below.

(1) Strengthening simple community-based measures to keep the production of coastal fisheries within sustainable bounds, including spatial management to protect spawning fish, appropriate size limits, regulations on fishing gear, and bans on some types of fishing, for example, spearfishing with lights at night and destructive fishing methods such as the use of poisons and explosives [41,49,50].
(2) Use of indicators to monitor whether harvests remain within sustainable bounds, and adaptive management to help address problems when they arise. Such indicators include changes in the density of target species per area of habitat, body size, catch per unit effort and the relative abundance of different trophic groups [64,65]. Where information for these indicators is unavailable, PICTs should establish simple, inexpensive systems for collecting it regularly from communities and merchants. Digital technology has much to offer here.
(3) Providing rural communities with dedicated access to coastal fisheries to create incentives for sustainable harvesting regimes [51,66], and the support needed to apply appropriate local governance and impose compliance on 'outsiders'. Throughout much of the Pacific, this will involve re-establishing customary marine tenure [49,67–69].

(4) Implementing national fishery regulations, such as size limits, closed seasons and export bans, to underpin community-based management in a way that prevents overfishing.
(5) Promoting awareness of the inter-dependence of fishing communities within the range of self-replenishing populations of target species, and the need for all stakeholders to manage fisheries for these species co-operatively. This inter-dependence stems from the likelihood of connectivity between habitats and areas in the life cycles of many species [70–72].

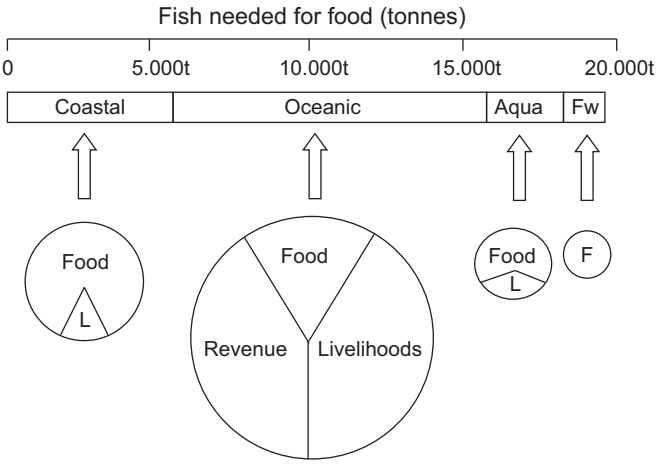

Fig. 3. Hypothetical example of allocation of oceanic (tuna), coastal and freshwater (fw) fisheries, and aquaculture, resources to meet a national need for fish for food. Pie diagrams represent allocations of fish to food (F), livelihoods, including local sales for food and employment on vessels and in canneries in the case of tuna (L), and economic growth (revenue) for each resource sector. The size of pie diagrams indicates the relative production of fish by each resource sector.

Co-management approaches [73–75] between fisheries agencies, NGOs and communities should be promoted to develop local fisheries management plans to implement these measures as appropriate. Government departments, with the assistance of NGOs, can also help communities engage in the alternative livelihoods required to reduce fishing pressure to maintain or restore the production of coastal fisheries [76,77].

Management of aquaculture for food security will need to centre around (1) establishing and maintaining systems for distribution of juvenile fish to subsistence producers in keeping with protocols for retaining the growth potential of introduced strains and (2) limiting any negative effects on biodiversity [56]. For larger enterprises supplying urban markets, management must also oversee compliance with licensing conditions and food-safety standards.

6. Meeting the challenges

Although meeting the three key challenges outlined at the beginning of Section 5 cannot be planned by any PICT in detail due to the difficulties in identifying sustainable production from coastal fisheries, the quantities of fish needed in the future (Tables 4–6) make it clear that the fisheries resources currently available to many rural communities (Fig. 4a) leave them vulnerable to food insecurity for three reasons. First, coastal fisheries in many PICTs do not have the capacity to provide more fish [19,40]; therefore, per capita fish consumption in rural areas will decrease as

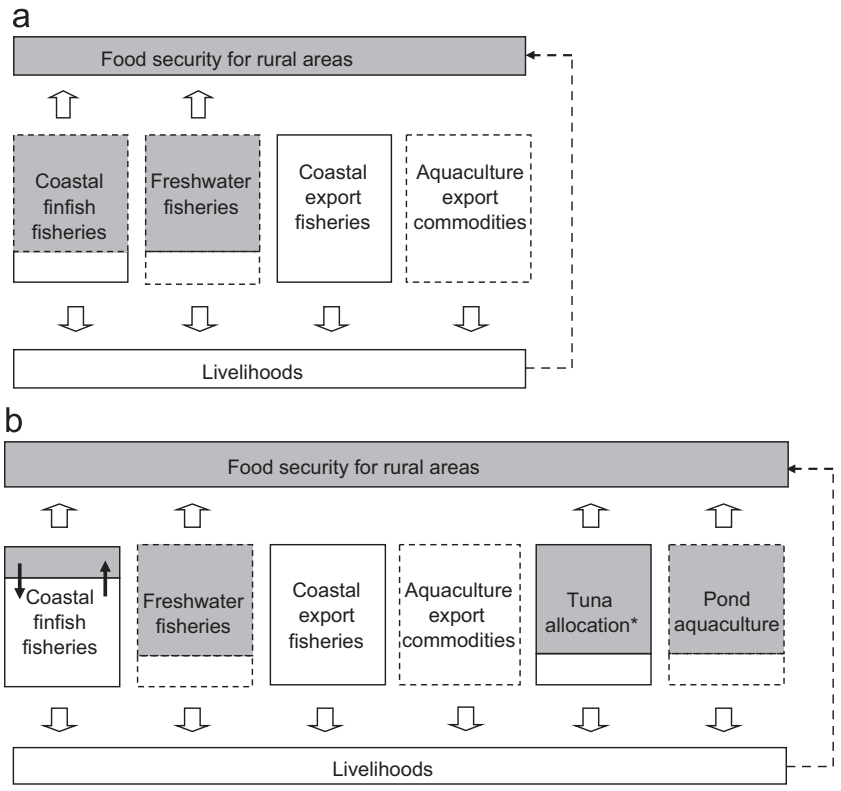

Fig. 4. (a) Components of fisheries currently contributing to food security of rural communities in Pacific island countries and territories (PICTs) and (b) improved food security based on providing more access to tuna and development of pond aquaculture. Dashed lines around boxes indicate that these vehicles only apply to a subset of PICTs. *Refers only to the proportion of tuna allocated for consumption by rural communities, not the entire national catch. Arrows in (b) infer that the proportion of coastal finfish used for livelihoods and directly for food security can change at the discretion of communities, depending on their ability to meet food requirements from tuna and small-pond aquaculture.

populations grow. This applies mainly to Melanesia and is unlikely to be corrected by increased consumption of traded substitutes due to lack of disposable income to buy canned fish, and inadequate national distribution systems for fresh fish. Second, increased demand for coastal fish by urban centres will place pressure on rural communities to use their fisheries resources for both subsistence and livelihoods (sales to urban markets), increasing the risk of overfishing and reducing local availability of fresh fish for food. This risk is exacerbated by the need for rural people to earn income to reduce hardship, the increased monetisation of economies and few alternative opportunities for livelihoods [78]. Third, climate change is likely to reduce the diversity and abundance of reef-forming corals [79–81] and therefore the productivity of fish associated with coral reefs [46–48].

The good news is that there are at least two possible ways of providing more fish for consumption by rural households throughout much of the Pacific—improving access to tuna and small-pond aquaculture (in PICTs with adequate freshwater). Most of the PICTs in the western Pacific are endowed with an abundance of tuna [3,36]. If policies and vehicles can be implemented to enable coastal communities to catch tuna more easily, much of the future need for fish in rural areas could be met. Low-cost, inshore fish aggregating devices (FADs) promise to be a suitable vehicle [4,82,83]. Trials in Cook Islands and Niue show that the value of fish harvested around low-cost inshore FADs was 5–7 times the cost of building them [84]. Another important feature of these FADs is that they can produce food faster than any other local production systems during periods of greatest food insecurity, e.g., following a devastating cyclone (R. Gillett, L. Chapman, pers. comm.). The shelf life of good catches made around FADs could be extended by training villagers in simple post-harvest methods, such as drying and smoking.

Policies that PICTs can use to increase the supply of fish through the use of low-cost inshore FADs include the following: allocating more of the national tuna catch to subsistence and small-scale fishers; diversifying the national infrastructure necessary to provide food security to include installation and regular replacement of low-cost inshore FADs over the long term; and supporting enterprises involved in post-harvest and national distribution of tuna.

Small-pond aquaculture for food security is practiced widely throughout Asia [85] and is already under way in the Pacific [86,87]. It has the potential to supplement household fish consumption throughout much of Melanesia, and in some other PICTs as well. For example, culture of Nile tilapia in ponds of 450–500 m^2 in Fiji can yield up to 500 kg of fish every 4–5 months, equivalent to ~25 tonnes ha^{-1} yr^{-1} (T. Pickering, pers. comm.). Key activities involved in establishing small-pond aquaculture as a subsistence vehicle for food security are as follows: (1) identifying appropriate species and culture methods; (2) minimising effects on biodiversity; (3) developing cost-effective feeds based on locally available ingredients; (4) investing in national systems for producing and distributing fry; (5) training farmers; and (6) reducing barriers to entry, such as the costs of constructing ponds. For small-pond aquaculture to contribute to food security through the development of small-scale farming enterprises, these activities need to be integrated into economically viable production systems with minimal government subsidies.

Adoption of both these vehicles will require rural communities to embrace new fishing and farming methods. This has not been a problem in places where tuna and/or tilapia are already included in the diet. For example, fish caught around low-cost inshore FADs, and farmed tilapia, are now making a contribution to food security in Nauru [83,88]. However, where these species are not eaten regularly, adoption of the two vehicles may depend on facilitating the broad acceptance of these fish in the diet of the local population.

Diversifying the supply of fish for rural communities by improving access to tuna and developing small-pond aquaculture (Fig. 4b) would have three important benefits. First, it would provide them with options for use of coastal finfish resources—valuable reef species can either be kept for subsistence or sold to buy non-perishable food for times when it is not possible to harvest, e.g., during natural disasters. Second, it can help communities to rebuild over-exploited coastal fisheries to more productive levels by transferring fishing effort to other resources. Third, it should make communities more resilient to the uncertainties of climate change—they can switch to whichever resource/production system is favoured by the prevailing conditions.

Clearly, the need for these two vehicles will not be as great in PICTs where coastal fisheries have the capacity to meet future food requirements (see Table 7 for PICTs where this may be the case). For much of the region, however, these two vehicles should be launched as soon as possible. They should then be developed progressively to keep pace with local needs for food security, and for livelihoods based on demands from nearby and urban markets.

The corollary to the proposed model for increasing the contribution of fish to food security of rural communities is that PICTs must also plan to provide increased access to fish to meet the expected future demand from rapidly growing urban populations (Tables 4–6). Here again, national allocations of tuna for this purpose, and development of pond aquaculture on a larger scale on the outskirts of major towns [89,90], have much potential to provide the additional fish needed. For example, annual catches of tuna in the EEZs of PICTs currently total ~1 million tonnes (FFA, unpublished data). Allocating just a small percentage of these catches locally would provide much of the fish needed in urban areas. In fact, much of the demand could probably be met with undersize fish currently discarded by purse seine vessels, and the bycatch from longline operations. Policies for increased domestication of the tuna industry [1], such as incentives for the private sector, regulations to retain all fish caught and investments in infrastructure for storing, marketing and distributing fish, will be the key to delivering more tuna to urban areas at reasonable prices. Ultimately, improved access to fish for urban dwellers is likely to be achieved through an amalgam of larger-scale enterprises, and via rural livelihoods (Fig. 5). Care will be needed

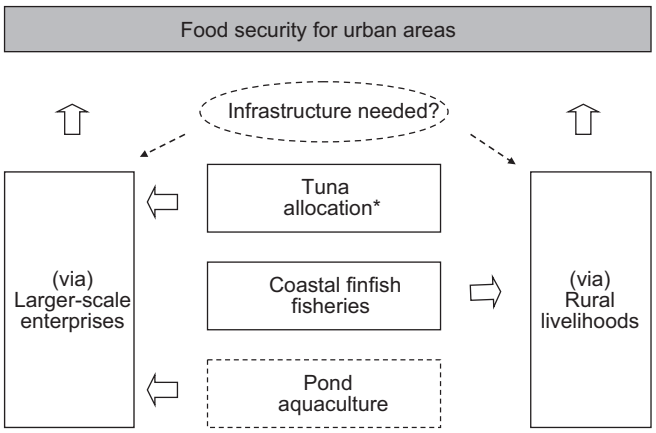

Fig. 5. Components of fisheries contributing to food security of urban populations in Pacific island countries and territories (PICTs). Dashed lines around the pond aquaculture box indicate that this vehicle applies only to PICTs with adequate freshwater. *Refers only to the proportion of tuna allocated for consumption by urban populations, not the entire national catch. Note that infrastructure such as storage, shipping and market facilities will be needed in some PICTs to deliver increased supplies of fish to rapidly growing urban populations.

to stage the development of larger enterprises supplying tuna and the products of larger-scale pond aquaculture so that smaller enterprises selling any fish surplus to needs in rural areas are not eliminated by flooding the market.

Successful implementation of the plans outlined here for rural and urban areas will need broad consultation with stakeholders and consideration of gender issues. Women are involved heavily in many aspects of fisheries and aquaculture in the Pacific [91–93] and need to be included in all decisions concerning the planning of fish for food security and livelihoods. The use of FADs and small-pond aquaculture in rural areas will also depend on people capable of operating these vehicles residing within coastal communities.

Each PICT will need to steer its own course—national scenarios will differ depending on the need for fish in rural and urban areas, the mix of resources available to address the forecast needs and the availability of supporting infrastructure. Providing more fish to the large inland populations of PNG is a special case. Although this will also be tied partially to the development of small-pond aquaculture [87], and finding ways to distribute processed tuna inland, considerable additional analysis is needed.

7. Discussion

The extraordinarily high consumption of fish by many PICTs underscores the vital contribution of fish to the food security of the Pacific. Nowhere else do as many countries rely so heavily on subsistence fishing to supply the majority of the protein needed for good nutrition. These patterns of fish consumption can be expected to persist for two reasons: (1) there is a strong tradition of eating fish in Micronesia, Polynesia and the coastal areas of Melanesia [2,19] and (2) the hurdles to economic growth in much of the region [78,94] will make it difficult to access other sources of protein.

The high dependence on fish should not be interpreted as a lack of development. Rather, the high rates of fish consumption in rural areas provide 'subsistence affluence' in the context of food supply [1]. The responsibilities of PICTs are to ensure that coastal communities continue to have the opportunity to harvest the fish they need themselves. The forecasts of fish required to provide good nutrition in Melanesia, or the greater amounts of fish people expect to eat traditionally in Micronesia and Polynesia, show that PICTs are likely to fall into three broad categories (Table 7). (1) A group of six PICTs where estimated sustainable coastal fisheries production is expected to meet the future needs for fish. This should be confirmed by further analysis, however, because some of the production is currently unavailable due to high incidences of ciguatera poisoning [95], and the difficulties in travelling from settlements to nearby unexploited areas to fish. The predicted effects of climate change on coral reefs [79–81] are also expected to reduce the productivity of coastal fisheries. Taken together, these factors may mean that accessible production from coastal fisheries is overestimated for these counties and territories. (2) Five PICTs where sustainable production from national coastal resources has the potential to meet the forecast needs for food, but where a shortfall in supply will probably occur in urban centres because of the difficulties in delivering reef fish there from remote areas. (3) Eleven PICTs where coastal production will be insufficient to meet the forecasts for fish. For the 16 PICTs in the latter two categories, the sustainable production from coastal resources will have to be supplemented by allocating some of the tuna currently used by DWFNs and/or export-oriented domestic fleets to food security, and by developing small-pond aquaculture (in PICTs with adequate freshwater). Such interventions may also be required to relieve local shortages of fish in some PICTs in the first category.

In principle, the future food security needs of the 16 PICTs in categories 2 and 3 could be supplied through market substitution, i.e., purchasing canned fish and meat with income earned from selling other goods and services. However, this is not a feasible option in many of the rural areas because of the scarce opportunities to earn income and the high price of processed food due to the cost of freight. Improving access to fish in ways that people can catch or grow it themselves is a more practical, and healthier, solution for rural communities.

The rapid urbanisation underway throughout the region [11] adds another dimension to the plans required to provide continued access to fish for food. For some PICTs, this will involve strengthening the infrastructure required to get fish to markets. For others, mainly larger PICTs, there are two additional imperatives associated with the widespread urban drift. First, ensuring that the increasing urban demands for coastal fish are not met at the expense of food security for rural communities. Second, addressing poverty and hardship among the urban poor [78] so that they have economic access to fish.

Although low-cost inshore FADs and small-pond aquaculture are the most promising vehicles for easing the growing pressure on coastal fish resources, the time required to establish them means that coastal fisheries will continue to bear the brunt of providing the fish required by larger PICTs in the short term. There is a severe risk of overfishing during this time because coastal stocks will be called upon to provide fish for both rural and urban areas. Coastal fisheries for export commodities, such as bêche-de-mer and trochus, provide a solemn lesson about the consequences of overfishing—valuable species no longer deliver their full potential because the spawning biomass has been reduced to very low levels, and sometimes extinguished [19,96,97]. Governments must prevent this happening to stocks of coastal finfish, otherwise the food security gap to be filled by increased access to tuna and small-pond aquaculture will be even greater. The key messages that must be conveyed to governments, development agencies, NGOs and coastal communities are as follows: (1) the amount of fish that can be harvested sustainably from inshore resources is often lower than most people realise and (2) coastal fisheries should be used for subsistence in preference to livelihoods unless additional sources of fish become available. In some PICTs, restrictions on internal sale and export of coastal fish will be needed.

Providing fish for food security will require a change in the planning priorities of most national fisheries agencies in the region. In addition to meeting their obligations under the 'Convention on the Conservation and Management of Highly Migratory Stocks in the Western and Central Pacific Ocean' [98], sufficient human resources must be dedicated to: (1) manage and monitor sustainable production of coastal fisheries; (2) identify how much of the national tuna catch should be allocated for food security; (3) oversee the installation of low-cost inshore FADs in rural areas, and distribution of undersized fish and bycatch from industrial fleets to urban areas, to provide access to tuna; and (4) transfer existing methods for pond aquaculture into a network of viable subsistence and larger-scale enterprises.

The reality is that many PICTs do not have the capacity to do this—they will need assistance from regional fisheries organisations to decide how best to allocate the various fish resources to different needs and aspirations, develop efficient vehicles to increase access to fish and implement the necessary policies and management. With the exception of expertise in freshwater fisheries and integrated planning to optimise the use of fisheries resources, most of the skills required to guide governments and

the private sector to deliver the fish needed for food security currently exist within FFA, SPC and their partners.

PICTs can also seek assistance in planning the use of fish for food security from outside the fisheries sector. The SPC Statistics and Demography Programme can guide PICTs on how to design future HIES and censuses to collect the representative and reliable information needed to (1) estimate the total catch from coastal fisheries; (2) measure the contributions of all fish to food security; and (3) gauge the performance of policies and management measures designed to deliver the fish required by households. To meet these objectives, future HIES should quantify the per capita fish consumption for urban and rural areas, disaggregated by (1) source (tuna, coastal fish and shellfish, freshwater fish, farmed fish, and local and imported tinned fish) and (2) means of acquisition (subsistence fishing, gifts and purchases). Per capita consumption of fresh meat, poultry and tinned meat should also be quantified to measure the contribution of fish to the total intake of animal protein. To measure the contributions of fisheries to livelihoods, future HIES and censuses should quantify: (1) the number of people and households deriving income from coastal, freshwater and tuna fisheries, aquaculture and fish processing on a self-employed and employed basis and (2) the earnings made from each activity.

The SPC Statistics and Demography Programme can also assist PICTs to identify the areas where populations are predicted to increase most rapidly, and which are therefore most vulnerable to shortages of fish. Although this paper has referred to predicted demographic trends on the broad scale of rural and urban areas [11], information on where populations are expected to grow within rural areas is also available on much finer scales. This information can be used to plan how best to implement the required vehicles. For example, it can be combined with GIS data on topography, soil type, rainfall, land use and poverty to prioritise the development of small-pond aquaculture.

In conclusion, it is clear that providing access to enough fish for good nutrition, or traditional levels of consumption, in coastal and urban areas to 2030 is within the grasp of most PICTs. However, decision makers in each country and territory need to be alerted to this issue and work with regional fisheries agencies and demographers to: (1) make assessments of when and where population growth is likely to place unsustainable pressure on coastal fish stocks; and (2) where forecasts indicate that shortfalls in supply from coastal fisheries will occur, allocate more of their tuna and develop small-pond aquaculture, to increase the supply of fish. The resulting improved food security should also make PICTs more resilient to natural disasters, social and political instability, and the uncertainty of climate change.

Acknowledgements

This paper benefited from the kind assistance of the statistical offices in several Pacific island countries and territories who gave their permission to use information from household income and expenditure surveys not contained in official reports. Thanks to Arthur Jorari and Gerald Haberkorn from the SPC Statistics and Demography Programme, who provided advice on the demography of Pacific island countries and territories, and Karen Fukofuka from the SPC Public Health Programme who supplied the information on fish and nutrition. Thanks also to Tim Adams, Gordon Anderson, Mike Batty, Chris Béné, Lindsay Chapman, Bob Gillett, Brett Molony, Silvia Pinca, Tim Pickering, Ben Ponia, Gary Preston and Meryl Williams, who provided useful discussions, information and/or helpful comments that improved the draft manuscript. Updated coral reef areas for PICTs come from the Millennium Coral Reef Mapping Project funded initially by NASA. This is WorldFish Center Contribution no. 1839.

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