IPNLF
INTERNATIONAL POLE
& LINE FOUNDATION

ENSURING SUSTAINABILITY OF LIVEBAIT FISH

The report has been compiled by Steve Rocliffe, University of York, UK, in collaboration with the International Pole-and-line Foundation.

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The International Pole-and-Line Foundation (IPNLF) works to bridge the gap between demand and supply of pole-and-line caught tuna. The objective of the Foundation is to help develop sustainable and equitable pole-and-line fisheries and to increase the market share of pole-and-line caught tuna. IPNLF is a not-for-profit organization; all revenue raised and generated will contribute directly to research and capacity building. Our goal is to use the generosity of the market to make a large positive impact for the pole-and-line fishing communities across the world.

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EXECUTIVE SUMMARY

Pole-and-line fishing offers one of the most environmentally and socially desirable ways of catching tuna. The method is dependent on the availability of small pelagic fish (baitfish) released live into the sea to attract tuna schools within range of a vessel's fishing gear. This report reviews and synthesises information on live baitfish fisheries for tuna pole-and-line fishing. It explores several elements of live baitfish fishery, including techniques used, locations and ecological characteristics of the key species targeted, baitfish desirability and supply and associated environmental and social impacts. Finally, it makes recommendations to reduce these impacts and to ensure that live baitfish fisheries are as sustainable and equitable as possible.

The report estimates that current live bait requirements for pole and-line tuna are between 19,000 and 48,000 tonnes per year, with a mean average of 25,000 tonnes. It finds that live baitfish fisheries have a number of environmental and social impacts, which together underscore the importance of conducting any expansion of pole-and-line fisheries within defined sustainable limits. Potential impacts highlighted include a reduction in the amount of forage available for the larger piscivorous species on which subsistence and commercial fisheries depend, incidental and deliberate capture of juveniles and of species targeted by artisanal fisheries, overexploitation of live baitfish fisheries and conflict between bait fishers and local communities or tour operators.

The report presents several solutions to help mitigate these impacts. It primarily finds that additional research is needed, especially studies that focus on the complex interactions between the live baitfish fishery and the local fishing communities, as well as those related to baitfish culture and other alternative baits. It concludes that these research initiatives need to be complemented by comprehensive fisheries management plans in pole-and-line nations. These plans should include regular stock assessments, be based on the ecosystem approach and the precautionary principle, and be third party audited on a regular basis.

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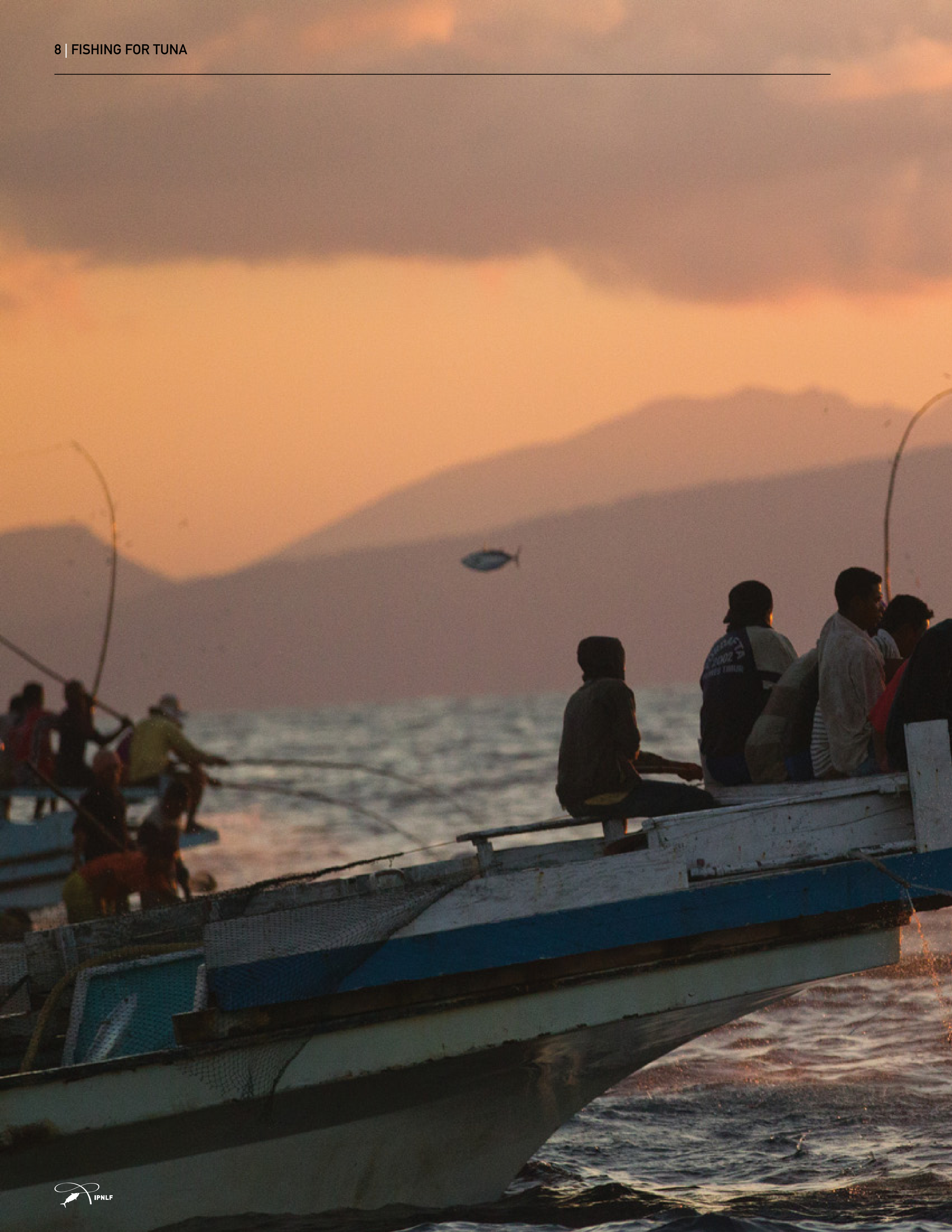
INTRODUCTION

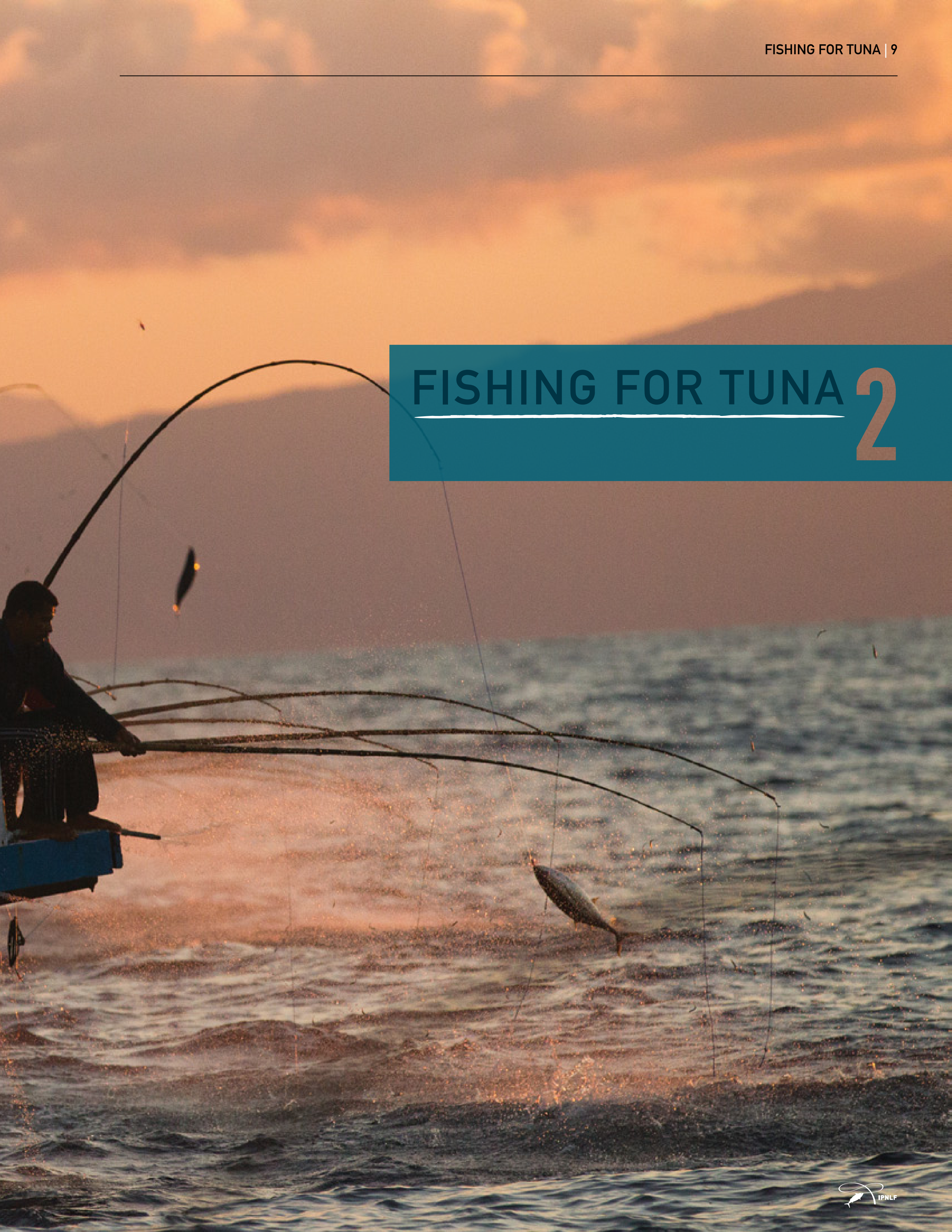
Tuna are caught throughout tropical and temperate waters by one of three principal methods: purse seine, longline and pole-and-line (Rawlinson et al. 1992). If conducted properly, the most environmentally desirable aspect of the pole-and-line method is the very low levels of bycatch (Stone et al. 2009; Gillett 2011a). Moreover, pole-and-line vessels use between eight and nine times more labour per unit catch of tuna than purse seining, increasing economic and social benefits for local fishing communities (Gillett 2011a).

Pole-and-line is dependent on the availability of suitable baitfish (i.e. small pelagic fish) released live into the sea to attract tuna schools within range of the vessel's fishing gear (Rawlinson et al. 1992). Thus, this fishing method comprises two distinct fishing operations: the first for the bait; the second for the tuna (Greenpeace 2009).

This report reviews and synthesises information on livebait fish fisheries for tuna pole-and-line fishing to improve organisational knowledge at the International Pole and Line Foundation (IPNLF). We explore five elements of bait fishing, namely:

1. where and how tuna are caught as well as the different methods of pole-and-line currently in use;
2. key aspects of baitfish fisheries, including techniques used, locations and eco logical characteristics of the key species targeted;
3. baitfish desirability and supply;
4. associated environmental and social impacts; and
5. the solutions available to reduce these impacts.





FISHING FOR TUNA 2

2.1. TRENDS IN WORLD TUNA CATCHES

The total catch of tuna and tuna-like species has grown steadily from 0.6 million tonnes in 1950 to a global record of 6.6 million tonnes in 2009, an annual growth rate of 4.13% (FAO 2010; FAO 2011). Catches of principal market tuna, (skipjack, yellowfin, bigeye and albacore) have shown a similar increase, but have remained at around 4.3 million tonnes since 2003 (ISSF 2010; FAO 2011).

2.1.1. BY OCEAN

Of these catches, 67% are from the Pacific Ocean, 24% from the Indian Ocean and 9% from the Atlantic and Mediterranean (ISSF 2010). The Western and Central Pacific Ocean (WCPO) supports the biggest tuna fishery in the world (Barclay & Cartwright 2007), accounting for 53% of the world total (ISSF 2010) and with an estimated landed catch value of more than USD 3 billion (Langley et al. 2009).

2.1.2. BY SPECIES

By species, skipjack accounts for 57% of the world principal market tuna catch, followed by yellowfin (27%), bigeye (11%) and albacore (5%) (ISSF 2010). Catches of skipjack and yellowfin have tended to rise year-on-year (Majkowski 2007) and in 2009, the skipjack catch was almost 2.6 million tonnes, the highest on record (FAO 2011).

2.1.3. BY GEAR

Table 1 outlines average catches of principal market tunas by gear type as well as key characteristics of the gears. Longlines and pole-and-line used to be the predominant gear types in tuna capture, but have rapidly declined since the beginning of the 1980s as purse seining started to become a cheaper, more efficient alternative (Gillett 2011b; Miyake et al. 2010).

Table 1: *Gear characteristics and average catches of principal market tunas by gear type, 2004-2008*

GEAR TYPE	TARGET SPECIES	END USE	CATCH (%)	CATCH (TONNES)
Purse seine	Surface swimming skipjack and younger age classes of yellowfin and bigeye tuna	Mainly canned	63	2,700,000
Longline	Older, deeper-dwelling bluefin, bigeye, yellowfin and albacore	Mainly sashimi/sushi (raw)	14	609,000
Pole-and-line	Surface swimming skipjack and younger age classes of yellowfin, albacore (in temperate waters) and bigeye tuna	Mainly canned	10	457,000
Other*	Varied	Varied	13	566,00

Sources for gear characteristics: (Gilman 2011; Majkowski 2007; Hester 1974; Miyake et al. 2010), Source for average catch data: (ISSF 2010)
* Other includes troll lines, handlines, driftnets, traps, harpoons, ring nets and coastal gillnets

2.2. POLE-AND-LINE TECHNIQUES

Pole-and-line fishing is a simple approach to catching tuna with a hooked line attached to a pole (Majkowski 2003b). Vessels tend to be up to 40 metres in length, with between 10 and 20 fishers fishing simultaneously with a rigid pole and a strong short line, from which hangs a lure mounted on a barbless hook (Majkowski 2003b; FAO 2001). There are three principal deck configurations. On smaller vessels, boat workers fish from the main deck all around the boat (FAO 2001). Large vessels can be either American type (used in the Maldives among other places) or Japanese type (used by the Japanese) (Majkowski 2003b; Stone et al. 2009). American type vessels move ahead during the fishing operation, as workers catch tuna from platforms positioned around the stern of the vessel (FAO 2001). Fishers on Japanese types stand at the bow, hooking fish as the vessel drifts along (FAO 2001).

There are five key stages of a pole-and-line fishing operation: baitfish fishing; school locating; chumming of baitfish, catching fish; and catch storage (Majkowski 2003b; Campbell & Hand 1998). Pole-and-line vessels carry live bait to attract tuna to the boat, so operations almost always commence by catching live bait in inshore waters with a small liftnet or seine net (this is discussed more fully in section 3) (Majkowski 2003b). On locating a school of tuna, the vessel is positioned nearby and live bait is scattered into the sea (Majkowski 2003b; Campbell & Hand 1998). This is known as chumming and is usually carried out in conjunction with water sprinkling (Majkowski 2003b). It creates the illusion of a large school of small fish near the surface, sending the tuna into such a feeding frenzy that they will bite at any shiny, moving object in the water, even un-baited hooks (Majkowski 2003b; Stone et al. 2009). To prevent them from spoiling, the tuna are stored in a refrigerated hold upon capture on larger vessels or on ice on smaller day boats (FAO 2001; Campbell & Hand 1998).

2.2.1. VARIATIONS ON THE POLE-AND-LINE TECHNIQUE

There are several variations on the pole-and-line technique. In Japan's distant-water and coastal fleets, pole-and-line fishing is in part carried out by robot gear that mimics the act of a fisher hooking a tuna (Majkowski 2003b). The distant-water fleet consists of large, sophisticated vessels (weighing 300-500 tonnes) and typically catches mature, high-grade skipjack, as well as smaller quantities of yellowfin, albacore and bigeye (Western Pacific Regional Fishery Management Council 2000). The vessels can freeze their catches and stay at sea for three or four months (Joseph 2003). In order to ensure a reliable supply of baitfish, the fleet transports live bait – usually the temperate water anchovy *Engraulis japonicus* – from Japan (Yoshida et al. 1974; Western Pacific Regional Fishery Management Council 2000). Before the trip, the baitfish are kept in holding pens to accustom them to captivity and to cull the weak (Western Pacific Regional Fishery Management Council 2000). On board, they are kept in temperature-controlled bait wells and fed daily (ibid.).

In the Atlantic Ocean and in the Senegalese fleet especially, pole-and-line operations are conducted by a team of two or three cooperating vessels (Fonteneau & Diouf 1994). Under this method, known as "associated-school fishing", Boat A does not catch all the tuna in a school and remains nearby after fishing (Fonteneau & Diouf 1994; Majkowski 2003b). This causes the vessel to behave like a floating object, aggregating the tuna under the vessel and enabling them to be caught over an extended period (Majkowski 2003b; Fonteneau & Diouf 1994). When Boat A has filled its hold, Boat B will swiftly manoeuvre close to Boat A and the association with the tuna school will be exchanged between the two vessels (Fonteneau & Diouf 1994). Boat A will then offload the catch in port before returning to the tuna school (ibid.). When Boat B is full, the now empty Boat A will switch positions once more (ibid.). A third boat, which does not catch tunas, can also be used to maintain the association between the school and vessel if Boat B is full before Boat A has returned from port (ibid.).

The Ghanaian fleet use a similar approach to Senegalese fishers: pole-and-line vessels often act as an auxiliary to purse seiners, aggregating fish schools for net-based capture and receiving a share of the proceeds (Miyake et al. 2010; ICCAT 2009).

2.3. POLE-AND-LINE FISHING AROUND THE WORLD

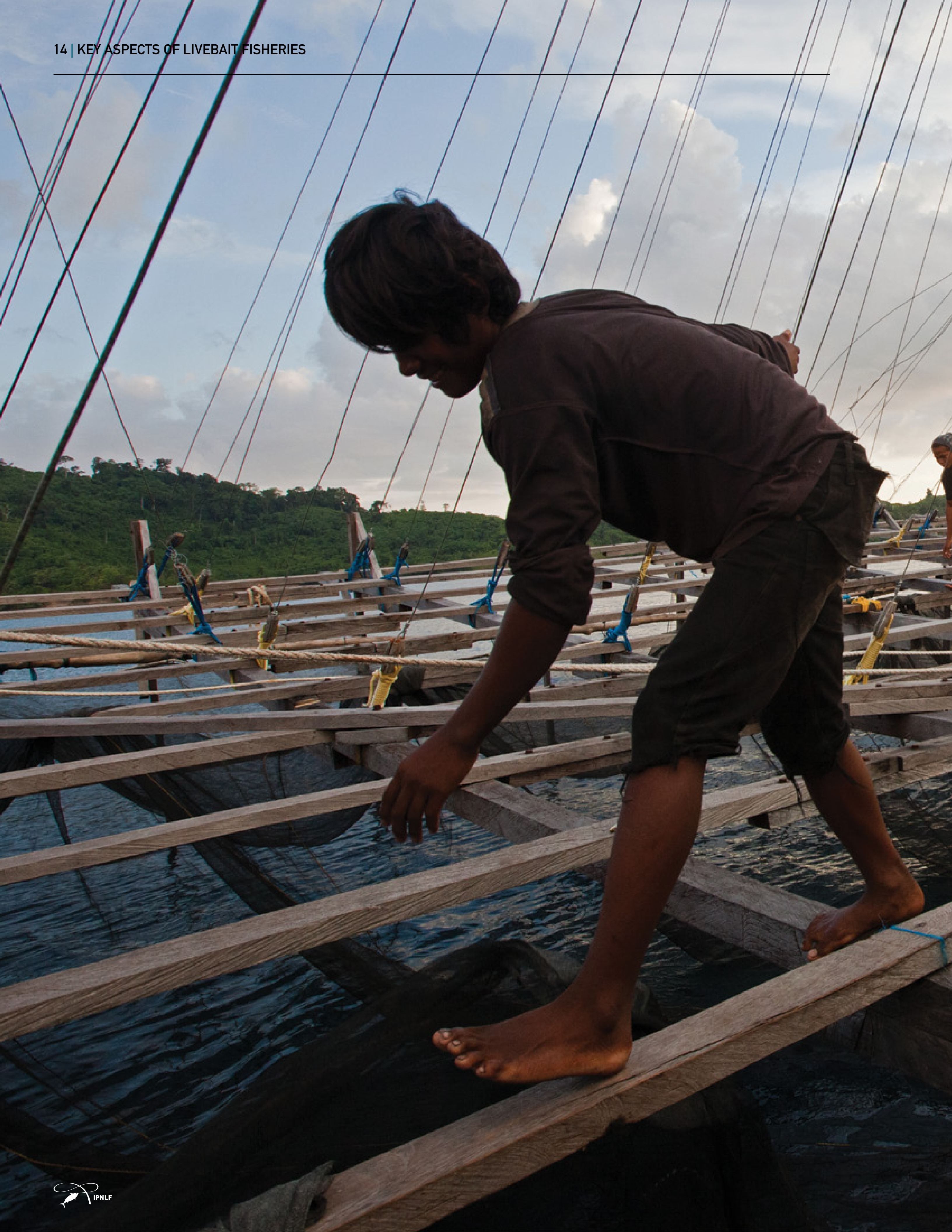
Three countries catch almost three quarters of pole-and-line tuna: Japan (37%); The Maldives (24%) and Indonesia (14%) (Miyake et al. 2010).

Catches from the Maldives and Indonesia are exclusively coastal, whereas those from Japan are a mixture of high seas and coastal (Miyake et al. 2010). Species-taken are almost entirely skipjack with small quantities of yellowfin, albacore and bigeye (Miyake et al. 2010). Table 2 presents key characteristics of selected pole-and-line fisheries by ocean region.

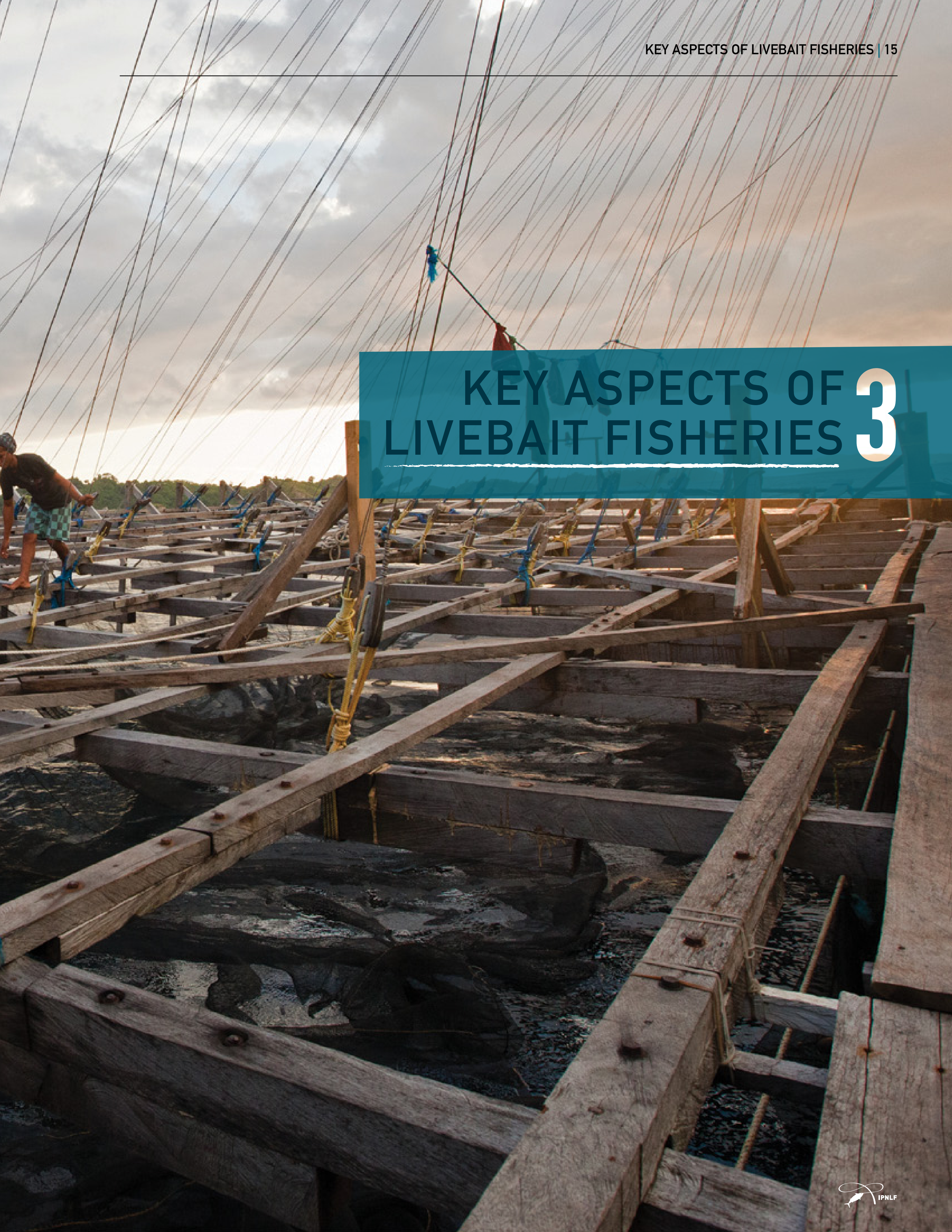
Table 2: *Characteristics of selected pole-and-line fisheries by ocean region*

FISHERY	NO. OF VESSELS	TONNES CAUGHT*	OBSERVATIONS
Western and Central Pacific Ocean (WCPO)			
Japan	96	169,000	Distant water vessels fish skipjack from late 4th quarter to early 2nd quarter and albacore from June to October
Indonesia	232	66,000	132 vessels over 30 GRT in NE Indonesia. 100 small outboard vessels (9-13m) in Sulawesi. Mostly for domestic consumption
Solomon Is.	4	-	Four active vessels - a re-entry into pole-and-line fishing by National Fisheries Developments Ltd (NFD) (with Trimarine)
Palau	1	-	One active vessel is unprofitable remnant of former fishery. Sells to domestic market only
Hawaii	1	-	One active vessel is unprofitable remnant of former fishery. Sells to domestic market only
Eastern Pacific Ocean (EPO)			
Mexico	2	500	Based out of Baja California, these are the only pole-and-line vessels in Latin America
USA	60	7,500	Vessels target albacore and have bait tanks, racks, and poles for nearshore fishing
Indian Ocean (IO)			
Maldives	1000	110,000	Vessels 7-30m. Catch consumed domestically, canned for export, smoked/dried for export to Sri Lanka, and exported frozen for canning in Thailand
Lakshadweep	-	10,000	Vessels 8-10m. Catch mostly smoked for domestic consumption
Atlantic (AO)			
Ghana	-	23,000	Pole-and-line vessels work with purse seiners making it difficult to separate out the share of the catch for each method
Senegal	9	12,000	Pole-and-line vessels with storage capacity of up to 200 MT
Brazil	-	25,000	Often have auxiliary launches to aid bait capture
Spain	52	20,000	Vessels based mainly in the Basque Country, Andalucía and the Canary Islands

Sources: (Miyake et al. 2010; Gillett 2011a; Oceanic Fisheries Programme 2010; ICCAT 2009)
*: Miyake et al. (2010). Data from 2007. Mexico and Lakshadweep figures from Gillett (2011a)



KEY ASPECTS OF LIVEBAIT FISHERIES 3



3.1. TECHNIQUES FOR CATCHING BAITFISH

Baitfish for pole-and-line are typically caught by the tuna vessel that is using the bait (Gillett 2011b; Gillett 2011a). This is usually accomplished at night using lights and in sheltered coastal waters or coral-island regions (Hester 1974; Hallier et al. 1982; Lewis 1990; Dalzell & Lewis 1989). Predominant gear type varies from ocean to ocean. In the Pacific, a simple stick-held dip net (boukeami) is used, whereas purse seine or shrimp nets dominate in the Atlantic (Lewis 1990; Gillett 2011b; ICCAT 2009). In the Indian Ocean, lift nets are the preferred technique (Anderson 2009).

Whichever gear type is employed, the overall approach to livebait fishing is similar: powerful underwater lights are used to attract fish (Hallier et al. 1982). When fish have aggregated around the lights in sufficient numbers, a net is set to catch them (Hester 1974; Hallier et al. 1982).The catch is then hauled into the flooded hull or a holding tank (Stone et al. 2009; Adam et al. 2003). Sometimes, lights are positioned above and below the water and satellite catching stations are used – small skiffs with mounted underwater lights that are positioned around the main vessel (Hallier et al. 1982; Dalzell & Lewis 1989).

Although the overall approach is broadly the same, there are important differences in some aspects of baitfish capture between Japan, Indonesia and the Maldives, the top three pole-and-line fishing nations. In Japan, a separate commercial fishery sells live bait to the tuna vessels (Baldwin 1977; Hester 1974). As noted above, the baitfish are kept in floating pens prior to use to habituate them to captivity. Japanese pole-and-line vessels are able to carry this “hardened” live bait on board for up to four months without significant mortality (Shomura 1974; Western Pacific Regional Fishery Management Council 2000).

Similarly, in Indonesia, live bait is often supplied by a separate lift net fishery that deploys fixed or mobile platforms to catch and hold bait (Wright et al. 1990; Williams 2009). These artisanal fisheries, which exist throughout the archipelago, harden stolephorid anchovies in anchored bait receivers for later sale to pole-and-line vessels (IOTC 2000).

In the Maldives, baiting was traditionally carried out in the early hours of the morning using a simple rectangular lift net and kept alive in the flooded hull of the masdhoni (Maldivian fishing boat) (Anderson 2009). Night baiting has been growing in popularity since the mid-1990s and approximately 75% of all live bait for pole-and-line is now taken at night (Anderson 2009). At the end of the day's fishing, any remaining live bait is discarded or kept overnight in net enclosures or in bait nets rigged in wooden frames (Anderson 1997).

3.2. KEY BAITFISH SPECIES

Baitfish fisheries target various species of small pelagic fish including sprats, anchovies and sardines (Majkowski 2003b; Lewis 1990; Baldwin 1977). Estimates of the number of species used vary from 160 in 31 families (Gopakumar et al. 1991) to 230 in 34 families (Baldwin 1977). Of these about 20 species – chiefly belonging to Fam: Engraulidae (anchovy), Fam: Clupeidae (herrings, sprats and sardines), Fam: Caesionidae (fusiliers) and Fam: Apogonidae (Cardinalfishes) – are the principal baits used in the major Atlantic, Indian Ocean and Pacific fisheries (Gopakumar et al. 1991; Luther et al. 1984). Table 3 lists these species in greater detail.

Table 3: *Baitfish species important to pole-and-line fisheries*

SPECIES	COMMON NAMES*	FAO AREA*	OTHER USERS
Engraulidae (anchovies)			
Engraulis japonicus	Japanese anchovy	NWP, WCP	Marketed fresh and salted, processed into fishmeal and oil
Cetengraulis mysticetus	Pacific anchoveta	ECP, SEP	Processed into fishmeal and oil.
Encrasicholina purpurea	Nehu	ECP, SEP	None known
Encrasicholina heteroloba	Shorthead anchovy	WIO, EIO, NWP, WCP, ECP	Mainly for bait but also for human consumption as dried fish or fermented sauce
Encrasicholina devisi	Devis' anchovy	WIO, EIO, NWP, WCP, ECP	Caught for human consumption in Indonesia
Stolephorus indicus	Indian anchovy	WIO, EIO, NWP, WCP, ECP	Processed into nuoc-man (fish pickle) in Indo-China
Stolephorus insularis	Hardenberg's anchovy	WIO, EIO, NWP, WCP, ECP	None known
Encrasicholina punctifer	Buccaneer anchovy	WIO, EIO, NWP, WCP, ECP	Processed into nuoc-man (fish pickle) in Indo-China
Stolephorus waitei	Spotty-face anchovy	WIO, EIO, NWP, WCP	None known
Engraulis encrasicolus	European anchovy	NEA, ECA, MBS, SEA	Marketed fresh, dried, smoked, canned and frozen; made into fish meal
Clupeidae (herrings, sprats and sardines)			
Herklotsichthys quadrimaculatus	Bluestripe herring	SEA, WIO, EIO, NWP, WCP, ECP	Marketed fresh and dried salted. Favoured food fish in Kiribati
Amblygaster sirm	Spotted sardinella	WIO, EIO, NWP, WCP, ECP	None known
Spratelloides delicatulus	Delicate round herring	WIO, EIO, NWP, WCP, ECP, SWP, MBS	Marketed fresh or dried-salted
Spratelloides gracilis	Silver-stripe round herring	WIO, EIO, NWP, WCP, ECP, SWP	Marketed fresh or dried-salted
Sardinops sagax	South American pilchard	SEA, WIO, EIO, NWP, WCP, ECP, NEP, SWP, SEP	Utilised mainly for fish meal; but also eaten fried and broiled, especially in Mexico
Caesionidae (fusiliers)			
Caesio caerulaurea	Blue and gold fusilier	SEA, WIO, EIO, NWP, WCP, ECP	Adults used as bait in yellowfin handline fishery in the Maldives
Pterocaesio chrysozona	Goldband fusilier	WIO, EIO, NWP, WCP, ECP	Adults used as bait in yellowfin handline fishery in the Maldives
Apogonidae (cardinalfishes)			
Rhabdamia gracilis	Luminous cardinalfish	WIO, EIO, NWP, WCP	Small amounts used in aquarium trade
Rhabdamia cypselurus	Swallowtail cardinalfish	WIO, EIO, NWP, WCP, ECP, SWP, MBS	Small amounts used in aquarium trade

Sources: (Hester 1974; IOTC 2000; Luther 1990; Luther et al. 1984; Lewis 1990; Lewis 1983; Baldwin 1977; Dalzell & Lewis 1989; Rawlinson et al. 1992; Sharma & Adams 1990; Maniku et al. 1989; Adam et al. 2003; Froese&Pauly 2011; Gopakumar et al. 1991; Nasser & James 1996; Ianelli 1992; Kwei et al. 1995; Yoshida et al. 1974; Pillai et al. 1986; Anderson 2009; Ianelli 1992)

* WIO = Western Indian Ocean; EIO = Eastern Indian Ocean; NWP = North West Pacific; NEP = North East Pacific; WCP = Western Central Pacific; ECP = Eastern Central Pacific; SWP = South West Pacific; SEP = South East Pacific; NEA = North East Atlantic; SEA = South East Atlantic; MBS = Mediterranean and Black Sea

When the preferred bait species is not available, pole-and-line vessels, particularly those operating in island areas, will take any fish of the correct size that can be obtained in sufficient quantities (Hester 1974). Almost all small coral reef fish can be used as bait, including bycatch species (Baldwin 1977), and the species composition of the bait catch can fluctuate wildly over short periods of time (1-2 years in some cases) (Rawlinson et al. 1992).

3.2.1. BAITFISH CATCHES BY FISHERY

The bait species assemblage is diverse and varies according to both habitat and geographical location (Lewis 1990) (Table 4). Note that most of these fisheries are presently non-operational. Almost all studies of baitfish fisheries date from the 1970s and 1980s when the majority of island nations in the WCPO had active pole-and-line fleets (Oceanic Fisheries Programme 2010; Gillett 2010). As purse seining gained in popularity, so interest in pole-and-line waned. Today there are just six vessels operating in the central Pacific: four in the Solomon Islands and one each in Palau, and Hawaii (Gillett 2010; Gillett 2011b).

70+% of total baitfish catch

40-70% of total baitfish catch

20-40% of total baitfish catch

Table 4: *Species composition of key baitfish catches in selected fisheries*

FISHERY	ANCHOVIES	SPRATS	SARDINES	OTHERS	FUSILIERS	HERRING	CARDINALS	SILVERSIDES	MACKERELS
Fiji	10.4–22.0	20.0–23.4	15.8–42.4	9.1–10.9		14.6	16.6	4.3–4.7	6.4
PNG	62.6–71.5	18.1	5.4	2.3	7.7		1.6	1.2	1.1
Solomon Islands	43.0–72.7	11.1	1–22.2	13–22.8	0.5	1.2	0.2	0.3–0.8	0.3
Palau	56.2–91	0–33.1	0–1.3	3.7–9				0–7.6	
Kiribati		29.3–40.5	8.9–27.8	8–36.7		17.7	0.8	5.3–25.0	
New Caledonia	62.5	3.7	15.1	18.4				0.3	
Hawaii	97			3					
Japan	97			3					
Fed. Sts. of Micronesia	64	5.4	12.6	2.1				15.7	
Tuvalu		90.3		5.1				4.6	
Western Samoa	69.5	1.3	1.3	22.9					
French Polynesia	0.7	17.4	64.6	17.3					
Marshall Islands		7.4	67.5					25	
Cook Islands		96.3		0.3				3.4	
American Samoa	89.4	10.6							
Vanuatu	29.4	34.6	10.4	7.8				17.6	
Tonga	23.8	16.3	15.5	25.3				19.2	
Maldives	7	43		3	37		10		
Lakshadweep		21.6–64.2		2.3–41.1	1.9–11.4	0–12.3	22.2–30.6	5.4–6.26	

Sources:(Dalzell & Lewis 1989; Lewis 1990; Anderson 1997; Yoshida et al. 1974; Pillai et al. 1986; Gopakumar et al. 1991; Adam et al. 2003; Anderson & Hafiz 1988)
Note: a range is given where more than one study presented data

It is clear from the table that in the western and central Pacific Ocean, anchovies were the dominant catches on the high islands (Wallis and Futuna, Solomon Islands, Papua New Guinea, New Caledonia, Western Samoa, American Samoa), whilst sprats and sardine were the principal catch on atolls (Kiribati, Tuvalu, Cook Islands, Marshall Islands). It is also clear that the Japanese pole-and-line fleet is overwhelmingly dependent on anchovies.

By comparison, in the Maldives and the Lakshadweep group of islands, from where almost 82% of Indian Ocean pole-and-line tuna catch is taken (ISSF 2010; Miyake et al. 2010), sprats, fusiliers, cardinals and damselfishes are the preferred live bait.

3.3. CHARACTERISTICS OF KEY BAITFISH SPECIES

In general, the most effective baitfish are between 4 and 12 cm in length, survive well in captivity; and engender feeding behaviour in tuna by schooling at the surface close to the pole-and-line vessel when they are thrown in the water (Hester 1974; Baldwin 1977; IOTC 2000). These characteristics are summarised below in Table 5 and discussed in more detail by family in the text that follows.

Table 5: *Evaluation of key baitfish species*

SPECIES	COMMON LENGTH (CM)	OPTIMAL LENGTH (CM)*	JUVENILE USE**	LIFE CYCLE STRATEGY***	HARDINESS	TUNA ATTRACTIVENESS
			Engraulidae (anchovies)			
Engraulis japonicus	14	5–10	Likely	2	+	+++
Cetengraulis mysticetus	12	5–10	No	2	+++	+++
Encrasicholina purpurea	7.5	5–10	No	1	+	+++
Encrasicholina heteroloba	7.5	5–10	Yes[1]	1	++	+++
Encrasicholina devisi	7	5–10	No	1	+	+++
Stolephorus indicus	12	5–10	No	2	+	++
Stolephorus insularis	12	5–10	No	2	+	++
Encrasicholina punctifer	13	5–10	Likely	2	++	+++
Stolephorus waitei	6.5	5–10	No	1		+++
Engraulis encrasicolus	13.5	5–10	Likely	2		
Engraulis mordax	15	5–10	Likely	2	+++	+++
			Clupeidae (herrings, sprats and sardines)			
Herklotsichthys quadrimaculatus	15	5–12	No	2	+++	++
Amblygaster sirm	20	5–12	Yes[2]	2	+++	++
Spratelloides delicatulus	7	4–10	Yes[3]	1	+	++

Table 5: Continued

SPECIES	COMMON LENGTH (CM)	OPTIMAL LENGTH (CM)*	JUVENILE USE**	LIFE CYCLE STRATEGY***	HARDINESS	TUNA ATTRACTIVENESS
Spratelloides gracilis	10.5	4–10	No	1	*	+++
Sardinops sagax	20	5–12	Likely	2	*	+++
Caesionidae (fusiliers)						
Caesio caerulaurea	23.5	4–8	Yes[4]	2	+++	+++
Pterocaesio chrysozona	21	4–8	Yes[5]	2	+++	+++
Apogonidae (cardinalfishes)						
Rhabdamia gracilis	6	4–8	No	1	+++	+++
Rhabdamia cypselurus	6	4–8	No	1	+++	++

Sources:(Baldwin 1977; Adam et al. 2003; Rawlinson et al. 1992; Rawlinson 1989; Luther et al. 1984; IOTC 2000; Maniku et al. 1989; Lewis 1990; Gopakumar et al. 1991; Wright et al. 1990; Milton et al. 1990; Nasser & James 1996; Pillai et al. 1986; Lewis 1983; Williams &Cappo 1990)

*Developed from IOTC (2000)
** Juvenile use is considered "likely" for fish with a common length more than 30% longer than the upper boundary of their optimal length as bait
***Life cycle strategies: 1 longevity up to 1 year; 2: Up to two or more years (see Section 3.3.4)

1: Milton et al (1990); 2: Lewis (1990), Williams &Cappo (1990); 3: Pillai et al (1986), Lewis (1983) 4,5: Nasser & James (1996), Rawlinson (1989)
+++ = Good, ++ = Average, + = Poor

3.3.1. ENGRAULIDAE (ANCHOVIES)

Anchovies are one of the most desirable and most used baitfish in both the Pacific Ocean and the Atlantic Ocean (Baldwin 1977; Lewis 1990; Luther et al. 1984). They are highly attractive to skipjack tuna, widely distributed and form large aggregations nearshore throughout the year (Baldwin 1977). Species are typically less than 13cm in length with a silvery, elongated appearance (Baldwin 1977). However, their scales tend to fall off easily, particularly during handling, and their survival in bait wells ranges from good to poor, depending on the species involved (Baldwin 1977).

3.3.2. CLUPEIDAE (HERRINGS, SPRATS AND SARDINES)

Clupeids are used throughout the Indian Ocean and Pacific Ocean as baitfish as they are extremely appealing to tuna (Baldwin 1977). These schooling fishes have a compressed, silvery body but typically lack obvious markings, making individual species difficult to identify (Baldwin 1977). There is strong evidence that juveniles of *Amblygaster sirm* and *Herklotsichthys quadrimaculatus* are often used, but older, larger fish are in the greatest demand (Baldwin 1977; Rawlinson 1989). Clupeid populations have little ability to alter their behaviour making them vulnerable to overfishing and climate change (Rawlinson et al. 1992).

3.3.3. CAESIONIDAE (FUSILIERS)

Caesionid fishes are in the order Perciformes. As Table 5 shows, they are an important baitfish in the Maldives pole-and-line industry (Adam et al. 2003), which, as noted earlier, accounts for a quarter of the world catch for this technique. Adults are generally too large to be used but juveniles are considered excellent baitfish

(Maniku et al. 1989; Gopakumar et al. 1991). They are easy to catch, chum well and are relatively hardy (Maniku et al. 1989).

3.3.4. LIFE CYCLE STRATEGIES

Lewis (1990) recognises two basic baitfish life cycle strategies. Type 1 species live for less than a year and are small in size (up to around 10cm) (Lewis 1990). They grow quickly, reach sexual maturity in 3-4 months and spawn over an extensive time period (Lewis 1990). This group includes many of the world's principal baitfish, including anchovies of the genus Encrasicholina and sprats of the genus Spratelloides (Lewis 1990).

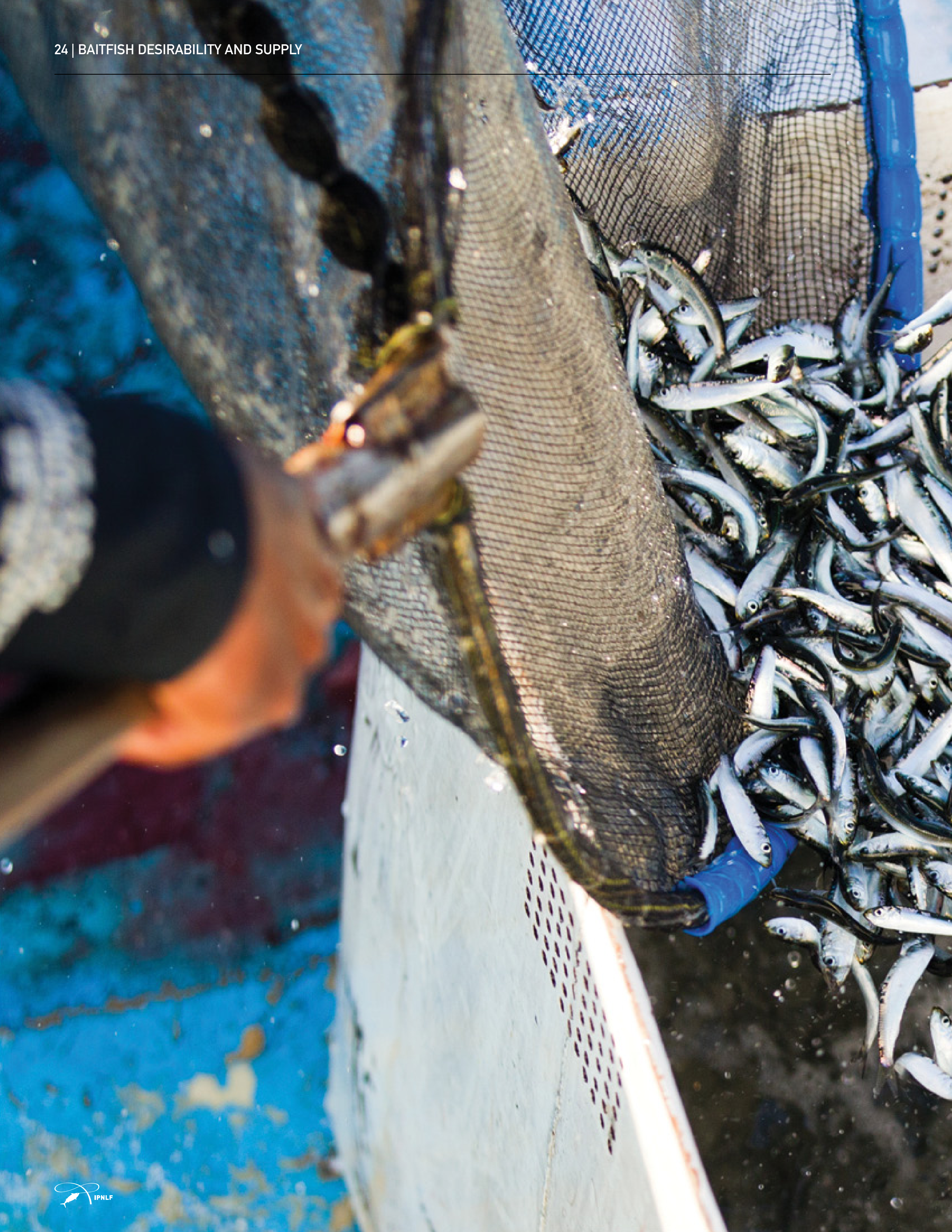
Type 2 species live for up to two years or more years and are larger in size (10-24cm) (Lewis 1990). They become sexually mature around the end of the first year and spawn seasonally (Lewis 1990). Key bait species in this group include the herrings and sardines (*Herklotsichthys* spp., *Amblygaster* spp.) and the larger anchovies (*Stolephorus indicus, Engraulis japonicus*) (Lewis 1990). With lower fecundity, slower growth and lower natural mortality, the Type 2 species are likely more vulnerable to overexploitation than highly fecund and rapidly growing Type 1s (Lewis 1990).

3.3.5. OTHER USES OF BAITFISH

Outside of pole-and-line, there are three other principal uses of baitfish. First, they are employed in the artisanal tuna handline fishery for skipjack, yellowfin and albacore (Majkowski 2003a). Handliners generally use squid, chopped pieces of scad, mackerel or hairtail, but those in the yellowfin handline fishery in the Maldives use red-tooth triggerfish (*Odonus niger*), scads and fusiliers (Anderson 2009; Majkowski 2003a). The only overlap is in the use of fusiliers, but the handline fishers typically use larger individuals whereas their pole-and-line counterparts use small juveniles (Anderson 2009). The quantities used in the handline fishery and the interactions between the two fisheries are yet to be estimated both in the Maldives and elsewhere (Anderson 2009).

Secondly, in 2008, 76% of world fish production destined for non-food purposes (20.8 million tonnes) was reduced into fishmeal and fishoil products (FMFOP) that was subsequently used as food for poultry, pigs and aquaculture (FAO 2010; Péron et al. 2010). Small pelagic anchovies, herrings, sprats and sardines are the mainstay of this reduction fishery, together accounting for between 20% and 30% of fishery landings (Péron et al. 2010). Key bait species used in this way include the Japanese anchovy *Engraulis japonicas* (approx. 540,000 tonnes per year in Japan and China), the South African sardine *Sardinops sagax* (approx. 57,000 tonnes in South Africa) and the European anchovy *Engraulis encrasicolus* (approx 1,300 tonnes in Morocco) (Péron et al. 2010). Although no work has been done to assess whether reduction fisheries pose a threat to live baitfish fisheries for tuna pole-and-line, catches for reduction purposes have been declining continuously in recent years whilst the proportion of fish used for direct human consumption has grown (FAO 2010). It is worthy of note, however, that production of fishmeal and fish oil is strictly linked to catches of key species, especially anchoveta (ibid.). As these catches are considerably impacted by the El Niño phenomenon, fishmeal production peaked in 1994 at 30.2 million tonnes and has followed a fluctuating trend since then (ibid.).

Finally, certain species of baitfish form important coastal fisheries for human consumption, especially those in Indonesia and India for stolephorid anchovies (Blaber & Copland 1990; IOTC 2000; Vincent 2003). This is discussed in more detail in section five.



BAITFISH DESIRABILITY AND SUPPLY 4

4.1. TUNA–BAITFISH RATIO

The quantity of tuna caught using the pole-and-line method is typically much greater than the quantity of baitfish used. The amount of tuna caught per unit of bait is known as the tuna–baitfish ratio. Several authors have estimated these ratios for Pacific and Indian Ocean fisheries; others have provided data on baitfish landings, enabling the ratio to be calculated by comparison with tuna fisheries statistics (Table 6).

Table 6: *Selected tuna to baitfish ratios by fishing region*

AREA	MAJOR BAIT GROUPS	RATIO	DATE	SOURCE
Indian Ocean (IO)				
Maldives	Anchovies, Sprats, Fusiliers, Cardinals	7.3–10.6	1978–1994	Anderson (1997)
Maldives	Anchovies, Sprats, Fusiliers, Cardinals	7.4–10.0	2003–2006	Anderson (2009)
Lakshadweep	Sprats, Fusiliers, Cardinals	53.1–95.6	1981–1985	Pillai et al (1986)
IO Average		**30.7**		
Eastern Pacific Ocean (EPO)				
EPO	Anchovies, Sardines	7.5	1950–1969	Sakagawa et al (1987)
Hawaii	Anchovies	23.1	1950–1972	Sakagawa et al (1987)
Japan	Anchovies, Sardines	9.7	1957–1971	Sakagawa et al (1987)
Japan	Anchovies, Sprats, Fusiliers, Cardinals	15.9	1966–1980	Sakagawa et al (1987)
EPO Average		**14.1**		
Western and Central Pacific Ocean (WCPO)				
WCPO	Anchovies, Sprats, Sardines	31.5	1977–1980	Gillett (2010)
WCPO	Anchovies, Sprats	20–40	1988	Lewis (1990)
Fiji	Sprats, Sardines, Herring, Cardinals, Anchovies	7.2–63.6	1976–1989	Sharma & Adams (1990)

***Table 6:** Continued*

AREA	MAJOR BAIT GROUPS	RATIO	DATE	SOURCE
Fiji	Sprats, Sardines, Herring, Cardinals, Anchovies	31.1	1978	Ellway& Kearney (1981)
Kiribati	Sprats, Sardines, Herring	7.1–21.3	1982–1989	Rawlinson et al (1992)
Palau	Anchovies	26.5	1964–1972	Gillett (2010)
PNG	Anchovies, Sprats	22.4	1970–1981	Sakagawa et al (1987)
PNG	Anchovies, Sprats	30.1	1972–1973	Gillett (2010)
Solomon Islands	Anchovies, Sprats	21.6–45.2	1973–1980	Argue & Kearney (1982)
Solomon Islands	Anchovies, Sprats	10.5–32.6	1973–1988	Nichols & Rawlinson (1990)
WCPO Average		**28.1**		
Overall Average		**25.3**		

Sources: (Rawlinson et al. 1992; Maniku et al. 1989; Gillett 2010; Lewis 1990; Adam et al. 2003; Oceanic Fisheries Programme 2010; Sharma & Adams 1990; Anderson 1997; Sakagawa et al. 1987; Pillai et al. 1986; Nichols & Rawlinson 1990; Argue & Kearney 1982; Kearney 1984; Kleiber& Kearney 1983; Ellway& Kearney 1981; Anderson 2009; Yoshida et al. 1974; Pillai et al. 1986).

Note: where a range of ratios exists, the mean of the upper and lower values was used in the calculation of the regional averages.

Maldivian tuna to baitfish ratios are broadly similar to those in the eastern Pacific, but noticeably lower than WCPO ratios and very much lower than estimated ratios from the Lakshadweep Islands in the Indian Ocean (SW of Kerala, India). Anderson (1997) concluded that this discrepancy was principally due to: i) profligate use of livebait when available in abundance by Maldivian fishers; and ii) differing methodologies for calculating bait usage.

In a less comprehensive study of baitfish requirements for pole-and-line fisheries in the Pacific, Gillett (2011a) estimated a tuna–baitfish ratio of 32.1 for the WCPO region. This compares well to the value of 28.1 for the same region and 25.3 for the world obtained by this study (Table 6). Taking the individual regional ratios and weighting them by the relative catches of principal market pole-and-line tuna producers gives the following crude estimates of annual bait requirements.

***Table 7:** Estimates of yearly bait requirements for tuna pole-and-line*

	WORST CASE		BEST CASE		AVERAGE	
AREA	RATIO	TONNES NEEDED	RATIO	TONNES NEEDED	RATIO	TONNES NEEDED
WCPO	7.1	25,825	63.6	2,883	28.1	6,516
Maldives	7.3	15,026	10.6	10,349	8.9	12,256
Other IO	53.1	692	95.6	384	74.3	494
EPO	7.5	2520	23.1	818	14.0	1,345
Atlantic	25.3	4,288	25.3	4,288	25.3	4,288

Note: Data for Atlantic pole-and-line catches was very limited, so the global mean was used as a proxy. Worst case denotes most conservative tuna-baitfish ratio; best case denotes most generous ratio.

As noted above, global pole-and-line catch of principal market tunas is approximately 457,000 tonnes per year at present, 10% of the world catch. From the information presented in Table 7, it is estimated that current live bait requirements for pole-and-line tuna are between 19,000 and 48,000 tonnes per year, with a mean average of 25,000 tonnes. In order to increase pole-and-line production, these figures would need to be increased unless efficiency gains could be achieved. For example, if the contribution of pole-and-line tuna to world catches was to be doubled to 20% then it is possible that bait supplies would also need to be doubled. These calculations make several assumptions:

1. That the Atlantic tuna catch per unit bait is comparable to global mean average

2. That the 25% of Indian Ocean catch which is not from the Maldives has similar tuna–baitfish ratios to those of Lakshadweep Islands

3. Were pole-and-line to increase to 20% of the global catch, that tuna stocks would be taken in the same proportion per region as they are at present

4. That technological breakthroughs and fleet industrialisation have not improved the ratios significantly since estimates were made in the 1950s, 60s, 70s and 80s or that such ratios cannot be substantially increased should effort be allocated to this

5. That anthropogenic and environmental pressures have not impacted the bait species assemblages since estimates were made in the 1950s, 60s, 70s and 80s

Due to these caveats, the baitfish requirement values should only be considered as crude estimations and should be interpreted with caution.

4.2. FACTORS INFLUENCING TUNA–BAITFISH RATIO

Tuna–baitfish ratios are heavily dependent on bait mortality, effectiveness and supply, hence the wide range of ratio values outlined in Tables 6 and 7 (Hester 1974). Effectiveness was covered in section two, so the discussion here is restricted to mortality and supply.

4.2.1. MORTALITY

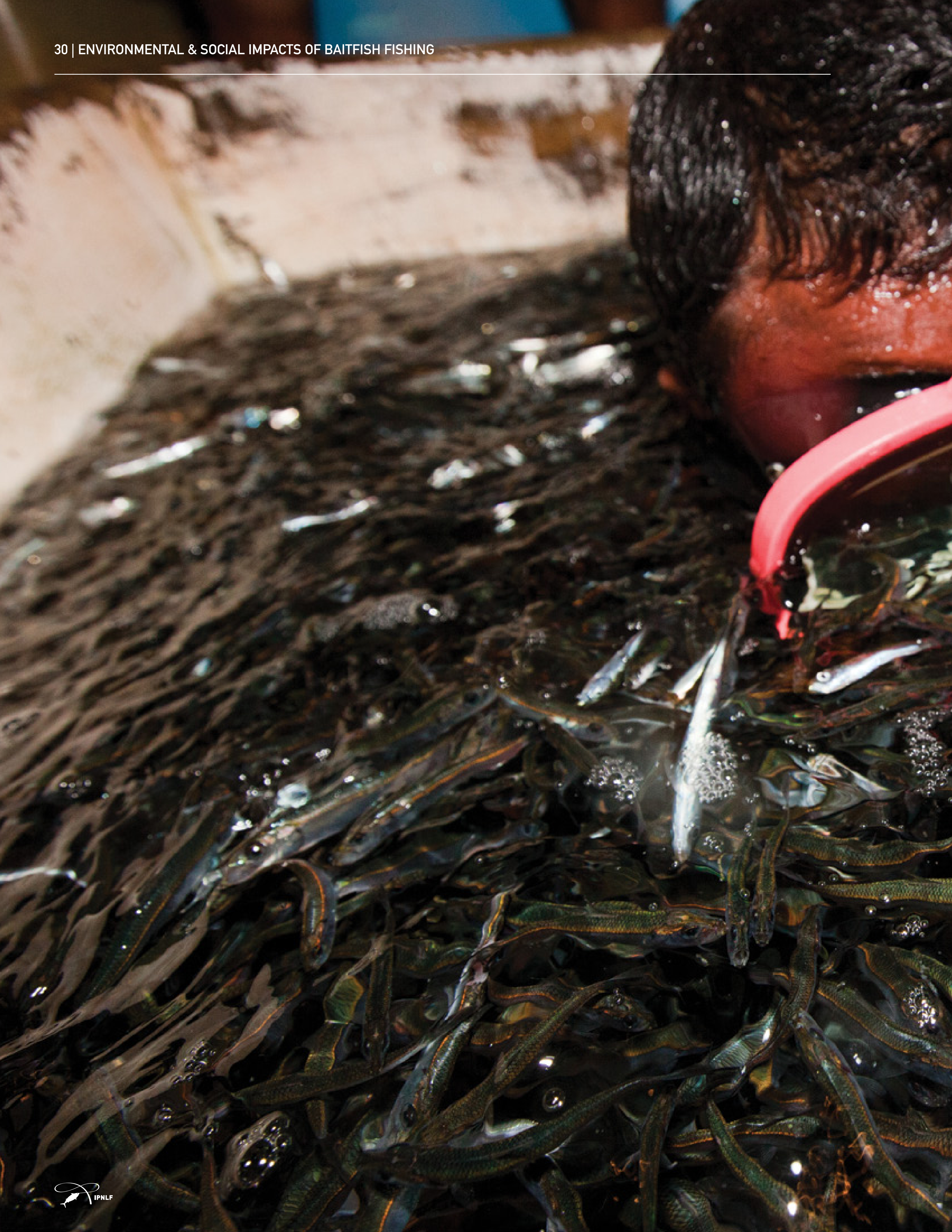
Live bait will start to die off from the time it is first caught and continue to do so until after it is chummed (Hester 1974). Capture, transfer and handling, bait-well design and environmental conditions all influence baitfish survival and, hence, the tuna–baitfish ratio (Baldwin 1977; Bryan 1980). Poor survival is typically due to overcrowding, inadequate holding facilities and rough handling (Baldwin 1977). Certain types of bait, especially juvenile anchovies and sardines are exceptionally fragile and do not survive the process well (Baldwin 1977). Bait mortality can be as high as 100% in a 24-hour period but varies enormously depending on the methods and conditions of handling, as well as the species used (Kearney & Rivkin 1981). There is evidence that night loading can trigger high losses (Kearney & Rivkin 1981; Baldwin 1977). By comparison and as noted above, some species like the Japanese anchovy (*Engraulis japonicus*) are hardened before use and can stay alive in captivity for months (Shomura 1974; Western Pacific Regional Fishery Management Council 2000). Overall, mortality of live bait is a multifaceted issue and needs significant additional research, especially in relation to long distance transport of bait and prehardening, as well as the holding of substantial quantities (Hester 1974; Shomura 1974).

4.2.2. SUPPLY

The foremost problem in baitfishing is obtaining an adequate and reliable source of bait (Hester 1974). Variations in supply are the result of multifarious interactions between baitfish recruitment periods (Rawlinson et al. 1992), weather conditions (rainfall, water clarity, wind, swell, wind-chop) (Rawlinson et al. 1992; Hallier et al. 1982), cyclicality, seasonality, and lunar phases (Kearney & Rivkin 1981), as well as previous fishing effort (Rawlinson et al. 1992) and other species-specific interactions (Dalzell & Lewis 1989).

4.2.3. OTHER FACTORS

The tuna–baitfish ratio varies depending on an array of other factors including proximity of bait to productive tuna fishing grounds (Lewis 1990; Argue et al. 1987), location of deployed fish aggregation devices (Lewis 1990), subtle species-specific environmental causes (Lewis 1990) and access agreements to fish in a given location (Sharma & Adams 1990). Environmental factors such as sea condition, sea surface temperature and weather are also important (Lewis 1990; Argue et al. 1987). There is evidence that skipjack tuna schools may respond more favourably to pole-and-line fishing in the morning and closer to shore and in the spring more than the autumn (Lewis 1990; Baldwin 1977). Other variables demonstrated to have an effect include: i) the type of food in the skipjacks' stomachs; ii) the length of time since last feeding; iii) the way that the vessel approaches the school; iv) the density of the school and; v) the proximity to the school of birds, sharks, whales and logs (Baldwin 1977).



5 ENVIRONMENTAL & SOCIAL IMPACTS OF BAITFISH FISHING

5.1. EFFECTS ON ARTISANAL AND SUBSISTENCE FISHERIES

There are four main areas where commercial bait fishing may have unfavourable effects on artisanal and subsistence fisheries. First, baitfishing operations may deplete the source of food for larger, piscivorous species on which the food fishery relies (Rawlinson 1989). Secondly, they may deplete common stock, reducing food security for local fishing communities (Ianelli 1992; Rawlinson 1989). The two further concerns centre on the by-catch of food species and of juveniles during bait fishing. The take of juveniles not only affects species that would otherwise become highly valued food fish (Ianelli 1992; Rawlinson 1989) but can also contribute to the overfishing of the species used for bait. Each of these issues is considered in more detail below.

5.1.1. INTERACTIONS WITH REEF FISHERY

Baitfish species are food for numerous other species of reef fish, so catching them on a large scale may detrimentally affect others in the food web (Anderson 2009). The most frequently voiced concern is that the removal of baitfish for pole-and-line reduces the available forage for larger species (Ianelli 1992; Leqata et al. 1990). This lowers the catch available to subsistence and artisanal fisheries as the larger fish are said to move away to areas of lower baitfish fishing activities in search of prey (Leqata et al. 1990). Fishers have reportedly expressed this belief throughout the Indo-Pacific region, especially in the Solomon Islands, Maldives and Kiribati (Anderson 2009; Nichols & Rawlinson 1990; Blaber et al. 1990b; Blaber et al. 1990a; Rawlinson et al. 1992; Leqata et al. 1990; Lewis 1983).

Lewis was among the first to review the impact of commercial baitfish fishing on coastal fisheries (Lewis 1983). He concluded that the natural fluctuations in abundance of bait species in the Pacific Islands did not typically coincide with changes in the abundance of predatory species often prized as food fish (Lewis 1983; Ianelli

1992). In essence, whenever a particular species of baitfish became less abundant, its predators sought alternative food items (Lewis 1983). Two later studies reached similar conclusions.

The first, by Blaber et al. (1990b), studied the effects of tuna baitfishing on other subsistence and artisanal fisheries in both the Maldives and the Solomon Islands. The authors found that in the Solomon Islands, most of the principal predators of baitfish were not caught by the subsistence fishery, concluding that there was little likelihood that the subsistence fishery was adversely affected by trophic interactions with the commercial baitfishery (Blaber et al. 1990b). In the Maldives, they found that four baitfish predators were important in the small but developing reef fishery and suggested that these predators may form a significant proportion of artisanal catches in the future (Blaber et al. 1990b). Their concerns appear somewhat unfounded, however, as more recent studies have seen this only as a minor issue (Anderson 1994; Anderson 2009). Barclay (2010) criticised the Blaber et al. (1990b) study for failing to account for the full range of fishing conducted by local communities and noted evidence of trophic interaction between the commercial tuna baitfishery and the subsistence fishery, both in the Solomon Islands and in Fiji (Barclay 2010).

The results of the second major study on interactions with the reef fishery were in broad agreement with those from Blaber et al. (1990b). The research, which focused on Kiribati, also found that baitfish predator families were only a small constituent of artisanal catches, concluding that a decrease in the numbers of baitfish caused by commercial fishing activities would have little impact on subsistence fishers (Rawlinson et al. 1992).

Other reef fishery interactions have been hypothesised but none has yet been suitably quantified. Theoretically at least, baitfishing may reduce the predation of baitfish on fish eggs or remove potential competitors for food(Rawlinson 1989). Further, capture of top predators by artisanal fishers might decrease the mortality on smaller-sized carnivores, increasing predation on bait fish species (Anderson 2009).There is also anecdotal evidence that the removal of large predators may reduce baitfish catchability, as these fish corral the baitfish making them easier for fishers to catch (Anderson 2009).

More broadly, a considerable amount of modelling research has been devoted to the role of small pelagics in marine ecosystems (see Smith et al 2011 for a discussion), arising out of concern over the impacts of industrial scale fishing on species which play a crucial role in supporting populations of higher order predators. However, most of the modelling has been conducted in temperate water ecosystems, where species diversity is lower, in some cases accentuating the ecosystem flow-on effects of heavy fishing pressure. For tropical systems, there has been markedly less work, although ecosystem modelling in eastern Indonesia suggests that intensive fishing of anchovies may reduce populations of larger fish predators such as tunas (Ainsworth et al 2008).

Overall, the question of trophic interactions with local artisanal and subsistence fisheries is not well studied and would certainly benefit from additional empirical research. This would require in-depth analyses of predatory fish stomach contents over a multitude of different prey species. As Lewis (1983) notes, given the multiplicity of factors involved, this would certainly not be an easy task.

5.1.2. DEPLETION OF COMMON STOCK

Small pelagic fishes are a resource in their own right and are caught by artisanal and subsistence fishers throughout the world. As Table 3 (p18) shows, several key species of baitfish are also used as food fish, including the Japanese (*Engraulis japonicus*), Shorthead (*Encrasicholina heteroloba*), Indian (*Stolephorus indicus*), Buccaneer (*Encrasicholina punctifer*) and European (*Engraulis encrasicolus*) anchovies, the Bluestripe (*Herklotsichthys quadrimaculatus*), Delicate Round (*Spratelloides delicatulus*) and Silver-stripe Round (*S. gracilis*) herrings and various fusiliers (*Caesionidae* spp.). Other accounts in the literature suggest that seasonal inshore concentrations of stolephorid anchovies and clupeids form important coastal fisheries in India and Indonesia (Blaber & Copland 1990; Vincent 2003; IOTC 2000). Between November and January each year local fishers of the southern Indian Nonna fishery catch large aggregations of post-larval anchovies and clupeids for human consumption (Vincent 2003). In Indonesia, the well-developed fisheries for tuna baitfish such as *Encrasicholina devisi*, *E. heteroloba* and *E. punctifer* also retain catch for direct human consumption as a dried product (IOTC 2000).

Artisanal and subsistence fishers often allege that the tuna pole-and-line baitfish fisheries reduce the stocks available (Ianelli 1992; Rawlinson 1989). A handful of authors have looked into this issue in more detail. In the Solomon Islands, both Tiroba et al. (1990) and Leqata et al. (1990) found no evidence of direct interaction between the bait and subsistence fisheries, as baitfish were not consumed by the Islanders. In Kiribati, Ianelli (1992) found that that the majority of local catches were species not used as live bait for pole-and-line and concluded that, in cases of overlap, the practices did not appear to exacerbate the conditions for either fishery. Others have suggested that conflicts between artisanal and baitfish fisheries in the Pacific were partly due to land/water ownership and the traditional tenure system rather than wider resource depletion concerns (Pers. comm. with Robert Stone 2008).

In a broader study of the catch composition of Pacific artisanal fisheries, Dalzell and Schug (2002, in Gillett 2010) listed the top 21 key food species, none of which are popularly used as baitfish. Finally, in two studies from the Maldives, Anderson (1997) and Maniku et al. (1989) found that, although the species involved in the food fishery and the livebait fishery were largely different, small quantities of some bait species, particularly *Spratelloides gracilis* and adult fusiliers were used in both. Anderson (1997) concluded that the quantities involved were so small that it was unlikely to cause problems for either fishery.

Nonetheless, The Ministry of Fisheries and Agriculture in the Maldives, mindful of the potential damage to the artisanal fishery were an export market to develop for any live bait species, placed a precautionary ban on the export of such species (Anderson 1997). Overall, as with indirect reef fishery interactions, this is a complex and multifaceted issue that would benefit from additional research. It would be particularly useful to examine direct interactions between the baitfish fishery and the food fishery for stolephorid anchovies and clupeids in Indonesia and India, where little work to date has been carried out.

5.1.3. USE OF JUVENILES

Many adult baitfish are longer than the ideal length of approximately 4-12cm and in such circumstances juveniles tend to be used (Baldwin 1977; Rawlinson 1989; IOTC 2000). Evidence of exploitation of juvenile baitfish is summed in Table 5 (p20). Species taken include *Encrasicholina heteroloba* in Indonesia (Wright et al. 1990), *Amblygaster sirm* in Kiribati (Rawlinson et al. 1992), *Spratelloides delicatulus* in the Lakshadweep islands (Pillai et al. 1986) and various caesionids in the Maldives and the Lakshadweep islands (Anderson & Hafiz 1988; Nasser & James 1996). As Table 5 shows, the common length of several key baitfish species is greater than their optimal length for attracting tuna. Where the difference is substantial (i.e. 30% or more), it is conceivable at least that some juveniles are used. These have been labelled as "likely" in the table.

Though juvenile baitfish are sometimes used in tuna pole-and-line, it is a common misconception that catches predominantly consist of juveniles of commercially important reef species (Lewis 1983). Lewis (1983) argues that this is simply not the case, but notes that small numbers of juvenile reef fish are taken incidentally on occasion. Despite an extensive review of the literature, only four studies were found that addressed this second point. The first, by Rawlinson (1989), reported incidences of by-catch of larval and juvenile fish in Papua New Guinea and Fiji and found that large numbers were caught by the (former) commercial baitfish fishery in the Solomon Islands. Rawlinson drew two primary conclusions: i) that some juvenile species taken incidentally formed an important part of the local subsistence fishery; ii) that this may have had a detrimental effect on the subsistence fishery but that it was not possible to quantify that effect (Rawlinson 1989).

The second, a review of the (former) live bait fishery in Kiribati by Ianelli (1992) took the view that, given the low survival rates at early life stages and high fecundity of many reef fish, incidental catches of juvenile species would not adversely affect adult recruitment. The third study, a report from the Maldives (Anderson 2009) noted that fish larvae were sometimes taken at night and that local fishers felt this must have had some impact on reef fish stocks.

The final study, by Sudirman and Musbir (undated), found that large quantities of juveniles were being caught in lift nets (bagans) in parts of Indonesia, underscoring the importance of considering the take of juveniles by the baitfishery in the context of cumulative impacts. Because so many juveniles were being taken this way, several jurisdictions banned the use of lights in baitfishing all together (UNEP 2007).

5.1.4. BY-CATCH

A couple of authors have addressed the related question of by-catch of adults of non-target species. In the former baitfish fishery of the Solomon Islands, Rawlinson (1989) found that large predatory fish, principally members of the families Carangidae (Jacks and pompanos) and Trichiuridae (Cutlassfishes), were often taken in commercial bait catches. He also noted the less-frequent capture of various barracudas, mackerels, snappers, parrotfishes and batfishes (Rawlinson 1989). Rawlinson called for further empirical study, concluding that although the numbers of adult fish by-catch per bait net haul were not substantial, totals over a whole season in a heavily bait fished area could be sizeable and potentially damaging to the food fishery (Rawlinson 1989).

In the Maldives, both Maniku et al. (1989) and Anderson (2009) have looked at by-catch in baitfish fisheries. The former estimated that bycatch of non-target reef species, primarily surgeonfish (Fam: Acanthuridae) and wrasses (Fam: Labridae) constituted between 0 and 30% of bait catches and totalled around a few hundred tonnes annually. The latter, based on four years of sampling data, found an extremely low level of by-catch, but concluded that large by-catches were taken on rare occasions and that this amount needed to be quantified (Anderson 2009).

5.2. OVEREXPLOITATION

Overexploitation of baitfish fishery target species is another major concern (Hester 1974). Here too, evidence is fragmented and incomplete. In the WCPO, research has suggested that livebait resources are difficult to overfish (Rawlinson et al. 1992; Dalzell & Lewis 1989). Nonetheless, Hester (Hester 1974) and Gillett (Gillett 2011a; Gillett 2011b) have concluded that it would be somewhat challenging to substantially expand baitfish catches in the region. Similarly, Lewis (1990) argued that the availability of sufficient quantities of bait in the region could not be assumed, and that supply varies considerably throughout the region. He identified large, high islands, with extensive mangroves and estuaries, and plentiful anchorages of adequate depth (20-40m) as those most likely to support productive baitfish fisheries (Lewis 1990).

In the Indian Ocean, Stone et al. (2009) reported claims by Maldivian fishers that baitfish resources are depleted in some locations, a finding echoed in earlier research by Anderson (1997). However, the latter found that any livebait shortage tends to be a short-term, seasonal problem and when probed in more detail, fishers cited lack of bait as the least important reason for not going tuna fishing (Anderson 1997). Anderson concluded that it was likely rather difficult to overfish stocks of the small, highly fecund pelagic fishes on which the Maldivian livebait fishery heavily depends and that a lack of formal stock assessments makes evaluation of the level of exploitation of livebait resources arduous – an observation which holds true for baitfish fisheries across the world's oceans (Stone et al. 2009; Hester 1974; Baldwin 1977; Anderson 1997).

5.3. OTHER ENVIRONMENTAL IMPACTS

There are five other environmental impacts worthy of brief mention. First, the risk of introduction of non-native species and pathogens from transported bait (Gillett 2011a). Two baitfish species – the Marquesan sardine (*Sardinella marquesensis*) and the Bluestripe herring (*Herklotsichthys quadrimaculatus*) were accidentally introduced to Hawaii by pole-and-line vessels (Gillett 2011a). Though little research has been done into the impacts of these introductions, potential adverse impacts stem as much from the species themselves as from macro- (e.g. snails and worms) and micro-organisms (parasites, viruses and bacteria) that are introduced at the same time (ibid.). These impacts can be severe, and may disrupt native species, as well as rural livelihoods, food security and public health (ibid.).

Secondly, there is evidence that some fishers in the Maldives have used destructive methods to catch live bait (Anderson 1997). When catching cardinal fishes, damselfishes and other reef-associated species, fishers may use poles or steel chains to "scare" baitfish out of the reef and into the net (ibid.).This can result in significant coral damage, particularly to branching corals (ibid.).

Another cause of reef degradation has been anchor damage from pole-and-line vessels (Anderson 1997). In the Maldives, this has become much less of an issue as the introduction of more powerful engines has made the masdhonis more manoeuvrable (Anderson 2009). Moreover, night baitfishing tends to take place in atoll lagoons, away from the reefs, which also helps to minimise coral damage.

The fourth potential impact involves the dumping of excess livebait at sea (Anderson 2009). In the Maldives, it is common practice to throw any remaining bait overboard at the end of the fishing day (ibid.). There are no estimates of how much bait is wasted in this way, but it may amount to several hundred tonnes per year (Anderson 1997).

Finally, (Gillett 2011a) suggests that lights used in night baitfishing may impact turtle nesting activities. He does not elaborate further and this potential issue appears to be unstudied.

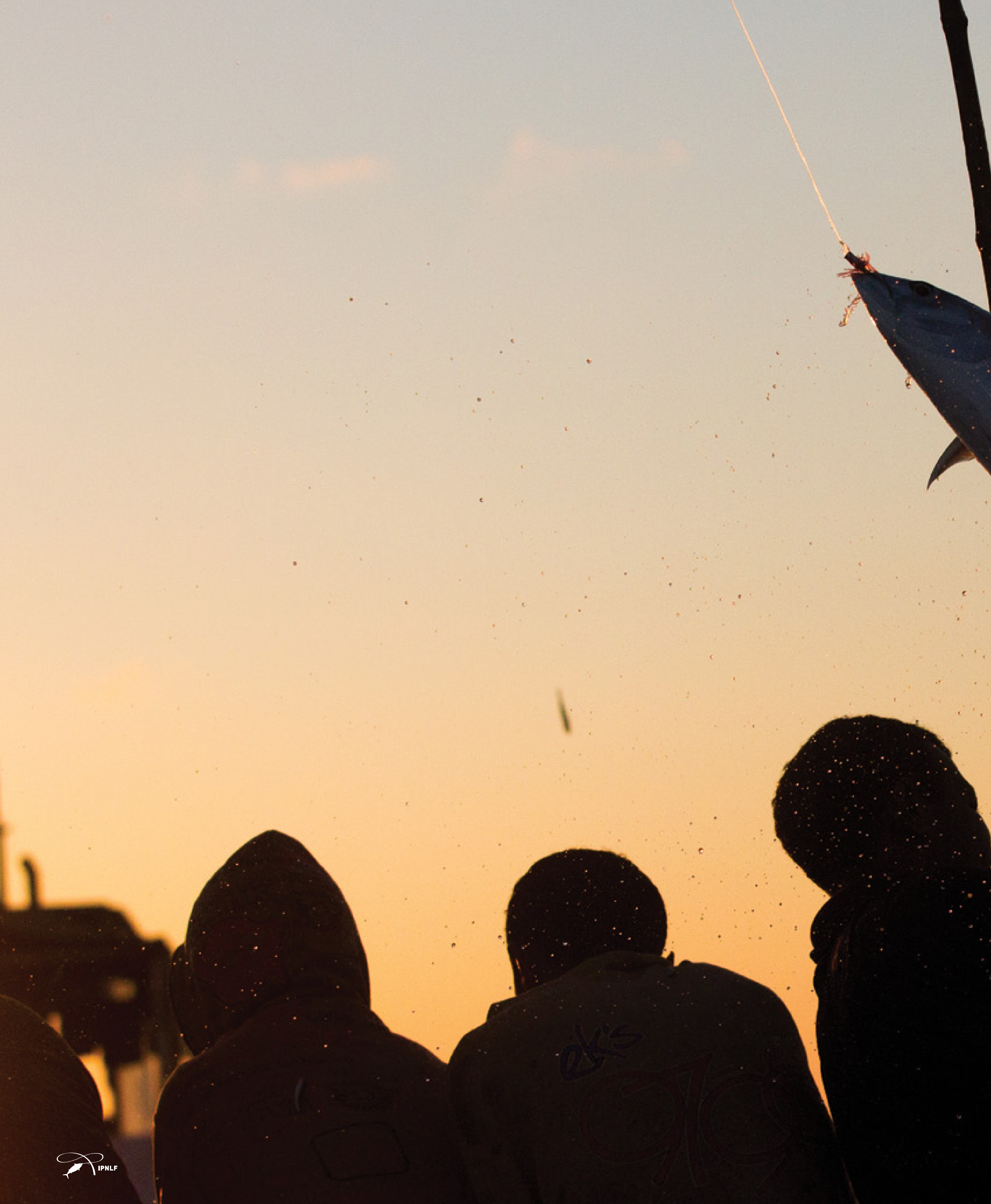
5.4. OTHER SOCIAL IMPACTS

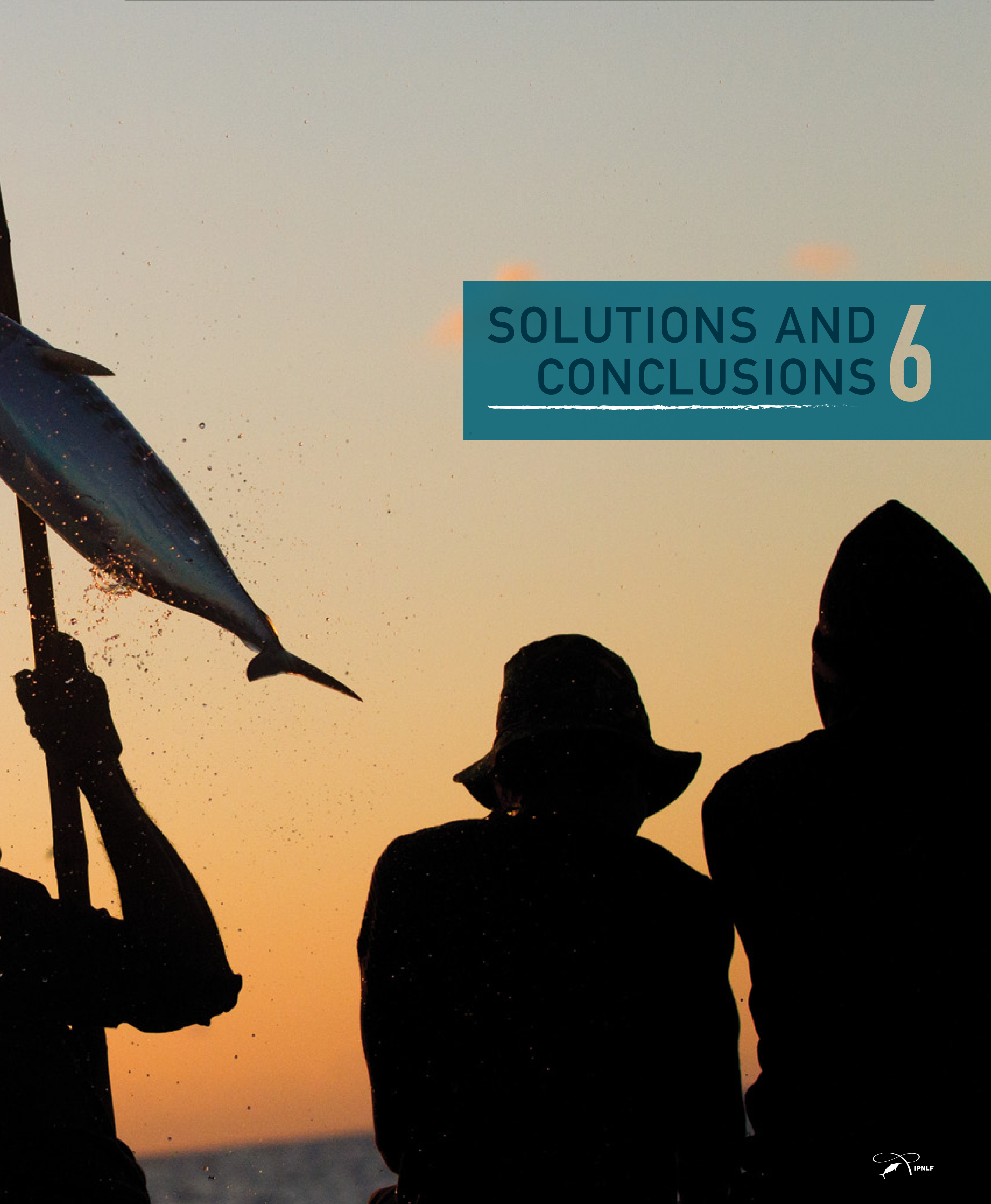
There are three other potential social impacts from baitfishing. Evidence for each impact is largely dated and anecdotal and would certainly benefit from further study.

First, conflict with dive and tourism operators caused by removal of bait from house reefs (Anderson 1997). Tourism is of substantial economic importance in the Maldives, and is largely contingent upon the same reefs that the bait fishers exploit (Anderson 2009). Tourism and dive operators often object to baitfishing on house reefs, saying that it depletes attractive schools of fish (Anderson 1997). By comparison, Maldivian fishers tend to believe very strongly that they have the right to fish almost everywhere, even in MPAs (Anderson 2009).

Secondly, conflicts with local artisanal fishers may arise over perceived ownership of bait resource (Barclay 2010; Gasalla & Rossi-Wongtschowski 2004). Several authors who researched the former pole-and-line fisheries of the WCPO noted this problem, including Lewis (1983) throughout the region, Sharma & Adams (1990) in Fiji and Rawlinson et al. in Kiribati (1992). In both Fiji and Kiribati, conflict between the baitfish fishery and the artisanal fishery was so great that bait fishers were forced to pay access fees (Sharma & Adams 1990; Rawlinson et al. 1992). Note that this is not an issue in the Maldives, which does not have a system of customary tenure comparable to Pacific island nations.

Thirdly, social interactions between villagers and bait vessel crews can be problematic. In a broad review of the impacts of tuna industries on coastal communities in Pacific Island countries, Barclay (2010) noted that tuna vessels in general contributed to negative social trends. She found a pervasive culture of hard partying amongst the crews (including those from pole-and-line vessels) when they came ashore, including alcoholism, substance abuse and prostitution (Barclay 2010). This was seen as increasing social issues such as sexually transmitted infections, unplanned pregnancies and violence (ibid.). Barclay's findings are largely echoed by more recent research into the social-economic dynamics of migrating fishers in the western Indian Ocean (WIOMSA 2011).





SOLUTIONS AND CONCLUSIONS 6

The previous chapter identified several environmental and social issues with the potential to impact pole-and-line fishing. This section discusses solutions that offer some hope of mitigating these impacts, as well as reducing baitfish mortality and improving supply.

6.1. IMPROVING MANAGEMENT

It is clear from the above discussion of potential of baitfish impacts that the status of baitfish stocks in key pole-and-line nations is not well known. It is therefore reasonable to assume that the overall yield from baitfish resources could be enhanced by establishing regular, comprehensive assessments of baitfish stocks and managing baitfish fisheries on an ecosystem basis and in accordance with the precautionary principle (Stone et al. 2009; Anderson 1997). Whilst the diversity of the bait species assemblage, the long-established nature of many baitfish fisheries and the extremely limited funding and human resources available for monitoring and management have made such approaches unrealistic in the past (Anderson 2009; Lewis 1990), these will be required from fisheries that want to qualify for export markets interested in sustainable and equitable pole-and-line products.

Baitfish management plans should also include: i) a code of conduct (potentially incentivised) to encourage efficient bait usage and raise awareness of unsustainable practices (Kearney 1984; Anderson 2009); ii) strategies for coordinating deployment of effort during the fishing season (Kearney 1984); and iii) recommendations for restricting bait capture in areas where local fishing communities rely on bait species for food (Rawlinson et al. 1992; Gillett 2011a). To maximise chances of long-term compliance and to ensure they fit the local reality and dynamics of the community and fishery, the development and implementation of management plans would need to involve effective consultation with local communities involved in or impacted by baitfish extraction (Cinner & David 2011).

It would be similarly prudent and cost effective to foster a pole-and-line nation information-sharing network. Such a network could share best practices in efficient and sustainable baitfish usage and include a skills exchange programme whereby master fishers from other pole-and-line countries visit each other's nations and share their techniques, technologies and experiences (Anderson 2009). For more on effective and suitable baitfish management regimes, see Box 1.

***Box 1:** Creating management regimes suited to the needs of the fishery and the capacity of the stakeholders*

There is a growing realisation in many developing countries that the costs of foregoing good fisheries management now outweigh the short-term gains. In other words, for fisheries to continue to provide the sorts of economic and social benefits desired by all stakeholders there needs to be an investment in suitable management arrangements. This is particularly the case where export markets are increasingly demanding that effective management regimes are in place such that any public risk for the sellers of seafood is minimised.

Increasingly the concept of co-management is being applied to small scale fisheries in developing countries as management models brought in from developed countries (i.e. top-down, command and control approaches) have not worked well. Co-management is based on having in place a governance structure that facilitates participation by all interested stakeholders. Thus, management is created by and is accountable to those whose livelihoods depend on decisions in favour of sustainability.

Whilst there is a wide variety of ways to manage fisheries and it is not the purpose of this report to be prescriptive, there are some common attributes of management systems that will likely prove beneficial to adopt.

The four main elements of a workable management regime include:

1. Governance structure – ensuring that there is a formal governance mechanism in place that encourages participation by stakeholders, clearly allocates responsibilities and is based on a decision making process accepted by all parties will ensure that stakeholders will accept and implement management decisions.

2. Legal framework – there is a need for an appropriate legal framework such that management rules and agreements can be enforced. Such a framework underpins both long-term and short-term objectives for the fishery.

3. Effective compliance and enforcement – without a credible enforcement regime, there is no incentive for all participants to comply with agreed management measures. Sanctions for violating the rules have to be sufficient to dissuade further violations and applied in an equitable manner.

4. Monitoring, research and evaluation –The management arrangements need to ensure that information needs are integrated into the overall plan for the fishery.

(Leadbitter, 2011)

6.2. MITIGATING EXISTING, KNOWN IMPACTS

It is clear from the literature that there is a potential for technical innovation at every stage of the process involved in baitfish capture and use. In particular, modifications to live-bait holding configurations, handling methods, chumming techniques, and lure use and design may substantially decrease baitfish mortality and improve the tuna-baitfish ratio (Baldwin 1977; Bryan 1980). During night fishing, there is evidence that the use of generator boats – small skiffs with additional underwater lights to attract fish whilst the main vessel is catching bait – can increase catch rates (Rawlinson et al. 1992), as can employing above water lights in addition to the usual underwater ones (Sharma & Adams 1990; Hallier et al. 1982). However, as noted above, there is evidence that using lights to aid in bait capture can substantially increase incidental capture of juveniles, so caution is urged here.

Injury and shock during capture and storage, in particular scale loss, account for at least a significant proportion of baitfish mortalities (Rawlinson et al. 1992; Hester 1974). As such, regularly mending baitnet holes to prevent fish from gilling themselves and understanding the relationship between baitfish mortality and size and material of the buckets used to transfer bait into the bait wells may also help to improve yields (Rawlinson et al. 1992; Hester 1974; Baldwin 1977). Other worthwhile avenues of exploration may include the transfer of bait by pumps, or the adaptation of pole-and-line vessels to include a waterline gate allowing bait to enter the wells directly and without the need for bucketing (Hester 1974).

A further way to reduce mortality and thereby to improve the tuna–baitfish ratio would be to research and develop better husbandry techniques. The amount of oxygen in the bait wells, the salinity and temperature of the water and the level of crowding all influence mortality, as does the amount of time the bait is given to acclimatise to its environment (Hester 1974; Hallier et al. 1982). Furthermore, if the bait is to be maintained for a longer period of time, it is necessary to implement a feeding regime. As such, investigating the effect of sustenance type and frequency of feeding on mortality could additionally prove worthwhile.

6.3. DEVELOPING A SEPARATE BAITFISH FISHERY

As noted above, pole-and-line vessels from Indonesia and Japan, which together take more than half of the world's pole-and-line catch, do not typically fish for their own live bait, preferring instead to purchase supplies from a separate bait fishery. In its efforts to promote pole-and-line in the region, the Pacific Islands Forum Fisheries Agency (FFA) is placing much faith in developing separate fisheries for bait, using the Indonesian bagan fisheries as a model (Gillett 2011b). This approach has some promise, but is not without its drawbacks, as Table 8 shows.

Table 8: *Benefits and drawbacks of applying Indonesian bagan bait fishery model to other pole-and-line countries*

BENEFITS	DRAWBACKS
• Allows for pole-and-line fishing by vessels too small to use adequately sized bait net gear • Can be operated as a separate commercial operation • Capital requirements and level of technical sophistication are such that communities could operate the fishing gear • Models of such operations are available in Indonesia	• Unproven elsewhere; limited to Indonesia where economic, social and baitfishing resource conditions are very different. • Bagans operated as separate commercial entities add additional expenses onto cost of pole-and-line • Vessels large enough to carry bait nets would probably need some incentive to purchase bait instead • Gear adds potentially unwelcome complexity to pole-and-line fishing (e.g. two commercial entities, required coordination)

Source: Adapted from Gillett (2011b)

6.4. FINDING ALTERNATIVES TO LIVE BAIT FISH

6.4.1. BAIT CULTURE

The culture of baitfish for pole-and-line fishing has been attempted at a number of locations, including American Samoa, Fiji, French Polynesia, Hawaii, Palau, Tonga, Western Samoa and Kiribati (Gillett 2011a; Kearney & Rivkin 1981; Bryan 1980). Almost all of these programmes targeted mollies (*Poecilia mexicana*) or milkfish (*Chanos chanos*), though some experimented with Hawaiian flagtail (*Kuhlia sandvicensis*) threadfin shad (*Dorosoma petenense*), mosquitofish (*Gambusia affinis*) and tilapia (*Tilapia mossambica*) (Kearney & Rivkin 1981; Bryan 1980; IOTC 2000). Tilapia initially showed some promise, but funding and interest waned (Bryan 1980).

Studies have found both mollies and milkfish to be resistant and somewhat effective baitfish (Kearney & Rivkin 1981; Argue & Kearney 1982; Bryan 1980; Baldwin 1977). Milkfish were generally found to be more attractive to tuna than mollies, but less hardy (Kearney & Rivkin 1981; Argue & Kearney 1982). Kearney and Rivkin (1981) estimated the tuna–molly ratio at 38:1 and the tuna– milkfish ratio at 56:1. Bryan (1980) found the molly ratio to be higher, at 59:1 and concluded that mollies performed as well as or better than the live bait *S. delicatulus*.

Today, milkfish are one of the most important aquaculture species in the Philippines, Taiwan and Indonesia (FitzGerald Jr 2004). There is a long history of milkfish culture in many of the Pacific Islands and Indonesia (ibid.). With wide environmental tolerances, abundant natural fry, rapid growth and omnivorous feeding behaviour at a local trophic level, milkfish are well suited to aquaculture (ibid.). Furthermore, the species is disease resistant and tolerant to overcrowding, and its euryhaline characteristics have enabled it to be cultivated in a broad array of aquatic environments – from freshwater lakes to ocean cages (ibid.). There are milkfish farms or pilot projects to establish farms in several countries, including Kiribati, Fiji, French Polynesia, Guam, Nauru, Tanzania, American Samoa and The Solomon Islands, as well as in Indonesia, the Philippines and Taiwan (Requitina et al. 2008; Personal communication with Michael Phillips, 26 October 2011; Fitz Gerald Jr 2004). Milkfish culture projects were also launched in Palau, Tonga and the Federated States of Micronesia, but these proved largely unsuccessful (FitzGerald Jr 2004).

Further, because of the popularity of milkfish for human consumption, previous baitfish culture schemes have struggled to provide sufficient quantities of bait at a price attractive to fishers (Kearney & Rivkin 1981; Gillett 2011a; Lewis 1990). In the Pacific islands, Guam and Kiribati had milkfish aquaculture programmes targeting the tuna baitfish market. Guam is no longer supplying that market, and Kiribati is, but at much lower levels than initially planned (FitzGerald Jr 2004). Moreover, milkfish aquaculture has a number of disadvantages and potentially negative impacts. These are summarised in Table 9.

Table 9: *Potential disadvantages and impacts of milkfish aquaculture*

DISADVANTAGES	IMPACTS
• Limited skilled workforce • Where it is not possible to culture in pens in lagoons, substantial capital investment is required for the construction of ponds, wells, water storage tanks, as well as for the purchase of the land for locating these facilities and the costs of equipment • Restricted suitable land resource in some regions • Difficult to produce baitfish at a competitive cost for tuna pole-and-line	• Generation of particulate organic waste products may lead to organic matter loading of underlying sediments and increase likelihood of anoxic conditions • Loss of essential ecosystem services through habitat destruction, including the provision of nursery habitat, coastal protection, flood control, sediment trapping and water treatment • Introduction of pathogens to wild fish stocks

Sources:(Shomura 1974; Requitina et al. 2008; FitzGerald Jr 2004; Gopakumar et al. 1991; Hester 1974; Holmer&Heilskov 2008; Kearney &Rivkin 1981; Naylor et al. 2000; Gillett 2011b)

Despite these drawbacks, in situations where natural bait resources are severely limited (either seasonally or in general) or where vessels need hardier bait to reach distant fishing grounds, cultured bait may be an economically and environmentally viable alternative (Rawlinson et al. 1992; Kearney & Rivkin 1981). In order to minimise the risk of failure, it would be prudent for operations to adopt a diversified strategy targeting the emerging market for live milkfish in tuna longlining, as well as the more established markets for pole-and-line livebait and for human consumption (FitzGerald Jr 2004).

6.4.2. BAIT TRANSPORT

Another approach to bait supply is the transport of quantities of it from an area with a proven surplus into the fishery (Hester 1974). The Japanese vessels, which, as noted earlier, are responsible for almost 40% of the world's pole-and-line caught tuna, purchase bait in Japan before transporting it to the fishery (Campbell & Hand

1998; Kearney & Rivkin 1981). However, this approach is only cost-effective when the bait is carried by the vessel on which it is to be used, and hence not suited to near shore fisheries in developing countries (Kearney & Rivkin 1981). As noted above, bait transportation can also introduce invasive species and diseases (Gillett 2011a).

6.4.3. OTHER BAITS

Some authors have suggested that artificial baits could be created to mimic the appearance and movement of livebait fish, possibly supplemented by the use of chemical attractants in the water (Hester 1974; Sharma & Adams 1990). Some work was carried out in the 1950s and 1960s to assess the effectiveness of shiny metals, calcium carbide and small brass cylinders at attracting tuna (Baldwin 1977; Shomura 1974). Whilst some of these baits appeared to engender a feeding response in skipjack tuna, none was of adequate strength or duration for commercial application (Shomura 1974). In recent years, the only work conducted in this field has focused on the tuna longline industry (Januma et al. 2003). Latex sponge and vinyl chloride baits were found to have poorer catch rate than traditional natural baits, though it is possible that these could be options for the future, if the catch rate can be improved (Januma et al. 2003; FitzGerald Jr 2004).

Two authors have suggested the use of animals other than fish for bait. Hester (1974) mentions brine shrimp, noting that such a bait could be produced cheaply, swiftly and from a small initial volume. Januma et al. (2003) developed an alternative bait using the liver of the Japanese common squid Todarodes pacificus. In both cases, the alternative bait was found to be less effective than the traditional bait (Januma et al. 2003; Hester 1974).

Finally, it is also possible to use frozen bait for tuna pole-and-line and it can be purchased in most fishing ports (Majkowski 2003b). However, the very strong preference of most pole-and-line fishers is to use live bait as tunas are significantly less likely to react to dead bait and are usually more rapacious with live bait (Majkowski 2003b; Tester et al. 1954). Recent work into the use of frozen bait in longlining has reached similar conclusions. FitzGerald Jr (2004) presents four studies, all of which found a 200-400% increase in the catch of tunas with live milkfish over that obtained by frozen baits.

Overall, the research into alternative and artificial baits can certainly not be regarded as exhaustive and appears worthy of some cautious support. However, Hester's (1974) conclusions that bait culture is more likely to bear fruit than this type of research are likely as applicable now as they were almost four decades ago.

6.5. CONCLUSIONS

At present, the global pole-and-line catch of principal market tunas is about 457,000 tonnes per year, 10% of the world total. This report has estimated that current live bait requirements for pole and-line tuna are between 19,000 and 48,000 tonnes per year, with a mean average of 25,000 tonnes. Unless efficiency gains can be achieved, any expansion of catches will require an increase in bait production and this needs to be approached in a cautious manner with decisions made on good information about availability and long term sustainable yields.

Livebait fish fisheries have a number of environmental and social impacts, which together underscore the importance of conducting any expansion of pole-and-line fisheries within defined sustainable limits. Potential impacts include a reduction in the amount of forage available for the larger piscivorous species on which subsistence fisheries depend, incidental and deliberate capture of juveniles and of species targeted by artisanal fisheries, overexploitation of baitfish fisheries and conflict between bait fishers and local communities or tour operators.

A variety of solutions offer some potential for mitigation of impacts and for improving the effectiveness, hardiness and supply of baitfish. Primarily, it is clear that substantial further research is urgently needed, especially studies that focus on the complex interactions between the baitfish fishery and the local fishing communities, as well as those related to baitfish culture and other alternative bait. The identification and implementation of priority research projects in key fisheries is something that could be taken up by the IPNLF and key development partners.

These research initiatives need to be complemented by comprehensive fisheries management plans in pole-and-line nations. These plans should include regular stock assessments and be based on the ecosystem approach and the precautionary principle and be third party audited on a regular basis. Ideally, the IPNLF would, as a priority, develop best practise guidelines for baitfish management plans and provide skill sharing, training and capacity building to develop community and coastal states' ability to manage baitfish fisheries on a long-term sustainable and equitable basis.

REFERENCES

Adam, M.S., Anderson, A.H. & Hafiz, A., 2003.The Maldivian tuna fishery. IOTC Proc, 6, p.202–220.

Ainsworth, C.H., Varkey, D.A. & Pitcher, T.J., 2008. Ecosystem simulations supporting ecosystem-based fisheries management in the Coral Triangle, Indonesia. Ecological Modelling, 214(2–4), p.361–374.

Anderson, R.C., 2009. Technical assistance to bait fisheries monitoring, Maldives: Marine Research Centre. Available at: *www.mrc.gov.mv/pubs/MEMP_Bait fish_TA_Final.pdf* [Accessed October 21, 2011].

Anderson, R.C., 1997. The Maldivian tuna livebait fishery: status and trends. In Workshop on Integrated Reef Resources Management in the Maldives, Male (Maldives), 16-20 Mar 1996.

Anderson, R.C., 1994. The size of the Maldivian tuna livebait fishery. Rasain, 3, p.178–181.

Anderson, R.C. & Hafiz, A., 1988.The Maldivian live bait fishery.In Expert Consultation on Stock Assessment of Tunas in the Indian Ocean, Moka (Mauritius), 22-27 Jun 1988.

Argue, A.W. & Kearney, R.E., 1982. An assessment of the skipjack and baitfish resources of Solomon Islands.Skipjack Survey and Assessment Programme Final Country Report, p.40.

Argue, A.W., Williams, M.J. &Hallier, J.P., 1987. Fishing performance of some natural and cultured baitfish used by pole-and-line vessels to fish tunas in the central and western Pacific Ocean, South Pacific Commission.

Baldwin, W.J., 1977. A review on the use of live baitfishes to capture skipjack tuna, *Katsuwonus pelamis*, in the tropical Pacific Ocean with emphasis on their behavior, survival, and availability. NOAA Tech. Rep. NMFS Circ.,(408), p.8–35.

Barclay, K., 2010. Impacts of tuna industries on coastal communities in Pacific Island countries. Marine Policy, 34(3), p.406-413..

Barclay, K. & Cartwright, I., 2007. Governance of tuna industries: The key to economic viability and sustainability in the Western and Central Pacific Ocean. Marine Policy, 31(3), p.348-358.

Blaber, S.J.M. & Copland, J.W., 1990.Tuna Baitfish in the Indo-Pacific region, Canberra: Australian Centre for International Agricultural Research. Avail able at: *http://aciar.gov.au/publication/pr030* [Accessed July 28, 2011].

Blaber, S.J.M. et al., 1990a. Diets of lagoon fishes of the Solomon Islands: Predators of tuna baitfish and trophic effects of baitfishing on the subsistence fishery. Fisheries Research, 8(3), p.263-286.

Blaber, S.J.M. et al., 1990b.Reef fish and fisheries in Solomon Islands and Maldives and their interactions with tuna baitfisheries. Tuna baitfish in the Indo-Pacific region, 30, p.159–68.

Bryan, P.G., 1980. The efficiency of mollies, Poecilia mexicana, as live bait for pole-and-line skipjack fishing: fishing trials in the tropical central Pacific. Marine Fisheries Review, 42, p.15–24.

Campbell, H.F. & Hand, A.J., 1998. Joint ventures and technology transfer: the Solomon Islands pole-and-line fishery. Journal of Development Economics, 57(2), p.421-442.

Cinner, J.E. & David, G., 2011.The Human Dimensions of Coastal and Marine Ecosystems in the Western Indian Ocean. Coastal Management, 39(4), p.351-357.

Dalzell, P. & Lewis, A.D., 1989. A review of the South Pacific tuna bait fisheries: small pelagic fisheries associated with coral reefs. Marine Fisheries Review, 51(4), p.1–10.

Ellway, C.P. & Kearney, R.E., 1981.Changes in the Fijian baitfishery, 1974-1980, South Pacific Commission.

FAO, 2001.Fishing Vessel types.Pole and Line vessels.Technology Fact Sheets. Available at: *http://www.fao.org/fishery/vesseltype/350/en* [Accessed July 28, 2011].

FAO, 2011.FishStatJ 1.0.0 RC4, Rome: Food & Agriculture Org. Available at: *http://km.fao.org/FIGISwiki/index.php/FishStatJ_download.* [Accessed, March 2012].

FAO, 2010.The State of World Fisheries and Aquaculture 2010.Food and Agriculture Organisation of the United Nations.

FitzGerald Jr, W.J., 2004. Milkfish aquaculture in the Pacific: Potential for the tuna longline fishery bait market, Secretariat of the Pacific Community, Aquaculture Section, Noumea, New Caledonia.

Fonteneau, A. & Diouf, T., 1994. An efficient way of bait-fishing for tunas recently developed in Senegal. Aquatic Living Resources, 7, p.139–139.

Froese, R. & Pauly, D., 2011.FishBase, Available at: *www.fishbase.org* [Accessed November 10, 2011].

Gasalla, M.A. & Rossi-Wongtschowski, C.L.D.B., 2004.Contribution of ecosystem analysis to investigating the effects of changes in fishing strategies in the South Brazil Bight coastal ecosystem. Ecological Modelling, 172(2-4), p.283-306.

Gillett, R., 2010. Marine fishery resources of the Pacific Islands, Rome: Food and Agriculture Organisation of the United Nations. Available at: *http://www.fao.org/fishery/nems/39577/en* [Accessed October 27, 2011].

Gillett, R., 2011a. Replacing purse seining with pole-and-line fishing in the central and Western Pacific: Some aspects of the baitfish requirements. Marine Policy, 35(2), p.148-154.

Gillett, R., 2011b. The promotion of pole-and-line tuna fishing in the Pacific Islands: Emerging issues and lessons learned., McLean, Virginia, USA: International Seafood Sustainability Foundation.

Gilman, E.L., 2011. Bycatch governance and best practice mitigation technology in global tuna fisheries. Marine Policy, 35(5), p.590-609.

Gopakumar, G., Pillai, P.P. &Koya, K.P.S., 1991. Population chacteristics of tuna live baits in Lakshadweep. Journal of the Marine Biological Association of India, 33(1&2), p.255-277.

Greenpeace, 2009.Retailers' Guide to Sustainable and Equitable Pole and Line Skipjack. Available at: *http://www.greenpeace.org/international/en/publications/reports/retailers-guide-skipjack/* [Accessed July 28, 2011].

Hallier, J.-P., Kearney, R.E. & Gillett, R.D., 1982.Baitfishing methods used by the skipjack survey and assessment programme and recommendations on baitfishing techniques for the tropical Pacific. In Methods used by the South Pacific Commission for the survey and assessment of skipjack and baitfish resources. Technical Report - SPC. SPC, pp. 71-107. Available at: *http://www.documentation.ird.fr/hor/fdi:16537*.

Hester, F.J., 1974. Some considerations of the problems associated with the use of live bait for catching tunas in the tropical Pacific Ocean. Mar. Fish. Rev, 36(5), p.1–12.

Holmer, M. &Heilskov, A.C., 2008. Distribution and bioturbation effects of the tropical alpheid shrimp Alpheus macellarius in sediments impacted by milkfish farming. Estuarine, Coastal and Shelf Science, 76(3), p.657-667. Available at: Ianelli, J., 1992. The status of the Kiribati live bait fishery. Papers on Fisheries Science from the Pacific Islands, 1, p.21–32.

ICCAT, 2009.ICCAT Manual. Available at: *http://www.iccat.es/en/ICCATManual.asp?mId=5* [Accessed October 26, 2011].

IOTC, 2000. Detailed report: Indian Ocean Tunas Tagging Programme (IOTTP). Available at: *www.iotc.org/files/proceedings/misc/TagProg/English/TPExtE.pdf* [Accessed October 26, 2011]

ISSF, 2010.Status of the world fisheries for tuna 2010, McLean, Virginia, USA.: International Seafood Sustainability Foundation.

Januma, S., Miyajima, K. & Abe, T., 2003. Development and comparative test of squid liver artificial bait for tuna longline. Fisheries Science, 69(2), p.288-292.

Joseph, J., 2003. Managing fishing capacity of the world tuna fleet, Rome: Food and Agriculture Organisation of the United Nations.

Kearney, R.E., 1984. An Assessment of the Skipjack and Baitfish Resources of Fiji.

Kearney, R.E. &Rivkin, M.L., 1981.An examination of the feasibility of baitfish culture for skipjack pole-and-line fishing in the South Pacific Commission area. Skipjack Survey and Assessment Programme Technical Report.

Kleiber, P. & Kearney, R.E., 1983.An assessment of the skipjack and baitfish resources of Kiribati, South Pacific Commission.

Kwei, E.A. et al., 1995. Tuna bait boat baiting time and the availability of anchovy in Ghanaian waters. In F.-X. Bard & K. A. Koranteng, eds. Dynamique et usage des ressources en sardinelles de l’upwelling côtier du Ghana et de la Côte d’Ivoire : actes du colloque DUSRU. Colloques et Séminaires. ORSTOM, pp. 263–278.

Langley, A. et al., 2009. Slow steps towards management of the world's largest tuna fishery. Marine Policy, 33(2), p.271-279.

Leadbitter, D., 2011. The Good Fish Code – better fisheries through co-management. Regional Fisheries Livelihoods Programme for South and Southeast Asia

Leqata, J. et al., 1990. Subsistence fishing in Solomon Islands and the possible conflict with commercial baitfishing.In ACIAR Proceedings Series. pp. 169–178.

Lewis, A.D., 1990. Tropical south Pacific tuna baitfisheries.Tuna baitfish in the Indo Pacific region, 30, p.10–21.

Lewis, T., 1983.Baitfisheries and their possible impact on coastal fisheries in Island states. In Dunedin, NZ, p. 11. Available at: *http://www.reefbase.org/pacific/pub_A0000003108.aspx* [Accessed November 4, 2011].

Luther, G., 1990. Biology of whitebait anchovies of Indian waters.Blaber SJM & Copland JW, Edits. Tuna Baitfish in the Indo-Pacific region.ACIAR Proceedings, 30, p.75–82.

Luther, G., Gopakumar, G. & Mohan, M., 1984.Tuna live-bait fish investigations at Vizhinjam., p.861-875. Available at: *http://eprints.cmfri.org.in/2323/* [Accessed November 4, 2011].

Majkowski, J., 2003a. Fishing Techniques.Tuna handlining.Technology Fact Sheets. Available at: *http://www.fao.org/fishery/fishtech/1012/en* [Accessed November 11, 2011].

Majkowski, J., 2003b. Fishing Techniques.Tuna pole and line fishing.Technology Factsheets. Available at: *http://www.fao.org/fishery/fishtech/30/en* [Accessed July 28, 2011].

Majkowski, J., 2007. Global fishery resources of tuna and tuna-like species., Rome: FAO.

Maniku, H., Anderson, R.C. & Hafiz, A., 1989.Tuna baitfishing in Maldives. In Tuna Baitfish in the Indo-Pacific Region: Proceedings of a Workshop, Honiara, Solomon Islands. pp. 22–29.

Milton, D. et al., 1990. Age and growth of major baitfish species in Solomon Islands and Maldives.Tuna Baitfish in the Indo-Pacific Region.ACIAR Proceedings, (30), p.134–140.

Miyake, M. et al., 2010.Recent developments in the tuna industry: stocks, fisheries, management, processing,trade and markets., Rome: FAO.

Najmudeen, T.M and Sathiadhas, R. (2008).Economic impact of juvenile fishing in a tropical multi-gear multi-species fishery.Fisheries Research 92: 322–332

Nasser, A.K.V. & James, P.S.B.R., 1996.Tuna Bait-Fishery in minicoy and agatti Islands of Lakshadweep., p.353-356. Available at: *http://eprints.cmfri.org.in/4602/* [Accessed November 6, 2011].

Naylor, R.L. et al., 2000. Effect of aquaculture on world fish supplies.Nature, 405(6790), p.1017-1024.

Nichols, P.V. & Rawlinson, N.J.F., 1990.Development of the pole-and-line fishery in Solomon Islands with reference to the baitfishery and its management.In. Tuna baitfish in the Indo-Pacific region, p.152–158.

Oceanic Fisheries Programme, 2010.Western and Central Pacific Fisheries Commission Tuna Fishery Yearbook 2009. Available at: *http://www.wcpfc.int/node/1759*.

Péron, G., François Mittaine, J. & Le Gallic, B., 2010. Where do fishmeal and fish oil products come from? An analysis of the conversion ratios in the global fishmeal industry.Marine Policy, 34(4), p.815-820.

Pillai, P.P. et al., 1986. Exploited and potential resources of live-bait fishes of Lakshadweep.Marine Fisheries Information Service, Technical and Extension Series, 68, p.25–32.

Rawlinson, N.J.F., 1989. Catch composition of the tuna baitfishery of Solomon Islands and possible impacts on non-target species. In Tuna baitfish in the Indo-Pacific region: Proceedings of a workshop, Honiara, Solomon Islands. pp. 11–13.

Rawlinson, N.J.F., Milton, D.A. &Blaber, S.J.M., 1992.Tuna Baitfish and the Pole-and-Line Industry in Kiribati, ACIAR.

Requitina, E.D., Mmochi, A.J. &Msuya, F.E., 2008.A Guide to Milkfish Culture in the Western Indian Ocean Region. Available at: *http://wiomsa.net/index.php?option=com_jdownloads&Itemid=53&task=view.download&catid=70&cid=989* [Accessed October 27, 2011].

Sakagawa, G.T. et al., 1987. Effects of tropical tuna fisheries on non-target species, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Center.

Sharma, S.P. & Adams, T.J.H., 1990.The Fiji tuna baitfishery.Blaber, SJM and Copland, JW (eds.).

Shomura, R.S., 1974. A Summary of the Tuna Baitfish Workshop.

Smith, A.D.M. et al., 2011. Impacts of Fishing Low–Trophic Level Species on Marine Ecosystems. Science, 333(6046), p.1147–1150.

Stone, R., Toribau, L. & Tolvanen, S., 2009.Developing sustainable and equitable pole and line fisheries for Skipjack. Available at: *http://www.greenpeace.org/international/en/publications/reports/pole-line-case-study/* [Accessed July 28, 2011].

Sudirman and Musbir (undated). Impact of light fishing on sustainable fisheries in Indonesia. Fisheries Resources Utilization Study Program Fisheries Department, Fac. of Marine Science and Fisheries Hasanuddin University, Makassar 90245. Indonesia.

Tester, A.L., Yuen, H. &Takata, M., 1954.Reaction of tuna to stimuli, 1953, US Dept. of the Interior, Fish and Wildlife Service.

Tiroba, G. et al., 1990. Length-Frequency Analysis of Major Baitfish Species in Solomon Islands'. In Tuna baitfish in the Indo-Pacific region, Proceedings of the workshop, Honiara, Solomon Islands. pp. 114–133.

UNEP, 2007.National Reports on the Fish Stocks and Habitats of Regional, Global, and Transboundary Significance in the South China Sea. UNEP/GEF/SCS Technical Publication No. 15.

Vincent, S., 2003. Biodiversity of marine fish larvae at the southern tip of peninsular India, needs conservation and further studies. CBD Technical Series No. 9, p.20.

Western Pacific Regional Fishery Management Council, 2000.Pelagic Fishing Methods in the Pacific. Available at: *http://www.wpcouncil.org/library/PacificPelagic.html* [Accessed October 26, 2011].

Williams, D.M.B. &Cappo, M., 1990. Life-histories of clupeids in north-eastern Australia: Preliminary data. Tuna baitfish in the Indo-Pacific region. Australian Centre for International Agricultural Research Proceedings, (30), p.70–74.

Williams, P., 2009. Indonesian tuna fisheries: Getting to know our neighbours. SPC Fisheries Newsletter #129. Available at: h*ttp://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/129/FishNews129_29_Williams.pdf* [Accessed October 27, 2011].

WIOMSA, 2011.Migrant fishers and fishing in the Western Indian Ocean: Socio-economic dynamics and implications for management, Zanzibar: WIOMSA. Available at: *http://wiomsa.net/index.php?option=com_jdownloads&Itemid=53&task=finish&cid=982&catid=84* [Accessed October 15, 2011].

Wright, P., Willoughby, N. & Edwards, A., 1990.Growth, size and age composition of Stolephorusheterolobus in north central Java. In Tuna baitfish in the Indo-Pacific Region: proceedings of a workshop, Honiara, Solomon Islands, 11-13 December, 1989. p. 141.

Yoshida, H., Uchida, R. & Otsu, T., 1974.The Pacific Tuna Pole-and-Line and Live-Bait Fisheries. Available at: *http://www.pifsc.noaa.gov/library/pubs/admin/SWFC_Admin_Report_74-23.pdf*. [Accessed October 26, 2011].

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